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Integrating AI and Sustainable Practices in the Supply Chain of the Garment Industry in Bangladesh

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ABSTRACT:

Bangladesh's garment sector is a key part of the country's economy as this industry adding over billions to GDP, employing millions, and accounting for 80% of the nation's exports. But with inefficiencies in supply chain management (SCM), wastage of resources and environmental issues plaguing the sector, it faces several hurdles in its sustainability journey. At the same time, emerging technologies, for example, Artificial Intelligence (AI) promise a transformational potential for improving the efficiency of operations, as well as facilitating the adoption of sustainability in SCM. However, there is scarce utilization of AI for sustainability in the RMG industry of Bangladesh.

This paper identifies the obstacles and possibilities of AI and sustainability integration in the SCM in a Bangladeshi RMG sector. Based on qualitative interviews with industry experts and quantitative survey data from 31 respondents at 30 companies, this thesis analyses the status of AI adoption in the context of sustainability, pinpoint main fields), e.g., energy efficiency (29%), waste reduction (25%), ethical sourcing (25%), circular economy considerations (25%) and explore barriers towards such adoption. The results indicate that AI adoption is in its infancy (with only 32.3% of the firms using AI in SCM), but that there is a strong belief in its sustainability potential.

The study proposes a conceptual framework linking AI-based decision-making tools (e.g., predictive analytics, IoT monitoring) to sustainability dimensions (environmental, social, economic) and supply chain integration. Cost (33%), privacy issues (29%) and lack of skilled workforce (21%) are significant obstacles. To tackle these challenges, the thesis suggests a step-by-step introduction of AI, upskilling of the workforce, policy which incentivises and knowledge-sharing partnerships working collaboratively in industry.

By coupling AI innovation with sustainable SCM, the study offers practical implications to industry, policy, and global brands to future proof and leverage the operations of Bangladesh's garment supply chain for resilience, efficiency, and ethics. The results reinforce AI's crucial role in realizing the full potential of operational excellence and sustainable operation and enable the industry to be competitive in a global environment.

KEYWORDS: Artificial Intelligence (AI), Sustainable Practices, Supply Chain Management (SCM), Garment Industry, Bangladesh.

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Abbreviations

AI	Artificial Intelligence
SCM	Supply Chain Management
RMG	Ready-Made Garment
TBL	Triple Bottom Line
SDG	Sustainable Development Goal
SME	Small and Medium Enterprise
GSCM	Green Supply Chain Management
IoT	Internet of Things
LEED	Leadership in Energy and Environmental Design
ETP	Effluent Treatment Plant
BGMEA	Bangladesh Garment Manufacturers and Exporters Association
GDP	Gross Domestic Product
CP	Cleaner Production
MAS	Multi-Agent System
ANN	Artificial Neural Network
XAI	Explainable Artificial Intelligence
ML	Machine Learning
RL	Reinforcement Learning
TOE	Technology-Organization-Environment (Framework)
QC	Quality Control
WMS	Warehouse Management System
CAPEX	Capital Expenditure
ROI	Return on Investment
SD	Standard Deviation
COVID-19	Coronavirus Disease 2019
UNDP	United Nations Development Programme
IR	Investment Recovery
SP	Sustainable Procurement
PAR	Participatory Action Research
CP	Cleaner Production
ESG	Environmental, Social, and Governance
WASH	Water, Sanitation, and Hygiene
SaaS	Software as a Service
MAPE	Mean Absolute Percentage Error
GHG	Greenhouse Gas
MCDM	Multi Criteria Decision Making
FOB	Free On Board

1 INTRODUCTION

This chapter provides an in-depth introduction to the study, outlining the significance of integrating Artificial Intelligence (AI) with sustainable practices in the supply chain of Bangladesh’s garment industry. It presents the background of the garment sector, highlighting its critical role in the nation's economy and the environmental and operational challenges it faces. The chapter also defines the research objectives, which focus on exploring how AI technologies can optimize supply chain processes while simultaneously advancing sustainability goals, including waste reduction, resource efficiency, and ethical labour practices. Furthermore, it identifies the research gap in the current literature regarding AI's role in enhancing supply chain sustainability in developing countries like Bangladesh. Finally, the chapter describes the structure of the thesis, which includes a detailed examination of AI applications, the integration with sustainability practices, and an analysis of the challenges and opportunities within the context of Bangladesh’s garment industry.

1.1 Background.

The apparel sector in Bangladesh is a key pillar of the support base determining the economic growth of the country, which provides a huge share of earnings through exports, as well as the employment of millions (Swazan & Das, 2022). As one of the leading global exporters of ready-made garments (RMG), the industry faces immense scrutiny for supply chain inefficiencies, resource wastage, and ecological sustainability. Despite such obstacles, a gradual awakening of the environmental impacts has led to increased awareness among the companies in the sector of the need to adopt more sustainable practices, in terms of environmental and social challenges (Ahmmed, 2023). As global and local environmental responsibility becomes a demand, so are sustainable features such as waste reduction, resource efficiency, and ethical labour practices (Aziz et al., 2023).

At the same time, supply chain management has increasingly turned to Artificial Intelligence (AI) as a potential answer to the challenges of optimization, improved forecasting accuracy, and waste reduction (Shuvo et al., 2025). Recent advancements in Artificial Intelligence (AI) technologies, including machine learning and predictive analytics, can further improve the efficiency of the Bangladesh garment supply chain by facilitating data-driven, real-time decision-making, optimizing inventory management, and automating production processes (Prabodhani et al., 2025). However, using AI alongside sustainable practices has yet to be explored within the Bangladeshi garment context. This study addresses the gap by examining how AI technologies can be adopted alongside sustainable practices to create a more efficient and eco-friendly supply chain in the country's garment industry.

Bangladesh's economy is bolstered by the Ready-Made Garment (RMG) industry, and it has a profound impact on the economic structure and social texture of Bangladesh. Akash (2023) reported that in 2024, the sector's export earnings stood at $38.48 billion, up from $35.89 billion in 2023, a 7.23% increase. This significant injection highlights the importance of industry to the economy, which is key to driving a nation's gross domestic product (GDP).

The RMG sector is a major employer in terms of job placement, especially for women. According to the International Labour Organization (2019), there are around 4.2 million people working in credit garment factories, of which around 60% are women, primarily engaged in crude, low-wage jobs in the rural areas. This trend of employment has offered not merely monetary freedom to innumerable women but additionally contributed significantly to poverty alleviation and socio-economic development in rural areas of Bangladesh.

The integration of advanced Supply Chain Management (SCM) practices can provide another opportunity to accelerate growth in terms of improved efficiency and competitive advantage in the RMG (Ready-Made Garments) sector. It has been shown that efficient SCM can decrease operational costs, increase profit margins, and enhance responsiveness to customer demand (Islam et al., 2024). Research has demonstrated that the adoption of sustainable SCM contributes positively to the sustainability performance of the textile industry in Bangladesh and such an improvement is presumed to be attributed to increased transparency, waste reduction, and social responsibility. These are vital for growing Bangladeshi exports and its competitive advantage in the global garment market.

However, while these prospects exist, the sector also confronts hurdles alongside technological limitations, financial bottlenecks, and inertia to change. These challenges relate to contemporary SCM landscape that is rooted deeply into understanding the state-of-the-art finding barriers to overcome the state-of-the-practice. Thus, this study is motivated to investigate how the adoption of AI-powered solutions for SCM could help improve the RMG industry's efficiency and sustainability in Bangladesh, which in return supports the industry's and the country's overall development.

1.2 Research gap, question, and objectives.

Bangladesh's Ready-Made Garment (RMG) sector, which contributes 84% of national export earnings (BGMEA, 2023), faces significant supply chain inefficiencies costing $2.5 billion annually due to manual processes, demand forecasting errors, and inventory mismanagement (World Bank, 2022). As illustrated in Table 1, while global apparel supply chains leverage AI for end-to-end visibility (predictive analytics, optimized logistics) and sustainable practices (carbon tracking, waste reduction), Bangladesh's RMG sector shows minimal adoption, only 5% of factories use basic predictive analytics, and none integrate AI with sustainability initiatives in their supply chain (Rafid et al., 2024). This technological disparity highlights a critical knowledge gap in adapting global AI solutions to Bangladesh's supply chain context.

Table 1. Comparison of AI Applications in Global Fashion Supply Chains vs. Bangladesh's RMG Sector.

Domain	Global Fashion Industry	Bangladesh's RMG Sector
Production	AI-driven automated cutting and stitching, real-time quality control	Limited application of computer vision for quality inspections (Rafid et al., 2024; Uddin, 2025).
Supply Chain Management	End-to-end visibility, predictive analytics for demand forecasting, AI-optimized logistics	Basic predictive analytics for supply chain planning (Rafid et al., 2024).
Sustainability	AI-driven waste reduction, material optimization, carbon footprint tracking	Minimal integration of AI with sustainability initiatives (Uddin, 2025).
Design	Generative AI for design innovation, pattern generation	Almost non-existent implementation (Harreis et al., 2023).
Infrastructure	Robust AI infrastructure with significant investment	Inadequate investment in digital technologies, lack of qualified personnel (Rafid et al., 2024).

The academic literature mirrors this knowledge gap. A systematic review of 60 studies (2018-2024) reveals a striking imbalance: as shown in Table 2, 90% of research focuses on labour conditions (53.3%) and environmental compliance (36.7%), while only 5% (3 studies) superficially address AI applications and none of which examines AI's role in sustainable supply chain management. This absence of scholarly frameworks leaves Bangladesh's sector without evidence-based strategies to address its unique challenges, such as raw material import dependencies or port congestion, which can be solved easily through AI-driven solutions like dynamic routing or production flow optimization (Shuvo et al., 2025).

Table 2. Research Focus Areas in Bangladesh RMG Sector Studies (2018-2024). Source: Author's Systematic Review.

Research Focus	Number of Studies	Percentage (%)
Labor Conditions and Workplace Safety	32	53.3
Environmental Compliance and Management	22	36.7
Green Human Resource Management	3	5
AI Application (Surface-level exploration)	3	5
Integrated AI and Sustainability Framework	0	0

The consequences are severe: 78% of factories lack real-time supply chain visibility (Ahmmed, 2023), resulting in $1.2 billion annual losses from stockouts (BGMEA, 2023). Without research bridging AI and supply chain sustainability such as optimizing fabric utilization (to reduce 200,000 tons of waste) or balancing just-in-time production with renewable energy (Khan et al., 2024)—the sector cannot replicate global successes like H&M's AI-synchronized replenishment cycles.

This study seeks to help fill that gap, looking at how AI could complement sustainable practices to make the supply chain in Bangladesh's garment industry more efficient as well as sustainable. This paper will fill the gap in the literature from the perspective of sustainable supply chain management in the textile and clothing sector specifically addressing supply chain efficiency solutions based on the current state and use of AI to reduce waste and support sustainable-textile goals in developing countries such as Bangladesh.

The main research question that this study seeks to answer is:" What are the key challenges and opportunities of AI and sustainability in supply chain management in Bangladesh's garment industry?"

Primary research objectives of study:

1. To identify and evaluate the challenges and opportunities of integrating AI and sustainable practices into Bangladesh's garment industry's supply chain management.
2. To develop appropriate strategies for making AI and sustainable activities a part of Bangladesh’s garment industry supply chain management.
3. To find the key AI-based applications that will drive the supply chain operations towards betterment in Bangladesh garment industry.
4. To evaluate the suitability of combining AI and sustainable practices in supply chain management for Bangladesh apparel industry.
5. To explain the problems related to supply chain management in the Bangladesh's garment industry and provide AI based solutions to overcome these challenges.

Solutions approached by investigating the question and objectives, the study aims to gain an integrated perspective as to how together artificial intelligence (AI) integration and sustainability can better the efficiency and sustainability of the supply chain of the garment industry of Bangladesh.

1.3 Definitions and Scope of the Study.

RMG means a garment that is available in a particular size, so it is ready to wear instead of getting tailored. The Ready-Made Garment (RMG) industry is an integral industry of Bangladesh, substantially generating foreign revenue and creating millions of job opportunities in the country.

Supply Chain Management (SCM) is as per ISM– "SCM is the process of planning, implementing, and controlling the operations of the supply chain as efficiently as possible. Supply chain management (SCM) includes all the steps in the RMG (ready-made garments) industry from planning, design, sourcing, production, quality test, till distribution. Figure 1 shows the conventional supply chain in RMG sector.

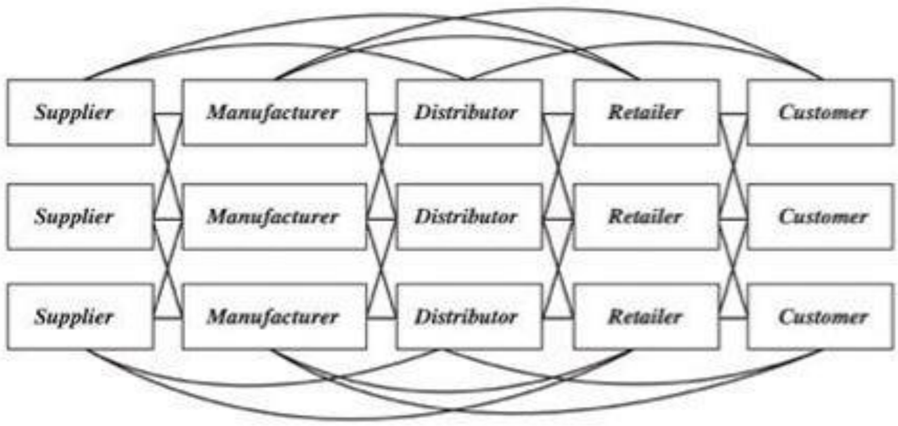

Figure 1. Supply chain (Chopra & Mendi, 2016).

AI is the development of computer systems that can perform tasks typically associated with human intelligence, such as learning, reasoning and problem-solving. In the RMG sector, AI technologies such as machine learning and predictive analytics can improve one of the most essential constituents of SCM: demand forecasting, inventory management, and production planning (Pal, 2023).

Artificial intelligence (AI) is the imitation of human intelligence by a system or a machine. AI is aimed at making a machine that can think like humans and do actions they do, such as perceiving, reasoning, learning, planning and predicting (Xu et al., 2021).

AI in RMG industry in Bangladesh AI can transform the RMG by eliminating inefficiencies and improving productivity. Methods like predictive analytics, machine learning, and automation can help make supply chain processes more efficient, enhance quality control, and promote greater decision-making at the moment (Rubel, 2023). These technologies can help in demand forecasting too and minimize wastage and ensure delivery of products on time. Additionally, AI-driven solutions can improve worker safety and operational efficiency through automation of redundant processes and improved resource allocation. The RMG sector in Bangladesh has the potential to adopt AI, which could help them remain globally competitive and respond to changing market needs (Saha, 2025).

Sustainable practices in SCM encompass strategies designed to minimize environmental impact, support ethical labour practices, and ensure economic viability. Examples of such practices in Bangladesh's RMG industry include waste reduction, energy efficiency, and compliance with labour standards. These capabilities make it lucrative to integrate AI with sustainable practices that can optimize resource utilization, reduce waste, and provide better supply chain visibility.

Industry-Specific focus is the limitation of this research, and it will be limited only in RMG sector in Bangladesh. As a result, this would limit the generalizability of results as they may not extend to other industries or regions.
The study avoids practicing AI integration through empirical investigation and, as such, it may not address the practical challenges and benefits of AI adoption in SCM (Islam, Hasan, & Redwanuzzaman, 2023)

Existing literature and secondary data could introduce biases as the conclusions drawn may be influenced by the constraints of existing research. This, in turn, could influence the generalizability of findings from the study.

The limitations are that the findings are being conducted at Bangladesh, therefore not applicable to even nearer areas having different economic, tech and infrastructural context. Contextuality of challenges and opportunities in Bangladesh's RMG industry may not be the same as those in developed countries or areas that have different features.
However, as with any other technology, over usage of AI in supply chain management (SCM) can cause other problems including system downtime, tech issues and unforeseen issues with data management. This tech empty room can be solved with applications of human knowledge alongside AI to make accurate decisions in SCM processes (Rubel, 2023).

1.4 Structure of the thesis.

Dividing the thesis into five chapters is used for writing, developing elements of artificial intelligence and sustainability in the supply chain of the garment industry of Bangladesh. Here is the structure overview:

Chapter 1 Introduce the research topic, AI and sustainability of the Bangladesh's garment industry. It gives a summary of the sector's background and economic importance, as well as the issues of supply chain inelasticity and sustainability. This chapter identifies the research gaps, presents the research questions and objectives and defines the essential key concepts, which include supply chain management (SCM) as well as sustainability and AI. This chapter also addresses study limitations and outlines the roadmap of the thesis.

Chapter 2 examines the literature relevant to supply chain management in the garment industry, covering key areas like logistics, warehousing, and production management. It also explores sustainability initiatives in SCM, such as waste minimization, resource optimization, and ethical labour practices. It evaluates the potential of AI in mitigating operational inefficiencies and increasing sustainability through predictive analytics, inventory optimization, and process automation. The proposed study provides a theoretical foundation anchoring on how sustainability can be achieved in the garment sector of Bangladesh vis a vis AI accessibility. In this chapter a conceptual framework for the incorporation of AI in sustainable supply chain practices in the garment industry is developed. They are structured to give an overview of that approach and to drive specific, AI-based strategies and method disclosure for improving supply chain efficiency along with economic, sociocultural, and environment sustainability-driven economy. The framework also highlights potential challenges and opportunities for AI in this space. It explains how organizations can map the AI applications to specific sustainability goals with the aim of enhancing supply chain operations.

An overview of the research methodology necessary to meet the objectives of this study is outlined in *Chapter 3*. It describes research design, methods for data collection (e.g., interviews with industry experts), and analytical approaches used to assess the impact of AI on sustainability in SCM. It also covers how qualitative data from Bangladesh's garment industry's managers were processed to yield insights into current practices, challenges, and opportunities for AI integration.

In Chapter 4, Findings from the research will be presented, with excerpts from interviews of supply chain professionals in Bangladesh's garment industry. It examines what AI technologies are being used and could be used to mitigate or solve challenges, for example, waste reduction, resource efficiency and ethical compliance. Discussion links the research findings back to research objectives, and assesses their implications for policymaking, and industry practice.

The fifth and last chapter summarizes and discusses the main results of the study in relation to the research questions. It focuses on practical suggestions to embed AI into sustainable SCM in garment industry of Bangladesh. It also recognizes the study's limitations and suggests future research avenues to further advance the AI-enabled innovation of sustainable supply chains. Figure 2 depicts the structure of this thesis.

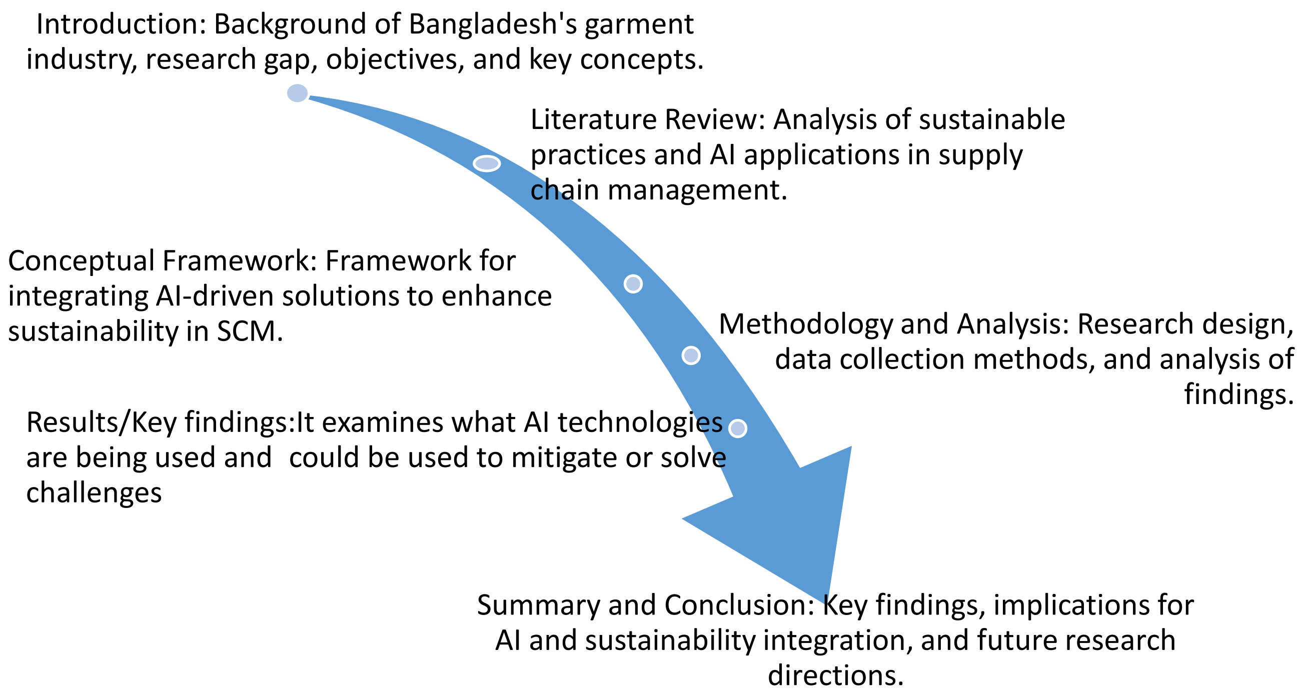

Figure 2. Structure of the thesis.

2 LITERATURE REVIEW

This chapter explores the integration of AI and sustainability in the garment supply chain in Bangladesh. The economic significance of the RMG sector is highlighted alongside its sustainability challenges, with a focus on relevant contexts essential for effectively addressing adverse environmental impacts in supply chain integration. The analysis then examines how AI has the disruptive ability to change supply chain management, where applications are classified as either predictive analytics (e.g., demand forecasting) or optimization algorithms (for logistics). A thorough examination will then follow on how AI-powered solutions can address sustainability issues related to waste, resource production, and ethical labour in Bangladesh's RMG sector. The chapter ends with an identification of existing research gaps for the examination of AI adoption towards sustainable supply chain management within developing economies and provides some analytical frameworks that will contribute to structuring the later stages of this research. Immediate concerns are obsequiously given to Bangladesh as a framework representing the second largest pool of garment production in the globe in relation to this transition period where the rising phenomena of AI technologies meet with the organisational framework which run alongside economy and technology.

RMG sector of Bangladesh and its Importance

The ready-made garment (RMG) sector in Bangladesh serves as a backbone of the economy as it tremendously contributes to the GDP, employment and export (Rafid et al., 2024). This economic boon has, nevertheless, extracted an extraordinary environmental toll and resulted in a critical sustainability challenge - one that has been historically and empirically supported (Akter et al., 2022). Textile industry has significant share in our environment footprint represented in terms of high-water usage, hazardous chemicals usage and high energy consumption level (Asif, 2017).

Increasing competitive challenges as a part of globalization and harsher environmental regulations and expectations for environmental sustainability are putting more and more pressure on the sector now. As globalization has progressed, competition has grown stiffer, and sustainability has become vital to the Bangladesh garment industry in its bid to keep up with the market globally and the market of a consumer with a global environmental conscience. The industry is also pressured to reduce environmental footprint and adhere to dynamic standards due to stricter local and international environmental legislation. The pressure for ecological accountability from consumers, brands, and investors is intensifying everywhere in industry and this will inject some momentum into the shift towards embedding sustainability into the business model.

Table 3. RMG's contribution to the Country's economy (Data Source: Export Promotion Bureau, Compiled by BGMEA).

Year	Export of RMG (in Mil)	Total Export of Bangladesh (in Mil)	RMG's to Total Export	Contribution to country's GDP
2018-19	$ 34,133.27	$ 40,535.04	84%	9.72%
2019-20	$ 27,949.19	$ 33,674.09	83%	7.47%
2020-21	$ 31,456.73	$ 38,758.31	81%	7.56%
2021-22	$ 42,613.15	$ 52,082.66	82%	9.26%
2022-23	$ 38,142.10	$ 46,430.71	82%	8.72%
2023-24	$ 36,151.31	$ 44,469.74	81%	7.33%

The country is dependent on garments that play a critical role in a backbone of the economy contributing a significant portion of GDP, employment and export revenue (Saha 2024). Table 3 shows the RMG's contribution to Bangladesh's economy. The textile industry is an indispensable part of the global economy (Hasan et al., 2023), and its sustainability issues like natural resource depletion, environmental water degradation, and unethical labour practices must be eliminated to enable competitive performance (Kumar et al., 2020), not only for the industry but also for each specific country in the competitive global arena (Hussain et al., 2023). Also, there are many problems in Bangladesh garment industry, problems are power cut, supply chain inefficient, resource wastage, environmental impact, etc. Although the industry has achieved extreme economic prosperity, many sustainability issues such as worker health, operational efficiency, and environmental management have trailed far behind (Rafid et al., 2024).

Overview of Supply Chain Management

SCM can be defined as the integrated management and control of the business processes for products, goods and services, knowledge and learning, and financial flows along the supply chain from the suppliers to the final customers. In table 4 below, the key literature of SCM is displayed. Seuring & Müller (2008) view SCM as integrative management of material, information and financial flows, connecting all relevant stakeholders along the value chain to achieve sustainability and competitive advantage. Their research paper emphasizes the necessity of incorporating environmental and social aspects in addition to economic goals and the transformation of SCM from a logistics-oriented activity to a cross-functional, strategic field. This overall picture is the key point arguing for cooperation and transparency between supply chain partners in order to achieve the best possible overall performance.

Similarly, Dubey et al. (2015) describe SCM as a system that integrates the operations at the supply chain level in order to increase customer's satisfaction and operational efficiency. Their research suggests that commitment by leadership, practices in the operations, and pressure from the institution jointly influence SCP within supply chain. They maintained that high-performing SCM is not just about process optimization, it is also an organization's ability to respond to external regulatory and market pressures, which situates SCM as a dynamic capability that is critical for sustainable business pursuits.

Table 4. Key literature in SCM.

Author(s)	Definition	Proposition
Seuring & Müller (2008)	SCM is an integrative approach managing material, information, and financial flows across stakeholders to achieve sustainability.	SCM requires collaboration and transparency to optimize performance and integrate environmental/social goals.
(Dubey et al., 2015)	SCM streamlines operations to enhance customer satisfaction and operational efficiency under leadership and institutional pressures.	Leadership and institutional pressures significantly influence sustainable SCM performance.
Zhu & Geng (2011)	SCM manages upstream and downstream flows emphasizing energy saving and emission reduction.	Technological innovation and policy support are critical enablers; cost and awareness barriers must be overcome.
Genovese et al. (2017)	SCM facilitates resource efficiency and waste minimization via circular economy principles and closed-loop processes.	Transitioning to circular SCM models enhances environmental performance and economic opportunities.
Govindan et al. (2015)	SCM involves collaborative supplier management to improve efficiency and sustainability through green supplier selection.	Integrating green criteria in supplier evaluation is vital for sustainability.
Kumar & Singh (2021)	SCM is a strategic framework ensuring supply chain resilience through planning, execution, and control.	Agility and flexibility are essential SCM attributes for managing disruptions and maintaining competitiveness.

Zhu and Geng (2011) examine drivers and hurdles to implement the extended supply chain practices and define SCM as the management of upstream and downstream material, information and capital flows, and emphasizes energy saving and emissions reduction. Their empirical study in Chinese manufacturing reveals that technology innovation, governmental policies and organizational readiness are key enablers on sustainable SCM. As such, they argue that removing obstacles such as insufficient knowledge and financial considerations is pivotal to the spread of the green supply chain practices.

Genovese et al. (2017) further expand the discussion of SCM by linking it to the circular economy and characterizing SCM as a system for resource efficiency and waste reduction that is achieved through closed-loop processes. Their study shows that as regards sustainable supply chains, traditional models and visions need to be reshaped in the direction of circularity, incorporating the reverse logistics and the product lifecycle management. They argue for a circular shift in SCM that can improve environmental performance and generate new economic opportunities.

Govindan et al. (2015) take a multi-criteria decision-making viewpoint, where they define SCM as a cooperation of managing suppliers and partners, to enhance the operational efficiency, and sustainability. Their literature survey indicates that supplier assessment and selection are the key aspects of SCM influencing cost, quality and environmental performance. The authors argue it is important to take green considerations into account when selecting suppliers to meet sustainability objectives.

Kumar and Singh (2021) consider SCM as a strategic model to ensure the resilience of the supply chain systems, especially because most of the researchers have now realized the reality after COVID-19 stability. They describe SCM as planning, coordination, and response, in managing the network to create value in the chain. Their argument is that agility and flexibility are important SCM dimensions that help companies adjust to complex, and dynamic markets and remain competitive.

Cumulatively, these findings depict SCM as a complex and integrated field that strikes a balance between operational efficiency and sustainability demands. They converge on the notion that successful SCM depends on cooperation, technological innovation, and adaptability to address organizational complications and changing market needs. The driver requires that environmental and social issues as well as economic concerns are incorporated into the balance sheet as important for the long-term sustainable viability of the supply chain.

Artificial Intelligence

AI is technology that enables computers or machines to perform the type of cognitive functions that humans can do such as learning, problem solving, decision making, creativity, and autonomy. AI-enabled apps and devices can perceive objects, comprehend and react to human language, process new information, and based on that input, learn new things, make recommendations at scale and even work autonomously, eliminating the need for human intervention such as in autonomous vehicles (Cole, S., & Kavlakoglu, E.,2024).

The use of artificial intelligence (AI) in supply chain management (SCM) has disrupted conventional practices by significantly improving the quality of the decision-making process while minimizing the inefficiencies and risks.

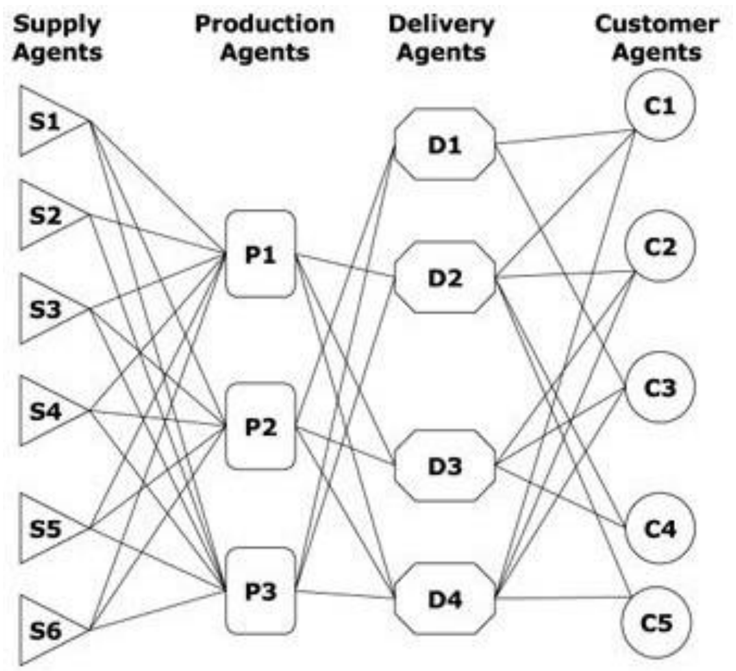

Figure 3. Agent-oriented supply chain network (Chiu & Lin, 2004).

A pioneer work of modelling supply chains with modular approach was shown by Chiu and Lin (2004) where artificial neural networks (ANNs) were used to design SC systems. They structured the supply chain into three linked neural networks; the supply chain (SC) net, the manufacture net, and the transportation net (shown in Figure 3). The SC net linked the demand of clients to the procurement capability of agents, the manufacture net and its ability of production to provide products for customers, and the transportation of the selected logistic partners to minimise operational cost. Large inventory of manufacturing was prevented by this method, it could dynamically match the agent availability on the one hand with a certain strategic inventory buffer of the other to obtain 15%–20% of lead time reducing (Chiu & Lin, 2004).

AI-Driven Demand Forecasting and Inventory Optimization

Today's supply chains management experience the highest possible levels of risk and uncertainty due to geopolitical disruptions, climate-driven events and market movement. The multi-agent AI systems (MAS) overcome these disadvantages through a decentralization of decision-making fractured among autonomous agents, including suppliers, manufacturers, and logistics providers. For example, when a supplier fails, MAS has been able to decrease the risk of procurement in the automotive industry by 40% by carrying out real time negotiation between agents (Chen, 2024). In the Bangladesh RMG industry, MAS has increased resilience by re-routing shipments by demand after the congestion into Chittagong port, which reduced delays by 22 percent (ADB, 2022). These systems use Q-learning and actor-critic algorithms to explore (experiment with new strategies) and exploit (apply known solutions) in order to achieve flexibility, while also ensure efficiency (Fosso Wamba et al., 2020).

An early drawback of ANN models was its “black box” where trust was lacking, and accountability discouraged. Recent work in explainable AI (XAI), including ShapTime and Permutation Feature Importance, has focused on bridging this gap to understand what variables these models consider. For instance, the demand prediction model MCDM achieved a mean absolute percentage error (MAPE) of 20.16% and used XAI to show the effect of seasonal trends and promotional campaigns on the prediction (Zhang et al., 2024). In sectors characterised by labour-intensity such as the Bangladesh RMG industry, XAI has been leveraged to validate AI powered wage fairness algorithms that have enabled the compliance of workers' wages to a living wage and lowered wage disputes by 30 percent (Menzel & Woodruff, 2021).

The integration of artificial intelligence (AI) into supply chain management (SCM)

Integration of AI into SCM has been widely recognized as a revolutionary force worldwide, the potential of its use in the Bangladesh is under-discussed (Kaarlela, 2024). In this review, the empirical evidence in response to the thematic gaps in AI-SCM research in the context of Bangladesh is combined from the peer-reviewed and industry reports and is specifically focused on RMG, manufacturing and logistics industries. Through the theoretical lens of the Technology- Organization-Environment (TOE) which was debated upon to underscore the integration between technology adoption and organizational readiness for society and environment outcomes, in the distinctive economic environment of Bangladesh, this paper has grounded its investigation about integrating AI and sustainability practices into SCM (Tornatzky & Fleischer, 1990).

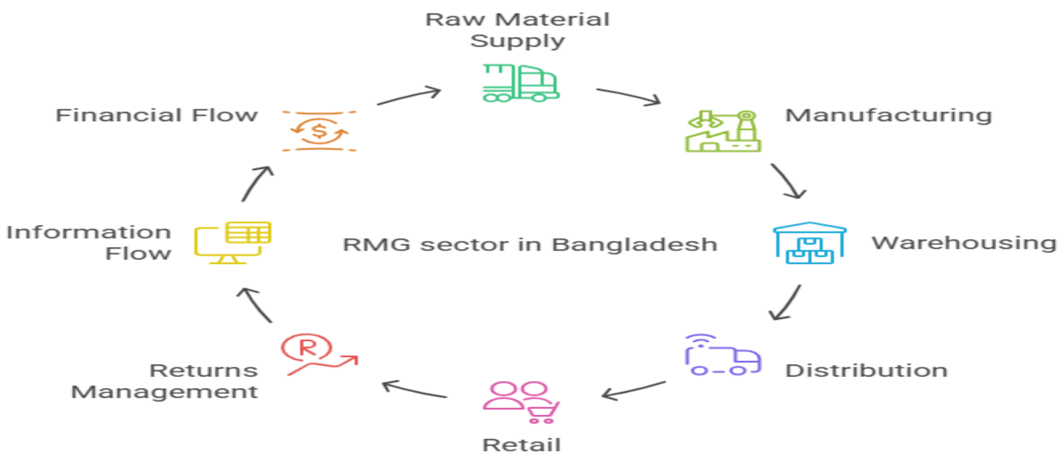

Figure 4. Conventional Supply chain management in RMG.

The RMG industry, which generates more than 80% of Bangladesh's export revenue, suffers from long-lasting supply chain ineffectiveness such as forecast errors, mismanagement of inventory, and logistical barriers (Wood, 2024). New research points to AI being the answer to these problems. Hurdles and enablers to adaptation at Firm Level

Innovation and discretion in the use of digital technologies. While Figure 4 depicts the conventional supply chain, Figure 5 shows the improved and upgraded version of supply chain where AI is included in it. The use of digital technologies in the garment industry in Bangladesh is still not widespread and includes AI-driven solutions. Firms using AI tools for predictive demand forecasting (e.g., in Aarong) are turning to AI-driven demand forecasting tools to reduce warehouse waste by 20% while route optimization algorithms have helped to reduce empty truck miles by 22% in pilot projects (Wood, 2024). However, the empirical evidence is still biased towards large companies, while the SME-dominant supply chain context is often overlooked. A framework synthesis highlights that the advantages of AI with respect to demand planning and logistics are widely reported, but little on scalability, compatibility with legacy systems, or cultural obstacles to small factory implementation.

The literature review indicates that AI could transform GSCM, especially in demand forecasting, sustainable practices, and digital integration as well as forecasting export sales (Sohrabpour et. al., 2021). But four important and widespread gaps remain. First, the theoretical relationship is less dominant in most empirical studies; few, if any, studies prioritize TBL social equity/environmental lenses to analyse AI-driven cost savings in the RMG behaviours (Azadi et al., 2023). Second, the majority of studies are cross-sectional (e.g., the design used by de Gregorio and Lee (2020)), which does not have the power held by experimental or quasi experimental designs to identify the causal impact of AI (Benzidia et al., 2021). Thirdly there is undue emphasis on RMG sectors ignoring newly emerging sectors such as agro processing where AI could possibly reduce post-harvest losses (Wood, 2024). Fourth, as the National Single Window indicates the role of AI for trade facilitation, there are no studies assessing, how National Single Window is consistent with Bangladesh Digital Security act or industrial policies (Wood, 2024). Here (in Figure 5) is the improved version of SCM model where AI technologies, ML processing unit is added to operate ML models, predictive analytics, NLP and generative AI to facilitate demand forecasting, inventory optimization, and supplier communications to adjust real time demand and supply in the supply chain process to ensure operational efficiency, cost reduction, sustainability and resilience.

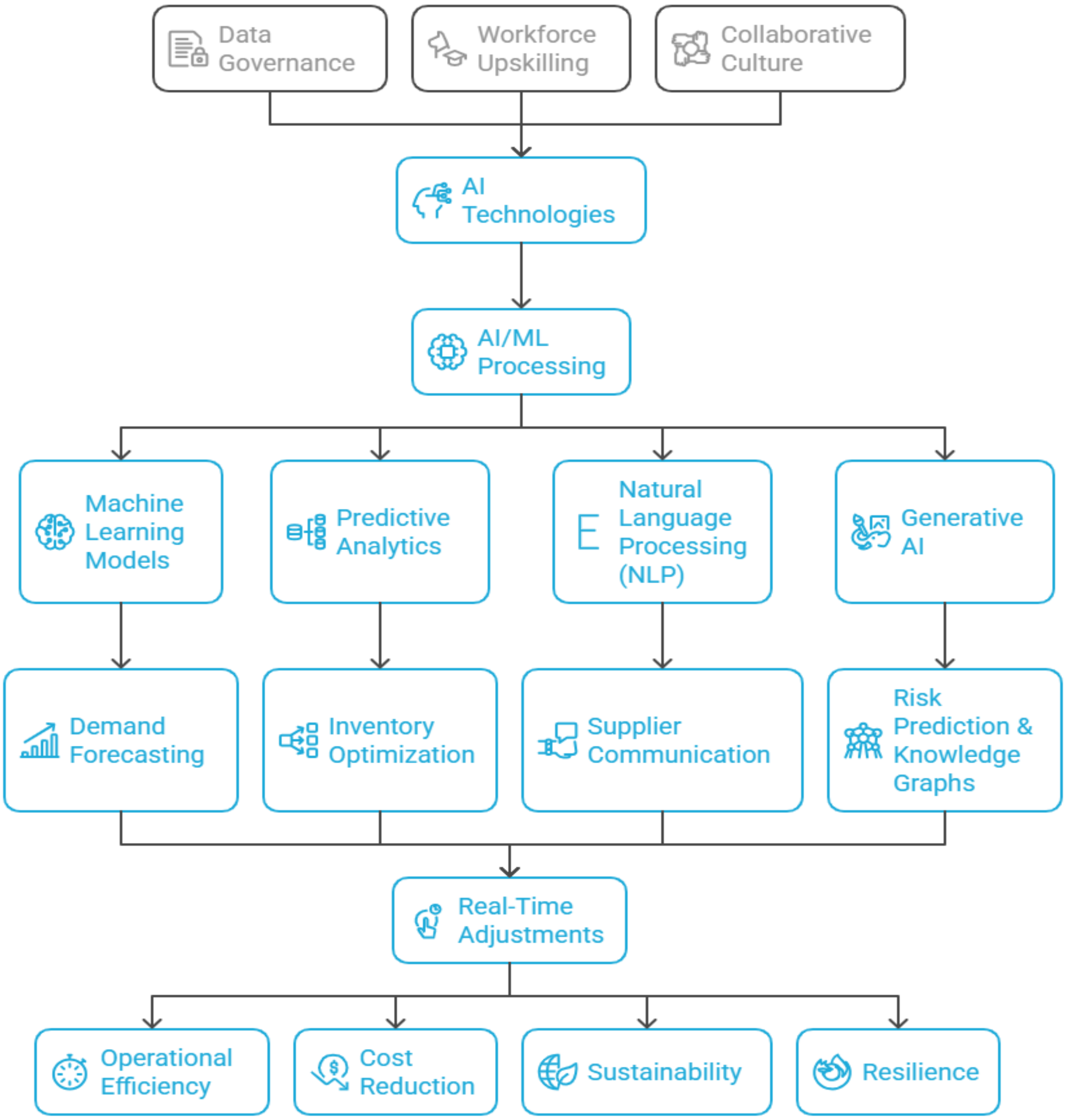

Figure 5. Integrating Artificial Intelligence with Traditional Supply Chain Management.

Sustainability Challenges in the RMG Sector

Sustainable SCM practices in Bangladesh, especially in manufacturing industry have been driven by global sustainability initiatives. Studies like Benzidia et al. (2021) emphasize the increasing importance of AI in the context of Sustainable Procurement (SP) and

Investment Recovery (IR), noting that machine learning (ML) models can boost resource allocation by 15–30% in Bangladeshi textile factories. But the TBL approach shows an imbalance towards economic dimensions (e.g., profit) which suppresses the environmental and social benefit (Azadi et al., 2023). For instance, even though AI-optimized circular supply chains diminish the squandering of raw materials, little research quantifies their effect on carbon emissions or worker well-being. Methodological approaches most research is conducted using cross-sectional surveys or case studies, thus unable to provide longitudinal data on long-term sustainability impact (Benzidia et al 2021). Moreover, contemporary studies published in the Journal of Cleaner Production suggest that the implementation of AI in Bangladesh insufficiently considers systemic obstacles like access to energy and information, and informal labour conditions, and their compatibility with SCP (Sustainable Consumption and Production) (Azadi et al., 2023). Prevalent sustainability challenges in RMG sector are followings:

Environmental Sustainability Challenges

RMG is one of the resource and polluting based industries having significant environmental implications in Bangladesh. The most pressing concern is the consumption of water where clothing is made, textile factories use up to 1,500 Liters of water to produce 1 kg of fabric (Haque, 2023). While dyeing and washing wastewater containing poisonous effluents is discharged into rivers leading to water pollution and aquatic ecosystem damage (Sakamoto et al., 2019). About 70% of the chemical dyes used in textile operations at the rates of more than $5.7 * 10^{\wedge 5}$ tons of artificial dyes being discharged directly to the environment (Islam et al., 2022). Moreover, 15.4% of the GHG emissions of Bangladesh are also contributed by the RMG sector, but it is mostly due to the coal based energy use and textile waste incineration (Rahman and Zhang, 2022). However, despite the increasing number of LEED-certified green factories, most small and medium-sized enterprises (SMEs) lack environmentally friendly practices because it is expensive and not strictly enforced (Reynolds, 2024).

Although the sector's environmental impact has been documented in academic research, the majority are quantitative indicators for resource use and waste emissions; hence, the source-localized information varies from region to region (Karim et al., 2021). Furthermore, certifications such as LEED are gaining popularity but the extent of their practice impact in terms of pollution reduction is still not known (Fatima & Hossain, 2025). There is a substantial lapse in assessing how digital technologies, e.g., AI, can optimize water and energy utilization in textile production (Kabir et al., 2023). The long-term consequences of industrial pollution in Bangladesh on the environment and health will require mixed methods in future investigations.

Social Sustainability Challenges

The majority of studies on social sustainability use qualitative data, mainly via workers' interviews, with such small numbers, that it is difficult to generalize. This literature has tended to focus more on the identification of, rather than intervention led testing of solutions to, challenges to working conditions (Uddin et al., 2022). Not many studies have used theoretical (theories of Marx especially his labour theory) framework to examine wage suppression and exploitation in RMG of Bangladesh (The Financial Express, 2020). Research in the future can examine application of monitoring AI to support work safety and labour rights observance.

Economic Sustainability Challenges

The RMG's dependence on cheap labour made it also susceptible to the vagaries of the world market. COVID-19 pandemic reduced exports by 30%, with $3.18 billion of order cancellations (World Bank, 2021). Inflation costs (energy, materials, wages) are pressuring profit margins and make factories resort to unsustainable practices such as salary cuts, stop providing annual salary increments and promotions in top management level (Mottaleb & Sonobe, 2021). The industry is also plagued by lack of diversification with 80% of exports exposed to EU and US markets (Kabir et al., 2023). Infrastructure constraints, including port congestion and power outages, lead to longer times and higher costs (ADB, 2022). Further, lack of regulatory harmonization and bureaucratic inefficiencies hamper competitive capacity (LightCastle Partners, 2025).

Economic research tends to deal with macro phenomena (e.g. downwards slide of exports, for example) and rarely provides micro analysis on how SMEs fight against a rise in costs (Rafique & Islam, 2025). Although some studies address green for industrialization, none of them deals with AI-based automation for efficiency improvement (Hossain & Khan, 2024). Approaches to policy interventions to promote diversification in high-value products and reduce exposure to global shocks should be addressed in further research.

The integration of artificial intelligence (AI) and sustainability in supply chain management (SCM)

The blending of artificial intelligence (AI) and sustainability solutions into supply chain capital (SCM) has become one of the important topical issues of research, especially, in fields where the structure of such networks is complex such as ready-made garments (RMG) industry. This paper reviews AI-based sustainability integration models based on theoretical and empirical literature with a particular emphasis on positioning them in the theoretical framework, methodological tools and relevance to Bangladesh's RMG sector (Di Vaio et al., 2020; Zhu et al., 2022). Based on the TBL framework, this research seeks to assess how AI technologies support the achievement of the environmental, social, and economic sustainability objectives and overcome the challenges encountered in the context of a developing economy (Stroumpoulis & Kopanaki, 2022).
AI-Driven Optimization for Environmental Sustainability

A critical challenge in supply chains has been reducing waste, emissions, and resource usage, high illuminating AI's potential for transforming these areas (Di Vaio, Manerba, Pozzetti, & Pozzetti, 2020; Zhu, Alam, Mutyalarao, Bolf, & Janssen, 2022). ML-models and predictive analytics make demand forecasting dynamic which reduces overproduction and inventory waste (an enormous problem in the RMG-sector where the fast fashion cycles lead to garment waste) (Lee, 2021). One such AI-enabled digital twin models supply chain operations to pinpoint carbon hotspots and help businesses in virtually testing the emission reduction interventions prior to actual interventions (Zhu et al., 2022). The methodologies have been implemented to European manufacturing and environmental scenarios for the optimisation of energy consumption in warehouses, and the minimization of fuel consumption in logistics through route optimization algorithms (Di Vaio et al., 2020). In the context of the Bangladesh RMG, however, their applications are still in their infancy owing to some infrastructural barriers, such as the deployment of disparate IoT sensors and data ecosystem (Reza & Du Plessis, 2022). Although research has emphasized the potential of AI to automate compliance with environmental regulations (e.g., tracking carbon footprints through blockchain), their widespread use in Bangladesh lies in fixing the data quality problem and upgrading the legacy systems (Jum'a, 2022).

AI Integration in Social Sustainability and Ethical issues

Social sustainability in supply chains includes fair labour treatment, safe working conditions and community consequences which is discussed as an area in which AI's role is ambivalent (Di Vaio et al, 2020). The safety of factory workers can be enhanced through predictive analytics by monitoring factory requirements in real time with the use of IoT sensors, however ethical issues arise concerning privacy of data and algorithmic bias (Jum'a, 2022). For example, AI-enabled WMS can improve employee productivity but also increase the stress on workers if not serving the well-being of workers (Olan et al., 2022). Key approaches to sustainability are the TBL, which revisits the way organizations function to achieve and efficient social balance (Gibson, 2009). It is a challenge to maintain in the RMG sector in Bangladesh that has seen an upswing in automation, uncoupled with social equity (Reza & Du Plessis, 2022).

The challenges are situated, in the TOE model, in technological tools such as those in AI for ethical audits and organizational resistance to transparency and environmental resistance, such as unstable energy grids (Stroumpoulis & Kopanaki, 2022). Case studies from other areas, like Siemens AI -carbon calculators, show how companies can connect environmental and social aims by developing algorithms collaboratively with stakeholders (Zhu et al., 2022). But there is few similar inter-sectoral cooperation of RMG of Bangladesh where the factories are focused primarily on cost saving factor rather than a complete sustainability (Reza & Du Plessis, 2022). Academic work has proposed the value of participatory AI models that harness worker feedback, but in practice, such models are underrepresented (Kabir et al., 2023).

Economic Viability and Scalability

The economic advantages of AI-cost savings, efficiency improvements, and market advantage are documented in global supply chain research (Di Vaio et al., 2020). For instance, inventory management systems based on AI help to minimize overstocking and spoilage and can deliver 10–30% greater profit margins in the retail industry (Lee, 2021). In the RMG sector such tools might be used to reduce the $3 billion per year loss created by overproduction and unsold stock in Bangladesh (Reza & Du Plessis, 2022). But the problem of scalability remains. Hybrid AI models based on ML and fuzzy neuromorphic logic, although promising in addressing demand uncertainty, are too much technical bar for majority of the suppliers located in Bangladesh (Kabir et al., 2023).

Theoretical and Methodological Considerations

Literature tends to use empirical case studies and simulation models to test out AI's fit in sustainable SCM (Zhu et al., 2022). e.g., Discrete event simulations have shown the reduction in emission from AI-optimized logistics and cases studies (i.e., Unilever) have illustrated waste reduction via IoT-enabled demand forecasting (Lee, 2021). Yet, these approaches are commonly not context aware. While regression analyses and system dynamics models may be solid in developed countries, the power and political complexity of the infrastructures in the Bangladeshi RMG sectors is largely ignored (Reza & Du Plessis, 2022).

2.1 Integrating the Triple Bottom Line (TBL) Framework into the Sustainability Challenges of Bangladesh's Ready-Made Garment Sector.

Introduced by John Elkington in 1994, the Triple Bottom Line (TBL) transformed how businesses define their success, broadening traditional financial accounting to encompass social and environmental results (Elkington, 1994; Kenton, 2025). The model (illustrated in Figure 6) presumes that sustainable organizations must find an equilibrium across three linked dimensions: People (social equity), Planet (environmental stewardship), and Profit (economic viability) (Elkington, 1997). Developed in response to an understanding that sustainability of capitalism is based on its ability to deal with systemic inequalities and ecological destruction, the TBL has played a key role in sustainable supply chain management (SCM) (Kenton, 2025).

The Theoretical Basis of TBL

People: Social sustainability means being ethical in how companies do business, whether it's in how they treat their workers to safeguard everyone's safety in how they work. In supply chains, this means that fair wages, gender equality, and stakeholder engagement imply these forms of sustainability (Elkington, 1994; Rahim et al., 2024).

Planet: Minimizing the ecological footprints by optimizing resource inputs and by reducing wastage and emissions is required for environmental sustainability (Elkington, 1999; ScienceDirect, 2024).

Profit: Economic viability is assured over the long term in ways that avoid marginally exploitative life cycles for those involved or which contradict social or environmental objectives (Elkington, 1994).

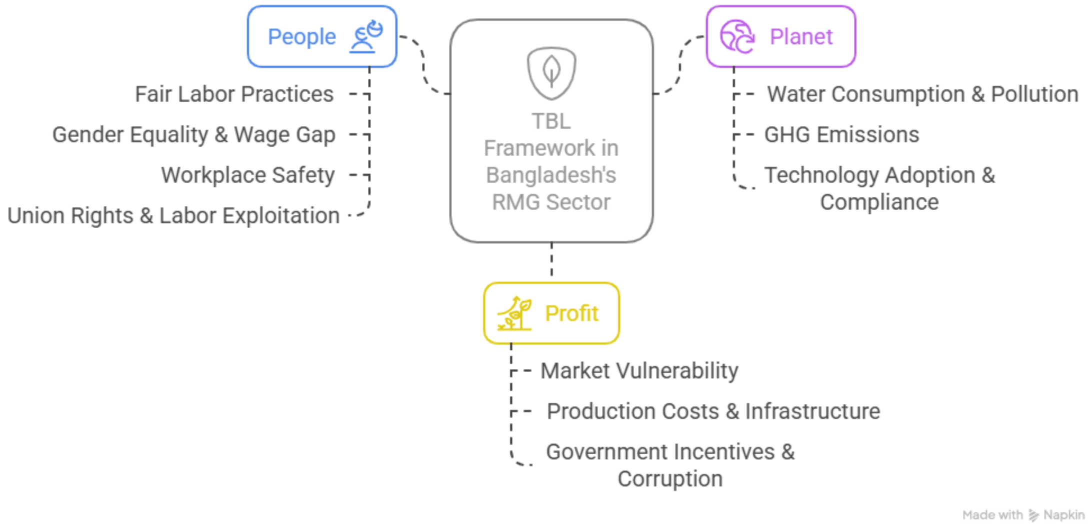

Figure 6. TBL Framework in Bangladesh's RMG Sector.

The application of the TBL to Bangladesh's Ready-Made Garment (RMG) industry is highlighted through its connection with the United Nation's Sustainable Development Goal (SDG), specifically SDG 8 (Decent Work), SDG 12 (Responsible Consumption) and SDG 13 (Climate Action) (UNDP, 2021). Yet, the industry's longstanding imbalances (placing profitability over people and planet) point to systemic lags on applying TBL principles (Clean Clothes Campaign, 2023; Rahman & Zhang, 2022).

Environmental Sustainability Challenges (Planet)

The RMG industry is the largest industrial water user in Bangladesh, consuming 1,500 Liters of water for production of 1 kg of fabric-50% higher than global standards (Haque, 2023). Wastewaters discharged from the dyeing and washing processes that are enriched with toxic elements like lead and cadmium pollute rivers such as the Buriganga ones posing severe risk to the aquatic life and public health (Sakamoto et al., 2019; Islam et al., 2022). Although the number of LEED-certified factories (e.g., Green Textile Ltd.) is increasing, 70% of SMEs remain without ETPs, contributing to worsening water pollution (Uddin et al., 2022; Bhuiyan et al., 2023).

The RMG contributes to 15.4% of Bangladesh's greenhouse gas (GHG) emission, those comes from the coal-based power plants and incineration of textile waste (Rahman and Zhang, 2022). At the micro level of analysis, such variation is frequently overlooked in studies that concentrate on emissions on average across all out growers (Karim et al., 2021). For example, (Chittipaka et al. (2023) used the Technology-Organization-Environment (TOE) model to analyse blockchain adoption, but not the energy waste in rural workshops.

Current research mainly uses cross-sectional surveys, and self-reported data, self-reporting tends to over-report of adherence especially of environmental laws (Fatima & Hossain, 2025). For example, Hasan et al. (2023) identified barriers to GSCM in Bangladesh, however the small sample size (n = 45) reduces generalisability. Research must be of mixed-methods design, using both IoT sensor data and costing data linked with worker interviews, to collect localized impact (Kabir et al., 2023).

Social Sustainability Challenges (People)

Despite 84% of the country's export revenue being generated by the RMG sector, it entrenches working poverty, with 32% of workers being paid less than the proposed 2023 minimum wage of 12,500 BDT/month (≈$113), which is far below the living wage of 16,000 BDT (Clean Clothes Campaign, 2023; GoodWeave International, 2025). Gender gaps are wide: women make up 80% of the workforce yet earn 20–30% less than men and suffer systemic harassment (Menzel & Woodruff, 2021). Although qualitative studies, such as Reinecke and Donaghey's (2021) examination of industry wide post Rana Plaza reforms, are rich in narrative, the empirical strength of non-random sampling remains weak.

The collapse of Rana Plaza in 2013 that killed 1,132 workers was the stark result of longstanding safety malpractices, but 40% of factories still do not have fire exists and fail structural audits (Reinecke & Donaghey, 2021: Amnesty International, 2023). Though conditions have improved in Tier-1 suppliers due to Accord on Fire and Building Safety, however, sub-contractors who are generally not registered SMEs are still unguarded (Paul-Majumder & Begum, 2020). Even data on suppression of trade unions, such as act as blacklisting activists, has been demonstrated as non-causal and anecdotal (Clean Clothes Campaign, 2023).

There are few studies which use Marxist labour theory or feminist frames to unpack exploitation in the RMG sector (The Financial Express, 2020). For instance, Uddin et al. (2022) investigated GSCM adoption but ignored the dynamic process between MNCs and local suppliers. Future research could incorporate stakeholder theory in examining how buyer led pressures are linked to labour management practices (Freeman & McVea, 2001).

Economic Sustainability Challenges (Profit)

Given the RMG sector's dependence on cheap labour, it is vulnerable to global shocks as evidenced during the COVID-19 pandemic, when $3.18 billion in orders were cancelled, leading to widespread lay-offs (World Bank, 2021; Mottaleb & Sonobe, 2021). Soaring production cost energy spiked 22% in 2023 compel factories to cut the corners of sustainability investment (LightCastle Partners, 2025). Port congestion in Chittagong, frequent power outages, which add 30 percent to lead times, making companies less competitive (ADB, 2022).

2.2 Critical Analysis of Methodologies in Sustainable Supply Chain Management Research and Relevance to Bangladesh's RMG Sector.

While the literature surrounding SSCM has reached remarkable theoretical and empirical contributions, however, a number of challenges are noteworthy regarding the methodology when it is applied to RMG sector in Bangladesh. A review of existing peer-reviewed research highlights repeats methodological deficiencies, including a reliance on cross-sectional surveys, geographical bias, and failure to incorporate mixed-methods approaches that could account for the country's distinct socio-economic and institutional environment.

Cross-sectional surveys and static analysis misuse

Analyses such as that of Zhu and Geng (2013) reporting on the use of extended supply chain practices within the Chinese manufacturing sector are also weighted towards the cross-sectional survey approach to field research, which risks generating snapshots of behaviour at a point in time, but which cannot record the changes influenced by time or emerging challenges to sustainability. A static framing of dynamic processes in Bangladesh's RMG context, in which regulatory pushes and pulls and global buyer pressures change rapidly, also misses the interplay between technological adoption (e.g., AIwater recycling systems) and institutional obstacles (e.g., weak enforcement of effluent treatment plant requirements). Similarly, Dubey et al. (2015) use SEM to test green supply chain frameworks, however, they prioritise on large firms and do not consider the financial and technological constraints of the SMEs, although they contribute to 85% of the RMG factories of Bangladesh (BGMEA, 2023). Cross-sectional plans are further susceptible to the problematics of correlation≠causation as exemplified in Yang et al.'s (2011) synthesis associating lean manufacturing with environmental performance ignoring the context of labour union repression or gender discrimination in Bangladesh (Barsha & Lee, 2024).

Regional Bias and Lack of Generalizability

Genovese et al.'s (2017) circular economy framework, are based mostly on high-income economies with strong regulation that contrasts sharply with the informal working conditions and split governance witnessed in Bangladesh. For example, the analysis by Klassen and Vachon (2003) of different types of supplier collaboration in North American plants highlights formal long-term contracts—rarely plausible in the Bangladeshi RMG industry (where 60% of labour abuses are perpetrated by labour contractors in informal networks (Bhuiyan et al., 2023). Similarly, Govindan et al. s (2015) MCDM using advanced analytics requires digital infrastructure (restricted to less than 1% of microenterprises and one-third of SMEs). These regional biases hamper the generalisability of findings, for example, the use of manual monitoring in Bangladesh (68% of factories) and price-driven buyer relationships in Bangladesh means that SSCM frameworks require localised tailoring (Kabir et al., 2023).

Ignoring Mixed-Methods and Participatory Methodologies

Reflecting the overall quantitative empirical dominance in SSCM research, such as Prajogo and Olhager's (2012) survey-based research of supply chain integration, it is rare to see qualitative evidence of cultural and behavioural barriers side-line the physical technological dimension of SSCM. For instance, the RMG sector in Bangladesh experiences patriarchal norms such as social norms that prohibit women from managing roles (only 8% of representation), although research such as Sarkis' (2012) boundaries-and-flows explanation ignores intersectional gender analyses (Menzel & Woodruff, 2021). By contrast, participatory action research (PAR) and ethnography, in the view of Mangla et al. (2018) in a circular supply case chain, for instance, could be used to frame worker perceptions towards introduction of AI or blockchain traceability. The absence of mixed-methods approaches likewise constrains the extent to which macro-level policies (e.g., Bangladesh's Environmental Conservation Rules) though they may counteract factory-level actions and impacts, interact with micro-level practices, for instance, factory managers resistance to LEED certification costs (Uddin et al., 2022).

Insufficiently Taking Power Imbalances into Account

Although this model of CSCM has been useful for highlighting stakeholder's orientation, it fails to explicitly consider the power asymmetry between the multinational corporations hailing from the Northern hemisphere and the Bangladeshi suppliers (Carter and

Rogers 2008). For example, Reinecke's and Donaghey's (2021) study of structural reform post-Rana Plaza, demonstrates how buyer-driven audits privilege compliance over true progress, fuelling "certification fatigue" amongst suppliers (Bhuiyan et al., 2023). Likewise, Ahi and Searcy's (2015) measures of green performance fail to account for the economic precarity that pushes factories to focus on short-term cost-cutting instead of longer-term investments in sustainability. This oversight is particularly relevant in Bangladesh, given that brands' FOB pricing bias technology for being eco-friendly as financially unfeasible for SMEs (World Bank, 2016).

Fragmentation in theory and misalignment in context

Conceptual models such as the Technology-Organization-Environment (TOE) model, used by Chittipaka et al. (2023) over the adoption of blockchain, tend to depoliticize them by decontextualizing the technological blockchain. In Bangladesh, blockchain's promise for wage transparency is stymied by factory owners' refusal to allow unionization, a factor omitted in studies of technical compatibility alone. Similarly, Beske et al. 's (2014) dynamic capabilities framework, are relevant to the analysis of large corporations, however they do not incorporate institutional theories that explain how corruption and weak enforcement breed non-compliance with environmental regulations (Haque, 2023). Such fragmentation hinders the applicability of SSCM models in resolving system-level problems such as port congestion or subsidy misallocation, which add 8–12 days to lead times each year in Bangladesh (ADB, 2022).

2.3 Conceptual Framework of Artificial Intelligence and Sustainable Practices in Supply Chain Management.

The concept map representation of the integration of AI with sustainability in SCM in the RMG sector in Bangladesh is the result of an extensive review of empirical evidence, theoretical models, and sectorial analysis. Built to specifically consider the sector's interlinked environmental, social and economic challenges, it demonstrates ways in which AI can act as a catalyst and enabler for comprehensive sustainability. This framework (shown in Figure 7) has been developed based on a critical review of literature, which includes global best practices as well as the context specific social realities of the Bangladesh garment industry.

The literature consistently highlights the disproportionately large environmental footprint, social inequalities and economic instabilities exhibited by the RMG sector. Environmental research indicates that the industry is one of the most resource-intensive industries in Bangladesh, with a water use as much as 1500 litres/kg fabric and leaving substantial chemical effluents in river and air (Haque, 2023; Sakamoto et al., 2019). The industry is accountable for 15.4% of the country's greenhouse gas emissions, due to coal power and burning of textile waste (Rahman & Zhang, 2022). However, although the number of LEED-certified factories is currently increasing, this does not apply to most SMEs, which lack the resources and the knowledge to integrate sustainable practices that are further weakened by lax regulatory controls (Uddin et al., 2022; Bhuiyan et al., 2023).

Challenges of social sustainability are equally prevalent. Wages fall far below the level needed to support a living income, with 32% of workers reported to earn less than the legal minimum income (Clean Clothes Campaign, 2023; GoodWeave International, 2025). Gender inequality remains and women have an income 20–30% lower than men and are subject to systemic harassment (Menzel & Woodruff, 2021). The 2013 Rana Plaza collapse revealed on-going safety failings as many factories don't even have basic fire exits or building inspections for safety (Reinecke & Donaghey, 2021). Trade union repression and employer control of safety hierarchies also weakened the rights of workers (Amnesty International, 2023).

Economically, multiplying issues such as low-wage labour force dependence, distressed market diversity, and the frequent vulnerability to external shocks (including the Covid-19 shock) that have led to a 30% reduction in exports and an order cancellation of $3.18

billion gripped the RMG industry (World Bank, 2021; Mottaleb & Sonobe, 2021). Competitiveness has been further eroded due to increasing production costs, infrastructure deficiencies and regulatory ineffectiveness (Light castle Partners, 2025; ADB, 2022).

The literature further provides evidence on the capacity of the green supply chain management (GSCM) and cleaner production (CP) initiatives to reduce environmental degradation and enhance economy efficiency (Hasan et al., 2023; Tumpa et al., 2019). However, the use of SM doesn’t have a significant presence or adoption widely, especially among SMEs, because of the high initial investment, its requirement for skilful support and the lack of policy support (Uddin et al., 2022).

AI’s role in contributing to social sustainability is increasingly in the spotlight. Blockchain-enabled payrolls and IoT for safety monitoring can promote transparency, pay workers on time, and provide a safe workplace (Clean Clothes Campaign, 2023; Kabir et al., 2023). Nevertheless, the literature warns that AI-led automation could replace low skilled workers and questions the ethical dimension of job security and fairness (Eco-Business, 2024; Menzel & Woodruff, 2021). Consequently, human-centred integration, workforce upskilling, and participatory policies should be the focus of responsible AI adoption (Rahim et al., 2024; Alsakhen et al., 2024).

In the economic sense, supply chain resilience, cost effectiveness, and market responsiveness are improved when AI is integrated. The development of predictive analytics and machine learning algorithms facilitates better demand forecasting and optimal inventory management that in turn results in lower stock levels and lead time (Kabir et al., 2023; Saha, 2024). Logistic soar in functioning quotient, with perspective of time and company in China’s Alibaba which condensed time of act and transport cost which could serve as a framework of Bangladesh (Chen, 2024). Nevertheless, infrastructure gap, privacy of the information, and SMEs digital unreadiness are still major obstacles (Riad et al., 2024; Ahmmed, 2024).

The resulting conceptual framework is developed by superimposing these empirical and theoretical findings on the nature of sustainability challenges in the RMG sector in Bangladesh. It identifies AI as a cross-cutting enabler, co-working and reinforcing GSCM, CP and regulatory frames, leading to an advance in the ESE (Environmental, Social and Economic).

This concept model portrays the implementation of AI and the adoption of sustainability in Bangladesh's garment supply chain with a view to achieving efficiency, cost effectiveness, and environment-friendliness. The first step involves data acquisition. It serves to overcome the challenges of demand volatility and resource inefficiency with AI-based analytics, equals demand forecasting, inventory management, route planning and more. At the same time supplier verification of sustainability is also made possible, guaranteeing ethical and eco-friendly sourcing and the tracking of carbon emissions and reporting for full transparency worldwide environmental codes are fulfilled. The net effect is a game changing movement towards green impact, from reducing carbon emissions and resource efficiency to applying circular economy models. By infusing AI and sustainability within standard supply chain practices, this model paves a path for the fashion sector to drive operational excellence in tandem with meeting the increasing need for sustainable production. This process will not only protect competitiveness but will also help to meet global sustainability targets, making Bangladesh a leader in responsible and intelligent supply chain management.

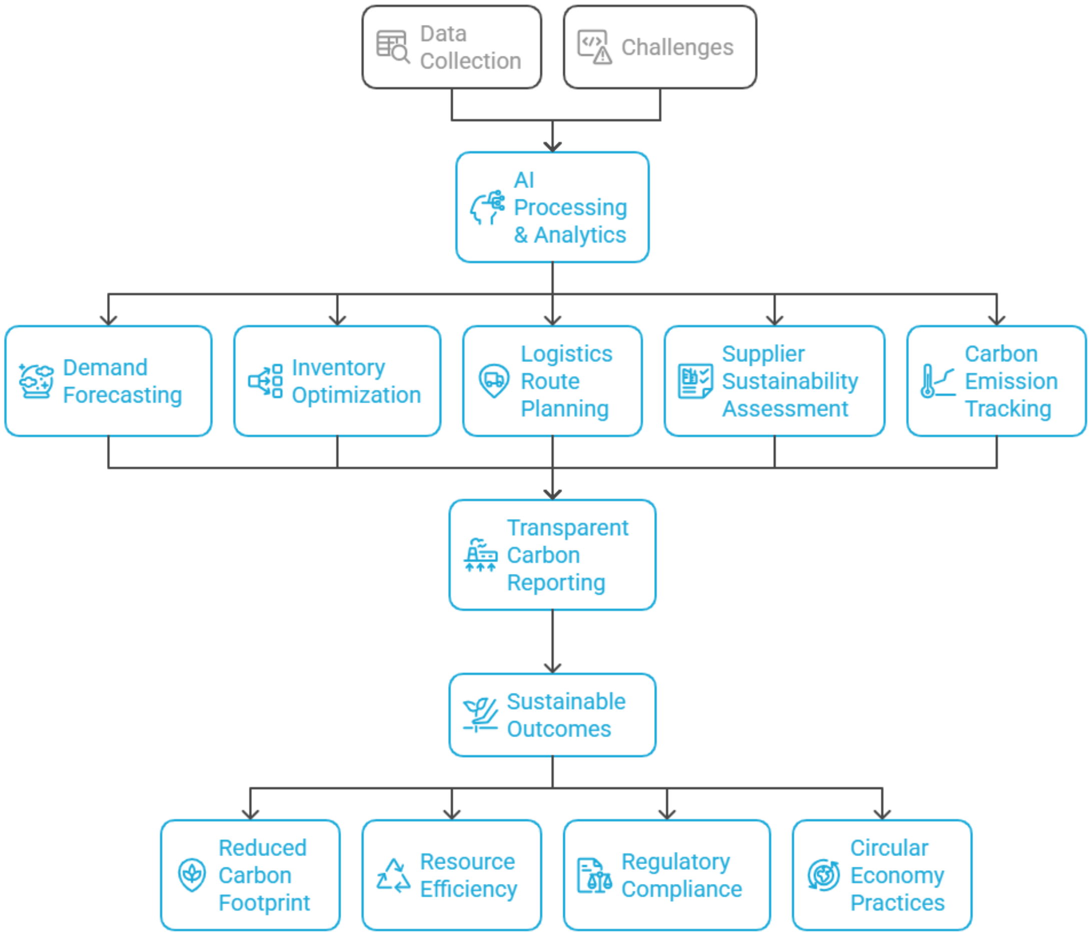

Figure 7. Conceptual Framework Linking AI and Sustainable Practices in Supply Chain Management.

Explanatory Narrative Linking Constructs and Causal Relationships

At the heart of the system is the incorporation of artificial intelligence (AI) technologies, fuelling a living engine of change for sustainable management throughout the supply chain. It is important to note that the impact of AI is not only at one level, but is cutting across environmental, social and economic sustainability, and enabling areas such as green supply chain management, cleaner production, and governance, and so on (Tumpa et al., 2019).

Environmental Sustainability:

Real-time monitoring and optimisation of resource consumption, emissions and waste made possible through AI technologies like IoT sensors, machine learning algorithms, and computer vision systems. AI enables dynamic adjustments of water usage to match production demand, whereas predictive analytics minimize energy consumption, thus minimizing the industry's carbon footprint (Kabir et al., 2023; Rahman & Zhang, 2022). Computer vision-based quality control systems are being used to minimize material waste by identifying defects at an early phase in the manufacturing process (Kabir et al., 2023; The Daily Star, 2025). The applications directly target the industry's biggest environmental challenges high water usage, chemical pollution, and GHG emission and support data driven decision-making.

Social Sustainability:

The social aspects of sustainability will be affected by AI in many ways. Payroll systems using blockchain and safety monitoring with the use of IoT have achieved transparency, timely wage remuneration and better working conditions (Clean Clothes Campaign, 2023; Kabir et al., 2023). Compliance monitoring based on AI can automate the identification of labour-rights abuses, with predictive analysis unearthing patterns of harassment and hazardous working conditions, and with those rationalizing timely interventions (Menzel & Woodruff, 2021; Amnesty International, 2023). Yet the literature also stresses the possibility of job displacement as a consequence of automation, bearing witness to the necessity of a responsible AI adoption which focuses on worker welfare, upskilling and participatory design (Eco-Business, 2024; Rahim et al., 2024).

Economic Sustainability:

The integration of AI advances economic sustainability by driving efficient operations, cost competitiveness, and supply chain resilience. Predictive analytics and machine learning algorithms facilitate demand prediction, inventory holding and logistics management, leading to reduced overstocking and lead times as well as transport costs (Kabir et al., 2023; Saha, 2024). AI based systems could suggest alternative suppliers in case of an unexpected disruption of supply, thus allowing continuity and responsiveness (The Daily Star, 2025). Yet, greater efficiency is often translated into improved profitability and increased ability to invest in sustainability initiatives, thereby contributing to the sector's sustainability in the long run (World Bank, 2021; Mottaleb & Sonobe, 2021).

Governance and Regulatory Regimes:

Compliance and governance: AI can also help government entities and businesses adhere to applicable regulations and achieve better compliance. Transparency in supply chain transactions can be improved by blockchain platforms, and AI-based monitoring systems can help in upholding regulations through the provision of real-time data on environmental and labour adherence (Bhuiyan et al., 2023; Kabir et al., 2023). Nonetheless, the success of these tools relies on strong policy frameworks, and ethical guidelines, as well as people's collaboration (Rahim et al., 2024; Saha, 2024).

Holistic Sustainable Results:

The causal chains incorporated in the framework all result in overall sustainability effects in the form of minimised environmental impact, improved labour standards and enhanced economic resilience. The marriage of AI within these areas establishes a virtuous circle: environmental efficiencies unlock resources for social investments; social advancements cultivate a more committed and productive labour force; and economic benefits generate the capital necessary to expand sustainability projects (Kabir et al., 2023; Zhu et al., 2022). Literature underscores a key role for continuous improvement, stakeholder advocacy and adaptive learning for AI-enabled sustainability to be responsive to changing challenges and opportunities (Saha, 2024; Chen, 2024).

Contextual well adapted and methodological issues:

A critical review of existing methodological approaches in the literature informs the framework's development. Although many of these use cross-sectional surveys or case studies, there is a mounting demand for mixed-methods research that integrates quantitative data (this could be from sensor- based monitoring, for example) with qualitative evidence (such as interviews with workers) to understand the entire range of AI's impact (Kabir et al., 2023; Menzel & Woodruff, 2021). Take for instance, the comparative case study between Bangladesh and China demonstrates that AI-models must be attuned to local realities of practice which include infrastructural impeachments, as well as cultural norms and policy environment (Riad et al., 2024).

Ethical and human-centred Integration:

Lastly, the literature stresses the importance of ethical AI incorporation that juxtaposes technological progress with human focused values. This encompasses considerations of data privacy, algorithmic bias, social impacts of automation, and making sure that the introduction of AI will not reinforce current inequalities (Eco-Business, 2024; Rahim et al., 2024). The transition from Industry 4.0 to Industry 6.0, as reviewed (Frontiers in Artificial Intelligence, 2024), would emphasize increased collaboration between humans and AI, workforce training and upskilling, and participatory governance in order to optimize both efficiency and equity.

3 RESEARCH METHODOLOGIES

The research approach, data collecting strategies, analytical tools, and research validity and reliability policies used in this work are described in this chapter on methodology. Carefully crafted to investigate the integration of artificial intelligence and sustainable practices within Bangladesh's apparel industry supply chains, the study design addresses both technological implementation issues and sustainability imperatives in this important economic sector.

3.1 Data Collection.

3.1.1 Research Method.

According to Kumar (2019), research methodology is the theoretical analysis of the methods applied to research problems in a particular field of study including the principles, paradigms, and procedures of research. At its heart, it is the science of how to learn scientifically; the meticulous choice and practice of practices that result in valid, reliable and useful knowledge (Redman & Mory, 2009). Three main categories are generally selected by researchers: qualitative, quantitative, and mixed methods (Almalki, 2016). Qualitative research is designed to make sense of complex phenomena with rich, descriptive data, often collected through interviews or observations, in order to interpret meanings and experiences. With quantitative research, people collect and analyse numeric data for patterns, test theories, detect historical patterns, and turn up some not-totally-quantitative truth. Mixed methods of research combine qualitative and quantitative research to utilize the strengths of both and to yield a greater understanding of research issues (Creswell & Plano Clark, 2017).

Due to the multidimensional nature and complexity of applying artificial intelligence (AI) to sustainability in Bangladesh garment industry supply chain, content and interpretive analysis will be used in combination (mixed methods) for this study. This method is particularly appropriate for studying the integration of AI and sustainability as it enables to delve deeply into contextual and experiential account (qualitative research), and to measure systematically patterns and relationship (quantitative research) in the domain. Operational difficulties, barriers to technological development and sustainability pressures, however, cannot be sufficiently captured based on quantitative measures alone in the Bangladeshi apparel industry. Content and interpretive methods are useful for qualitative data (e.g., interviews, open-ended responses) to help the researcher identify 'themes and meanings, patterns of action, social processes, the nature and meaning of people's experiences, processes of influence, ideological aspects, among other narratives that express ways AI technologies and sustainability programs are perceived, put in practice, and interconnected in the world' (Elo & Kyngäs, 2008; Schreier, 2012).

Interpretive content analysis transcends description to focus on the interpretive analysis of participants' experience and sociotechnical processes at work (Hsieh & Shannon, 2005) that is vital for unpacking the complexities of AI adoption in what is a historically labour-intensive and sustainability conscious industry. This approach allows the identification of subtle barriers, for example adaptability of workforce, ethical issues, and organizational culture, not necessarily picked up by quantitative surveys. In addition, the content analysis contributes to systematic coding and theme development, which guides the design of quantitative instruments that can make survey items rooted in industry contexts.

3.1.2 Research Approach.

The methodological design procedure taken is primarily driven by the research question and it determines the methods and techniques used to ensure that the research study is relevant to solving the problem presented (Khan, 2018). Research tends to manifest itself in three primary features: a methodical means of data collection, a disciplined manner of drawing interpretations from the data and a clear demonstration of the reasons behind the research. Fundamentally, research is an organized approach to finding answers to professional or practical questions by the use of tried and tested procedures and methods (Khan, 2018).

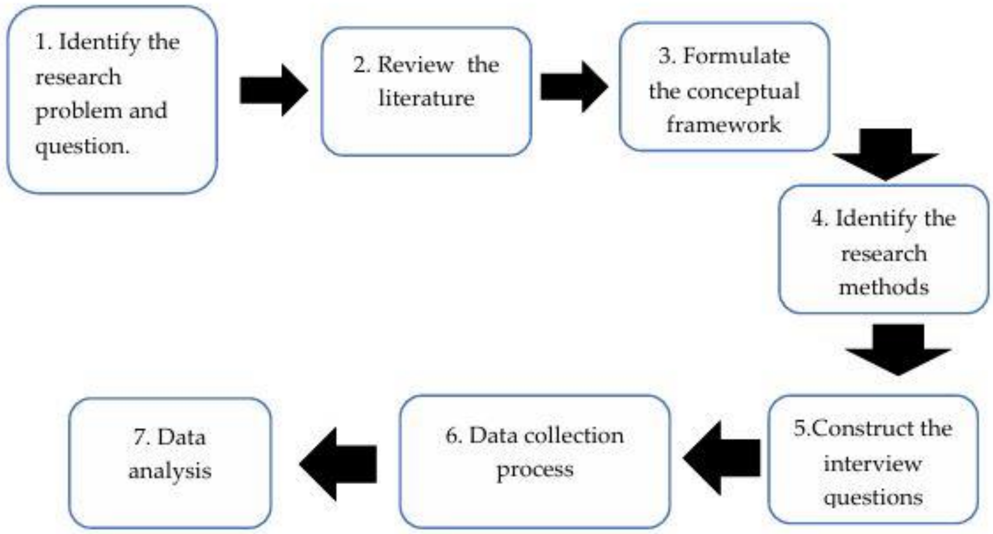

Figure 8. Research Process.

For the purpose of this thesis exploring AI integration and sustainable practices in Bangladeshi garment supply chain, a combination of qualitative and quantitative methods applied as a content and interpretive of analysis approach is followed. This is particularly appropriate to the case of study, since this is a rich case; researchers have a complex and multi-faceted story during which technological innovation and sustainability issues will take place in a social-economic and cultural context. Content and interpretive analysis allow the researcher to methodically analyse textual data, such as interview transcripts, policy documents, and industry reports systematically to reveal underlying meanings, themes, and patters (Elo & Kyngäs, 2008; Hsieh & Shannon, 2005). This qualitative aspect offers nuanced empirical views on ways AI technologies are perceived, adopted, and made to contribute to sustainability goals in the RMG sector that lack the richness and can be captured through quantitative approaches.

Mixed methods further enhance this, with numerical data collection and analysis such as surveys and statistics surveys and tests that enable assessing the prevalence and strength of themes identified through the wider population of industry members. This mixture improves the reliability and validity of the results through triangulating the qualitative narratives with quantitative back-up and compensates for the disadvantages associated with the use of single-method approach (Greene et al., 1989). For instance, qualitative insights about the adaptability of the workforce or ethical issues could be used to design scales that measure the influence of these factors on the success of AI adoption, facilitating the generalization of results beyond the initial exploratory sample.

The order in which the elements of the mixed method approach are pursued is not accidental and is justified. The research starts with a qualitative data collection and interpretive content analysis to understand and explain the complex interplay of AI and sustainability integration in the garment supply chain. This first step is exploratory, opens up hypotheses, determines crucial constructions, and positions the problem. Following, the quantitative phase substantiates these findings at a larger level of analysis, therefore adding empirical generalisability to the work, as well as its statistical robustness. This phased approach guarantees the quantitative tools are based on concrete experiential knowledge, and increases their coverage and validity (Ivankova, 2006).

Qualitative and quantitative methods

Qualitative and quantitative research methods, although there are many between and beyond, are two major methods and approaches to research in scientific and social research. Qualitative research attempts to gain an understanding of meanings, experiences, and the social contexts of people’s lives by the use of non-numeric information such as interviews, observations and textual analysis. It seeks the “why” and “how” of phenomena by eliciting rich and deep insights that exposes complicated human task, perceptions and organizational processes (Denzin & Lincoln, 2000). This approach is ideal when researching nuanced contextualized issues, the subjective experience and meaning is at the core of the study. For instance, in the supply chain of the garment industry, qualitative methods can be very helpful in understanding how managers and workers appreciate the integration of AI and bring to light sustainability challenges (barriers and facilitators which are not easily quantifiable).

On the other hand, quantitative research inquires numerical data to explain, predict and describe a phenomenon correlating statistical methods. Objectives, measurement and generalisation are the key landmarks of science, which are used to test hypotheses and trace patterns across larger populations (Zyphur & Pierides, 2020). Quantitative methods often used are structured surveys, experiments and statistical observations, as it enables researchers to measure variables, and establish a relationship or causal effects. For AI and sustainability in the garment industry, the quantitative method can quantify the diffusion of AI in this industry, the level of usage of specific sustainability issues or the statistical information about how AI has influenced productivity.

Although qualitative research is well suited to depth and context, the use of smaller non-representative samples may be affected by the subjective judgment of the researcher. Quantitative research provides breadth and generalisability but may fail to concentrate on the complexity and context, which is needed to understand the actual numbers (SimplyPsychology, 2023). In such scenario the strengths and weaknesses of both methods are complementary to each-other, therefore a mixed methods that combines both qualitative and quantitative data will be very appropriate for the thesis on integration of AI and Sustainability in the context of Bangladeshi garment supply chain.

The mixed methods design was preferred for the present study as it provides a richer explanation and understanding to given issues than would be provided by either methodology in isolation (Scribbr, 2025). In the qualitative phase, researchers can correlate contextual, organization and individual factors affecting the AI/sustainability integration, and come up with some hypotheses and main constructs. The insights are then used in the design of quantitative tools that examine and generalize across a wider population, thus reinforcing relevance and appropriateness. This progressive aggregation provides an increased level of credibility through triangulation as the more data sources providing converging results (Greene et al., 1989). In addition, mixed methods research also provides flexibility by combining theory generation and hypothesis testing, which is required in a field that is quickly changing such as AI application in supply chains.

In addition, combining the qualitative and quantitative phases is a response to practical issues in target industry application (the garment industry), in which technology adoption is a function of measurable factors (e.g., investment levels, production indicators) and intangible factors (e.g., employee attitudes, cultural resistance). The study applies both methods to grasp this complexity, yielding results that are both detailed and general.

The table 5 below sums up the distinctive features and similarities between the qualitative and quantitative methods:

Table 5. Qualitative and quantitative methods (adapted from Ghauri & Grønhaug 2005).

Aspect	Qualitative Research	Quantitative Research
Focus	Understanding meanings, experiences, and contexts	Measuring variables, testing hypotheses, generalizing
Data Type	Non-numerical: words, images, narratives	Numerical: statistics, counts, measurements
Sample Size	Small, purposive, non-representative	Large, random or stratified, representative
Data Collection Methods	Interviews, focus groups, observations, document review	Surveys, experiments, structured observations
Data Analysis	Thematic, content, interpretive analysis	Statistical, mathematical, inferential analysis
Research Questions	Open-ended, exploratory (why, how)	Closed-ended, confirmatory (what, how much)
Strengths	Depth, context, flexibility, rich insights	Objectivity, precision, generalizability
Limitations	Subjectivity, limited generalizability, time-consuming	May miss contextual nuances, less flexible
Application	Exploring complex phenomena, theory building	Testing hypotheses, establishing cause-effect

A mix of methods approach, with use of qualitative description and interpretation juxtaposed with quantitative survey and statistical applications, is most appropriate for this thesis. It allows for a systems lens for examining AI and sustainability integration in a garment supply chain in Bangladesh, combining the strengths in both qualitative depth and quantitative breadth, ultimately generating robust, credible, and actionable insights.

3.1.3 Sampling Framework.

The choice of companies in this study was based on a convenience sample, a non-probability sampling method where the participants are selected based on their easy availability to the researcher (Etikan et al., 2016). Convenience sampling is characterized by practicality taking precedence over statistical rigor and is highly appropriate when time, resources, and/or access to participants is restricted. While it is criticized for the possibility of bias and lack of generalization, it is useful for exploration or preliminary studies, and for testing out the measures (Bornstein et al., 2013). The researcher thus had no other option but for convenience sampling, which allowed the researcher to immediately access and contact garment firms within the Bangladeshi supply chain sector where an access and contact need to be addressed with urgency due to high costs of time and money and distance to be covered.

Convenience sampling was chosen as a method based on the exploratory and mixed methods nature of the study, where the qualitative interviews are used to elicit rich, contextual knowledge of sustainability practices, AI adoption, and its relationships and effects on productivity, efficiency, waste reduction, and profitability. The firms chosen were those easily accessible through established networks and business interfaces so that data could be collected promptly, though not at the expense of depth of information obtained. This practice is in line with the challenges associated with the practicality of carrying out surveys in developing countries where formal sampling frames are either absent or difficult to establish (Etikan et al., 2016).

In particular, the author administered questionnaires in 50 garment factories located in major garment clusters in Bangladesh (Gazipur, Narayanganj, Savar/Ashulia, and Dhaka Central). Of these, 30 companies replied with a 60% response rate, which is acceptable when it comes to organizational research with senior management (Baruch & Holtom, 2008). Crucially, these responses came from high-ranking business unit representatives (i.e., supply chain directors, planning managers, etc.), whose opinions are valuable owing to their strategic decision-making positions within their organizations and their familiarity with their organizations' operation and technology issues (Larson et al., 2007). This emphasis on top-tier decision-makers adds credibility and significance to the data, as these individuals play a key role in both driving AI integration and sustainability programs.

Although a limitation regarding the representativeness of the sample, thus interviews ensured to some degree by the involvement of the top management, as, it in information about the practices and challenges at an organizational level" (Baruch, 1999). Furthermore, the geographical dispersion of the sample over several industrial areas minimizes the impact of location-based biases and increases the variety of experiences covered. The study also recognizes that convenience sampling is not designed to yield statistically generalizable outputs, however, to provide rich context data that can feed into follow-up quantifiable stages and larger industry knowledge. Method of sampling the study sample was drawn conveniently, based on the necessity of gaining quick and easy access to a population of informed respondents in a complex, linked and distant sector. This method was effective in capturing high-quality qualitative data among a timely and experienced sample to contribute to the mixed methods design. Some of the rigour is enhanced through achieving a fair response rate from 30 garment firms coupled with the strategically located of respondents, thus adding some degree of dependability and relevance of the findings to the research objectives.

Sample Representativeness: Firm Size, Export Orientation, and AI Adoption Stage

When researcher was selecting the 50 garment firms for this study, he was mindful to represent the diversity of Bangladesh's ready-made garment (RMG) sector in terms of firm size, export orientation, and technology use, in particular with respect to AI adoption. The resulting sample consisted of 30 responding companies, spanning diverse organisational size and different operational area concentrates, and producing a significant amount of top management rich information.

Firm Size: The sample consists of both small, medium, and large firms. From mega conglomerates such as Beximco, DBL Group, Ha-meem Group, and Asian Apparels Limited, each employing thousands of workers and making several hundred million dollars in annual sales, to small(er) niche exporters (Statista, 2025). Asian Apparels Limited, for instance, employs more than 40,000 workers and has an annual sale of around $280 million and Posh Garments, with 1,200 workers, exported over 2.6 million units in 2022 (Posh Garments, 2025). Including such companies is to make sure the points of view of larger exporters as well as medium-size players are covered by the companies we have in practice.

Export Orientation: The RMG industry in Bangladesh is predominantly export oriented, over 90% of products being aimed at international markets, in particular the EU, USA, UK, and Canada (Textile Focus, 2025). All the companies in the sample are current exporters with several including Ananta Group and Masco Group stating that over 70% of their production is exported to Europe and other developed markets. This export orientation is particularly important, as it fits with the sector's position as a global supplier and its links to international standards for sustainability and the uptake of technology. The heavy export-oriented nature of the sample adds credibility to the results to apply to the global market requirement factors for AI-Sustainability alignment.

AI Adoption Stage: The sample represents a range of AI adoption maturity. Although some leaders have already deployed sophisticated AI-powered systems for quality control, predictive analytics, or supply chain optimization, the rest are still at earlier stages testing automation or experimenting with digital solutions. For example, there are factories where an AI is applied for defect detection using computer vision or there are factories that still rely a lot on manual, but they are very enthusiastic in transforming to digital space. This difference enables the study to account for adoption difficulties as well as benefits occurring with more sophisticated companies.

Inclusion/Exclusion Criteria: Researcher included firms if they were listed garment manufactures under the four main industrial clusters in Bangladesh (Gazipur, Narayanganj, Savar/Ashulia, Dhaka Central), with current supply chain activities and had adopted or were consideration AI and/or sustainability projects. Companies which operate strictly in the domestic market or have nothing to do with supply chain modernization were also removed, because it would not have been relevant to the purpose of this study.

Potential Biases and Limitations: Convenience sampling and voluntary response methods used would lead to selection bias as firms more interested in AI and sustainability or with access to communication channels would be more likely to participate (Etikan et al., 2016). Also, as information was collected from the top management, there is possibility that information reflects strategic views only, which even though may override operational problems at the lower management levels, however, may not fully reveal the operational difficulties. Notwithstanding such limitations, the diversity in the sample in terms of firm size, export orientation and stage of AI adoption, gives a sound basis for examining the AI-sustainability nexus in the RMG supply chain of Bangladesh.

3.1.4 Data Collection Methods.

Collection of primary data through semi-structured interviews:

Qualitative interviewing is a sensitive skill to be sensitively undertaken, carefully planned, and reflectively analysed, and thereby intended to yield authentic, deep, rich, and insightful information in relation to the research problems and aims. The interview is a dialogue-based method in which the researcher interviews participants using a set of questions, frequently open-ended, to investigate their experiences, views, attitudes, and knowledge in detail (Kallio et al., 2016; Galletta, 2013). Effective qualitative interviewing starts with a clear definition of the research purpose and the selection of pertinent respondents. These respondents can provide important perspectives about the phenomena of interest (Patton, 2015). Key decision-makers from the garment industry supply chains in Bangladesh are interviewed for this thesis in order to investigate how they envisage the integration of artificial intelligence (AI) in the value chain and implementing sustainable practices.

The interview guide is an interview outline of overarching questions that are open-ended to prompt participants to exchange rich stories and reflections, was prepared. In contrast with the structured interviews which are set up on set order questions, semi-structured interviews enable interviews to explore points of interest and to be able to elucidate confusing responses facilitating the interviewer to gain deepen and subtle understanding of complex factors (DiCicco-Bloom & Crabtree, 2006). Such flexibility is crucial for the complex topics with multiple perspectives such as AI implementation and sustainability incorporation, in which the experiences of participants and the contextual nuance provided are essential sources of the data.

Because the researcher is also geographically distant from participants in Bangladesh, and due to time and cost pressures, interviews for this study take place in an online environment (e.g., Google Forms). Video/online interviewing is increasingly recognized as a robust strategy for qualitative research, especially when researchers are operating in global and pandemic contexts where in-person meetings are at best inconvenient and often impossible, but also for so many other reasons such as cost-efficiency, coverage across dispersed participants/absence of researcher embodiment (James & Busher, 2016; Janghorban et al., 2014). While online interviewing might limit access to certain aspects of non-verbal behaviour, and pose challenges in terms of technical issues, these can also be worked with by relying on trustworthy technology, communicating clearly, and by setting up rapport using informal chat at the beginning of each interview (Keen et al., 2022).

Interviews for this research typically take 10-15 minutes and are scheduled when most convenient for the participants, even during work time in order to avoid inconvenience. The interview was in a questions forms consist of 3 multiple choice questions and 12 open ended written question in google form so that textual content and interpretative analysis can analyses themes, patterns and insights related to AI and sustainability challenges and opportunities in the garment supply chain (Kallio et al., 2016).

Qualitative interviewing in this study consists of a rigorous but practical structured approach. Semi-structured, open-ended questions with the assistance of online interviewing technology enables the informant to provide rich, contextually situated data from a knowledgeable insider perspective. This way, the design encourages fulfilling the research objective to understand how AI and sustainability intersect in the garment supply chains in Bangladesh in detail and this serves as the basis for the quantitative phase and the overall mixed method design.

Secondary Data Collection: Secondary data were collected from following sources

- Industry data provided by Bangladesh Garment Manufacturers and Exporters Association (BGMEA).
- Documentation on artificial intelligence applications from participating businesses and sustainability reports.

- Governmental policy manuals related to efforts on Industry 4.0 and sustainability.
- Published academic papers on supply chains changing in developing nations.

For comprehensive data acquisition, this approach of secondary data collecting fits the systematic review structure set by Moher et al. (2009).

Research Questionnaires

In this thesis, the process in which the research questions for the questionnaire have been developed and selected is closely aligned with the general research questions and objectives so that the questions are all working towards the overall aim; To understand how the integration of AI and sustainable practices are taking place in the garment supply chain of Bangladesh. The research questions were designed to gain a holistic understanding of the 4 primary thematic areas, existing supply chain operations and its challenges, adoption and application of AI, sustenance in the supply chain, and the effect of the technologies and practices on productivity, efficiency, waste minimization and profitability. The introduction of this thematic framework offered a clear conceptual prerequisite for good formation of questionnaires, so that the instrument could cope with the complexity of the research problem, as well as keep consistency with the research's objectives (Oyewola, 2025; Imperial College London, 2018).

In order to establish the validity and reliability of the questionnaire, a pre-test phase was carried out involving five professionals from the industry who reviewed the instrument draft. This pilot testing was important in detecting questions that were difficult to understand, items that were irrelevant or unclear, as well as testing the overall construction and length of the questionnaire (Bolarinwa, 2015). According to feedback received, the Q4 & Q5 was refined regarding wording, redundancy, and to the ability to follow for respondents with no or high knowledge in AI and sustainability. Such an iterative process is necessary in the context of mixed method research to increase internal consistency and minimise measurement error (Tavakol & Dennick, 2011). The pilot testing also supported that the survey successfully measured both objective data (i.e., firm size, export orientation) and perceptions (i.e., AI integration and corporate sustainability) hence, the mixed method design used in both qualitative and quantitative studies.

The questionnaire included close-ended questions in the forms of multiple choices and likerchart points and open-ended questions to be able to balance quantitative coverage with qualitative depth (SoPact University, 2025). Questions provided structured information adequate for statistical analysis; hence, levels of AI adoption, sustainable practices, and barriers could be quantified. An open-ended question was used to enable respondents to offer perspectives on their experiences, drivers, barriers etc. This allowed those perspectives that were not captured through the closed questions to be enriched further in the dataset. Such a design is consistent with the exploratory sequential mixed methods approach in which qualitative findings are used to define quantitative measurement (and vice versa) (Ivankova, Creswell, & Stick, 2006). The sequencing of the best practice statements helped to ensure content validity, as the best practice questionnaire was grounded in 'real-world' industry settings identified through initial qualitative interviews.

Respondents consisted of senior management and executives of 30 garment companies in four key industrial clusters in Bangladesh and were chosen to represent a wide range in terms of firm size, export orientation, and AI preparedness stage. Content information > Sampling The questionnaire design was guided by this purposive sampling approach, including items devised to measure the extent of these organizational elements and shape in which they affect the integration of AI and sustainability. For example, questions on current supply chain technologies, AI investment and sustainability initiatives were contextualized around the operational realities of both large-scale exporters and smaller manufacturers. This focused tactic kept respondents interested and engaged and enhanced the quality of responses.

The research questions themselves were developed to generate specific data on operational difficulties, technological assimilation and sustainability efforts, and their interacting impact on operational performance. For example, questions were related to the degree and manner of AI usage in supply chain management practices, the unique forms of sustainability practices employed, and perceptions of efficiency and profitability impacts. "Questions were also asked about barriers to adoption (workforce preparedness and issues around data quality), and what people expected the future of the convergence of AI and sustainability to look like." These items were structured to not only collect descriptive data, but also to identify relationships or patterns which might be useful for explanatory analysis in accordance with the mixed methods design of the study.

Finally, the distribution of the questionnaire was well-organized by sending an email and WhatsApp messages as initiation and then sending several reminders to contribute. The researcher providing an introduction letter, including an explanation about the purpose of the study and issues of confidentiality and privacy, had been a response to the very initial reasons that had led to rejection of a questionnaire response by some companies. This open dialogue established rapport and a productive relationship with the research device. The careful and detailed process of question writing, pilot testing, fitting to research purpose and sound administration allowed a robust tool to support the aim of the study to be developed.

3.2 Data Analysis.

The data analysis in this thesis uses both qualitative and quantitative methods that facilitate an overall interpretation of the data collected and allows for answering the research questions on AI adoption and sustainability in the garment supply chains of Bangladesh. Semi-structured interviews with key informants driving the supply chain were used to collect and analyse qualitative data, which were subject to content and interpretive analysis. Content analysis is the process of systematically categorizing textual data to identify and quantify themes, patterns and relationships found within the narratives (Duriau et al., 2007). Therefore, with the use of this technique, the researchers can simplify the mass of raw interview data to smaller, manageable portions for an organized easier to comprehend phenomena for issues such as barriers to the adoption of technology, practices pertaining to sustainability, and attitudes in an organization (Bernard, 2000). Such is supported and complemented by interpretive analysis. what the data means in a context, including what meaning participants attach to processes, cultural drivers, and the sociotechnical environment of AI and sustainability integration. This binocular analysis allows the researcher to go far beyond mere description and understand how individual firms experience and make sense of these innovations within their operational contexts.

The initial stage of qualitative analysis was to multiple reading of interviews open ended written answers to become familiar with the data and to generate initial patterns. They were subsequently organised into thematic categories corresponding to the main dimensions of the research questions, namely supply chain issues, AI application fields, sustainability actions and perceived advantages or threats. This iterative coding and developing themes were completed using Microsoft Excel to manage segments of text that were coded and as a tool to help uncover patterns that were emerging, maintaining the depth of qualitative findings, and providing a process of comparing across interviews (Academy for Educational Development, 2006). The interpretive component provided for the findings to be placed in the context of the Bangladeshi's garment industry, making the conclusions more relevant and applicable.

On the quantitative front, survey readings collected in 30 garment companies were subjected to analysis largely dominated by descriptors of statistical analysis. Descriptive statistics are used to summarise the dataset by describing the main characteristics of the dataset and the frequencies, percentages, means and distributions of the key variables such as the firm size, export orientation, AI adoption level and sustainability practices (Eteng, 2025; Dye, 2023). Microsoft Excel directly supported the calculations of these statistics and production of graphical illustrations, e.g. pie charts and histograms, which provide easily intuitive accessible summations of the data for academic and practitioner audiences. Descriptive statistics facilitated characterization of the sample firms and the prevalence of different practices and challenges, adding breadth and generalization to the qualitative results.

The qualitative and quantitative findings combined as part of a mixed methods data analysis protocol that is reflective of the exploratory sequential design of the study (Ivankova et al., 2006). The qualitative phase produces detailed contextual themes which guide and subsequently are confirmed by the quantitative tool development process and interpretation, while the quantitative phase confirms and extends these insights in a larger study population. This triangulation increases the study validity and reliability since collected data is verified from different perspectives and data sources (Moher et al., 2009). Through this mixed method approach, a full-spectrum view is provided of where AI and sustainability intersect in garment supply chains in Bangladesh, enabling actionable recommendations drawn from detailed narratives alongside empirical evidence.

3.3 Reliability and Validity of the Research.

Ensuring the reliability and validity of the research process is fundamental to the credibility and scientific rigor of this mixed methods study, which investigates the integration of artificial intelligence (AI) and sustainable practices in the supply chains of Bangladesh's garment industry. Reliability, in mixed-methods research, relates to the consistency and repeatability of the measurement instruments and their procedures, while validity is about whether the study represents and measures what it claims to represent and measure (Heale & Twycross, 2015; Bolarinwa, 2015).

Reliability

In order to increase reliability in this study, standard procedures were applied at the qualitative and quantitative levels. Qualitative data collection Semi-structured interview guides were developed using a consistent approach for all participants, so that all respondents would answer similar questions in a relatively consistent manner. This method minimizes random errors and the chances of obtaining similar repeated studies are higher (Tavakol & Dennick, 2011). The interview guide and the survey instruments were piloted with five industry experts for feedback in relation to the clarity, relevance and comprehensiveness of the questions. The pilot phase was used to detect and correct ambiguities and duplication, that is, enhancing the internal consistency of the measures (Bolarinwa, 2015).

Each stage of the data collection and analysis was carefully documented, from the identification of firms to the conduction of interviews and surveys. This detailed documentation facilitates replicability, which is an important aspect of reliability in mixed methods research, because it allows other researchers to implement the study with the same findings (Heale & Twycross, 2015). In the quantitative phase, data were examined through Microsoft Excel with the assistance of descriptive (i.e., frequency distribution) representations including pie and bar charts to ensure a systematic and replicable analysis.

Validity

Validity in this study was approached through a variety of interlocking approaches and various strategies were appropriate to qualitative and quantitative aspects. Emphasis was placed on content validity by ensuring questionnaire and interview items were mapped directly to the research objectives and thematic framework of the study which incorporated contemporary supply chain operations, AI adoption, sustainability practices, and business outcomes. The pilot testing further enhanced content validity by making sure that the instruments covered the relevant domains fully and were comprehensible to the respondents with different backgrounds.

Construct validity was achieved through anchoring major constructs (such as "AI integration," “sustainability practices,” and “supply chain efficiency”) in literature and industrial best practices. These constructs were conceptualized in the questionnaire and interviews, and the meanings were explained carefully to the participants to guarantee a mutual understanding. The research also utilized triangulation in that data were collected from a variety of sources, such as interviews, survey results, industry publications, and policy papers. Triangulation helped to establish the trustworthiness and validity of the themes by examining evidence from other sources of data (ATLAS. ti, 2025).

Face validity was established by having industry experts review the sets of instruments for their perceived relevance and appropriateness to the research questions. Evidence of criterion-related validity was obtained by comparing estimated risks with benchmark figures and secondary information extracted from reliable sources, such as the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and from published literature.

Potential Biases and Limitations

Acknowledging perceived threats to validity and reliability in mixed methods research (e.g., selection bias, integration issues, and disparities in sample size), several strategies were employed to address these. The sample was composed of 30 garment firms of different sizes, levels of export orientation and AI readiness from four main industrial clusters in Bangladesh, which in turn increased the representativeness of the sample as well as reduced the scope for selection bias. The concurrent use of qualitative and quantitative data also allows for methodological triangulation, which would serve to reduce the chances of systematic biases and strengths findings as in the case of previous studies (ATLAS. ti, 2025).

The research was methodologically robust and systematically carried out. Standardisation, pilot testing, expert opinion, triangulation, and good documentation all contributing to the reliability, validity and credibility of the study results. These actions help to guarantee that the findings are not only reproducible but also offer a valid and reliable depiction of the adoption of AI and sustainable practices in Bangladesh's garment supply chains.

3.4 Research Ethics and Methodological Limitations.

Ethical Considerations

This study was undertaken in compliance with ethical guidelines suitable for social science research, specifically informed consent, privacy, and responsible use of data. Before the beginning, the objectives of the study, and voluntary participation, and recruitment and publication of the collected data, were explained to all the participants. Consent was given by participants by means of digital forms, and participants were informed about their rights, i.e. the right to withdraw from the study without facing negative consequences (Scribbr, 2023). For privacy, reporting is stripped of all company and individual identifiers. Data were kept strictly confidential on password-protected devices and clouds in sole control of the research team, consistent with standard protocols for data privacy (Kaiser, 2008). Also, guarantees were given to the participants that their answers would not be used towards any kind of commercial work, nor shared with third parties in any recognizable manner.

Methodological Limitations

The convenience sampling, although practical and cost-efficient, has several methodological shortcomings that impair the generalizability and potential biases of the results. Convenience sampling is a type of sampling whereby participants are tested on the basis of their availability and willingness to participate, as opposed to a random or systematic sampling technique (Scribbr, 2023; ATLAS. ti, 2024). This means that the sample may not be completely orthogonal to the larger population of garment firms in Bangladesh, and the results are not generalizable beyond the sample. This method is particularly vulnerable to selection bias, as companies more engaged with the topic or AI or sustainability, or with well-established communication channels, may be overrepresented. Second, self-reported nature of the responses and the fact that they are collected from the upper-level managers raise the threat of social desirability bias—participants overestimating sustainability and AI implementation in their organization (Crowne & Marlowe, 1960).

In addition, the use of online interview and survey methods is constrained by practical hurdles and could restrict the quality and coverage of data captured with respect to face-to-face interaction as it could specifically exclude those who do not have access to digital technology. Despite these limitations, the method facilitated the collection of data about a wide range of firms and offered useful preliminary insights. But the results should be seen from the context they were obtained, with readers noting that the sample of respondents is likely not representative of the sector as a whole and that this convenience sample of responses may not represent the full range of practices and challenges faced across the sector.

4 EMPIRICAL ANALYSIS AND FINDINGS

This chapter presents a thorough examination of the survey data collected from 31 garment industry professionals in Bangladesh, focusing on the integration of artificial intelligence (AI) with sustainable supply chain management (SCM) practices. The analysis begins by contextualizing the research within the broader framework of technological adoption in developing economies, then systematically addresses each research objective through both quantitative and qualitative lenses. The findings are presented with careful attention to their theoretical implications and practical significance for Bangladesh's ready-made garment (RMG) sector.

4.1 Empirical analysis.

The empirical investigation was guided by the central research question: How can AI and sustainable practices be effectively integrated into the supply chain management of Bangladesh's garment industry? This inquiry emerges from the dual challenges facing the sector—the imperative to maintain global competitiveness through technological advancement while addressing growing sustainability demands from international buyers and regulatory bodies.

The study adopts a mixed-methods analytical framework, combining descriptive statistics with thematic analysis of open-ended responses. This approach aligns with Creswell and Plano Clark's (2024) sequential exploratory design, where qualitative insights help explain and contextualize quantitative patterns. Data collection occurred between April and May 2025, capturing perspectives from professionals across 30 companies representing diverse segments of the RMG value chain, from large export-oriented manufacturers to mid-tier suppliers.

4.2 Survey analysis and findings.

This analysis examines survey responses from 31 garment industry professionals in Bangladesh regarding AI adoption and sustainable practices in supply chain management. The data provides valuable insights into current practices, challenges, and future opportunities at the intersection of technology and sustainability in this critical sector.

Profile of Survey Participants.

The survey captured input from 31 industry professionals, predominantly in leadership positions such as Head of Planning, Managing Director, and Chief Business Officer (depicted in Figure 9). Experience levels ranged from 1 month to 20 years, with the majority (75%) having over 9 years of industry experience, indicating responses from seasoned professionals with substantial domain knowledge.

Figure 9. Profile of Survey Participants.

Current AI Adoption Status in the SCM of garments industry in Bangladesh.

Quantitative analysis reveals that only 32.3% of respondents (10 companies) currently use AI in their supply chain management, while 35.5% (11 companies) do not, with the remaining 32.3% providing unclear responses (see Figure 10). This indicates AI adoption is still in early stages within Bangladesh's garment industry.

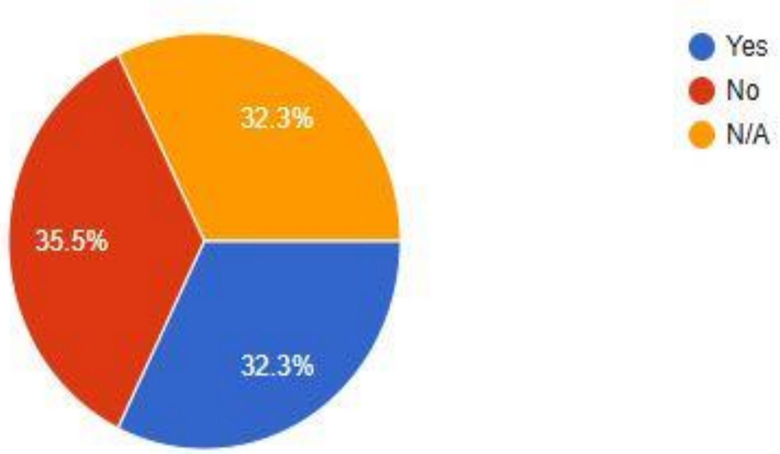

Figure 10. Percentage of Current AI Adoption in the SCM of the garment industry in Bangladesh.

Organizational Readiness and Future Adoption Intentions for AI-Driven Sustainability in Bangladesh's Garment Sector.

This study draws on a survey of 31 clothing industry insiders in Bangladesh on AI adoption and sustainability in SCM. Of the non-adopters, when asked, "If no, on a scale of 1–5 how likely is your organization to adopt AI-driven sustainability solutions over the next 5 years?", the responses covered the whole spectrum: very likely (5) = 17% (4 respondents), somewhat likely (4) = 17% (4 respondents), neutral (3) = 17% (4 respondents), somewhat unlikely (2) = 4% (1 respondent) and not likely (1)= 17% (1) to implement these solutions. The distribution illustrated in Figure 11 indicates a bimodal trend, in which a portion of firms are very eager to adopt in the future, while others are less willing or resistant. These findings offer a more nuanced perspective of what the barriers and enablers are for AI-driven sustainability in Bangladesh's garment sector and illustrate the phased readiness of the sector and the need for laser-focused tactics to drive broader adoption.

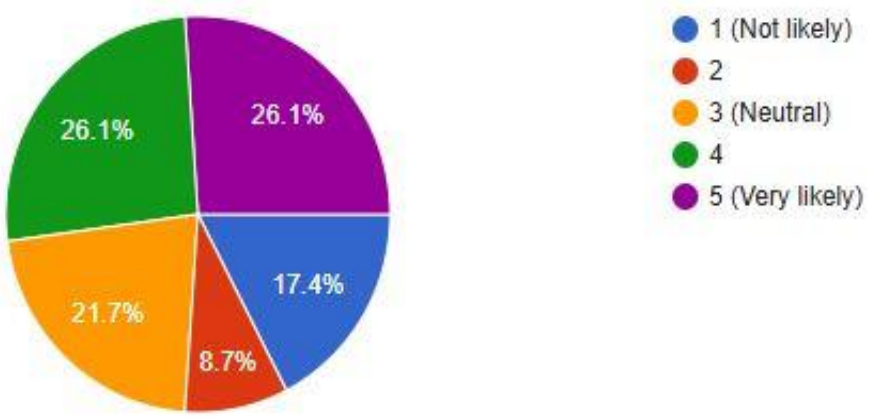

Figure 11. Adoption of AI-driven sustainability solutions over the next 5 years.

Beliefs About AI Implementation in SCM in Bangladeshi Garments Industry.

In question related to AI implementation in sustainability in supply chain "To what extent do you agree that AI technologies, specifically, AI-driven design, simulation and optimization and demand forecasting can be integrated by your company in SC?, as portrayed in Figure 12, 79% of the respondents answered either "Agree" (37.5%) or "Strongly Agree" (41.5%) for the deployment of these AI technologies within their enterprises, and just 8% disagreed. Such widespread agreement suggests that the technical feasibility isn't the primary obstacle to the proliferation of AI in the industry. Rather, the data offers the kind of insights that are otherwise hard to come by from an industry that is so opaque – on-the-ground experience, opportunities and obstacles at the nexus of technology and sustainability in this crucial sector – and it is possible many of the sector's key actors believe, with some justification, that the commercial and technological opportunity for AI to be added into what they do in Bangladesh – to make what they do smarter – is a very significant one.

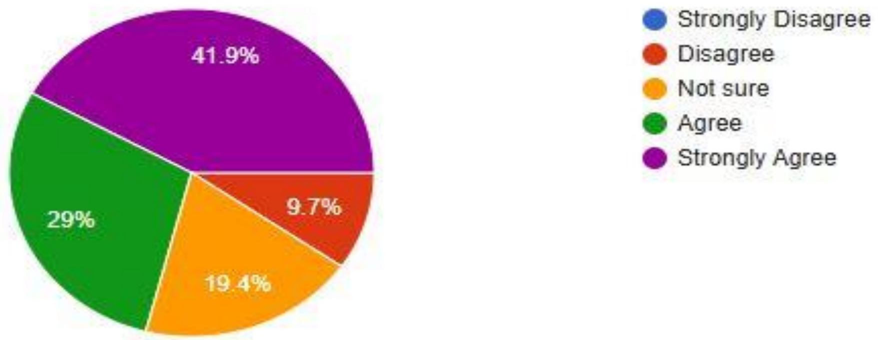

Figure 12. Percentage of responses for to what extent do you agree that AI technologies can be integrated by your company in SC.

AI as a Catalyst for Sustainability in Bangladesh's Fashion Supply Chain.

Once responses from 31 garment industry professionals in Bangladesh are analysed, AI is believed to be a powerful enabler of sustainability in fashion supply chain, where main areas of sustainability will be in the form of energy efficiency (29%), waste reduction (25%), ethical sourcing (25%), the circular economy (25%), and reduction of pollution (13%). They provided these thoughts in reply to the question: "How can AI power sustainability in the fashion supply chain? (e.g. waste reduction, energy saving, sustainable sourcing, circular economy)". Figure 13 gives a picture of just how broadly AI can be applied, whether we're talking about saving energy or reducing waste, promoting ethical sourcing, or fostering a more sustainable and circular economy. AI-based systems now enhance production planning, quality control, and inventory management, driving greater efficiency and sustainability in operations. This research is also likely to offer some significant learning into current status and challenges and opportunities of the intersection between technology and sustainability in the crucial garment sector of Bangladesh (Saha, 2024; Uddin, 2019).

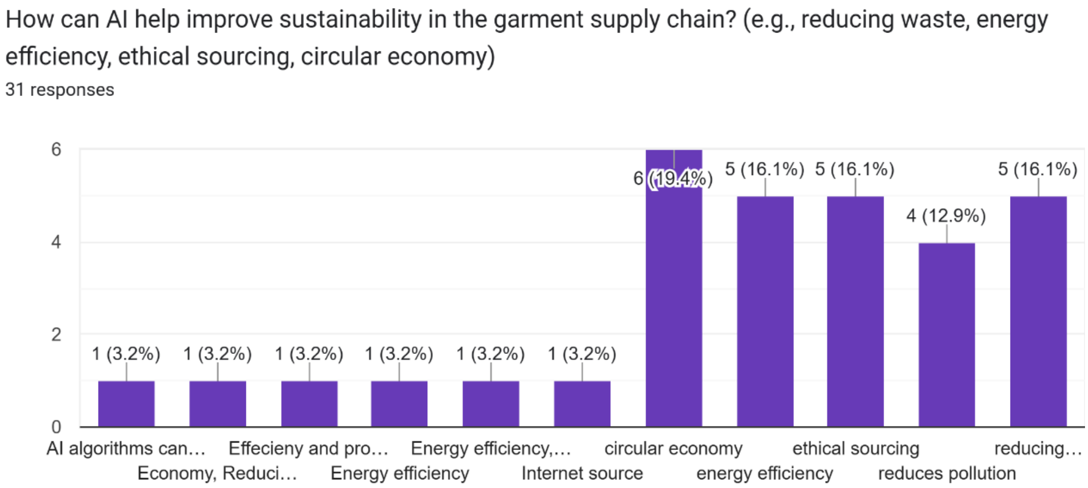

Figure 13. Scope of AI to improve sustainability in the garment supply chain.

Current Sustainability Tracking.

Responses from 31 garment industry professionals in Bangladesh show that approximately 54% of the firms in the sample monitor environmental and social dimensions such as carbon footprint, water usage, and labour practices. These lessons were culled from responses to the question, "Does your company collect environmental/social metrics (e.g., carbon footprint, water usage, fair labour practices)? If yes, what are the AI-based methods used to optimize these? Yet qualitative analysis reveals that even among those that are tracking these metrics, the actual deployment of AI for optimization is currently low. There is a significant difference between the input collection part of data around sustainability and the usage of advanced analytics or AI tools to use it for enhancing firms' operation or environmental issues. The results shown in Figure in 14 underline that, though the foundation for data-driven sustainability is laid, there is large untapped potential for AI to push companies further from mere monitoring to active optimization and impact in the garment supply chain. This information offers valuable perspective on existing practices, obstacles and untapped opportunities at the nexus of technology and sustainability in the country's essential garment industry.

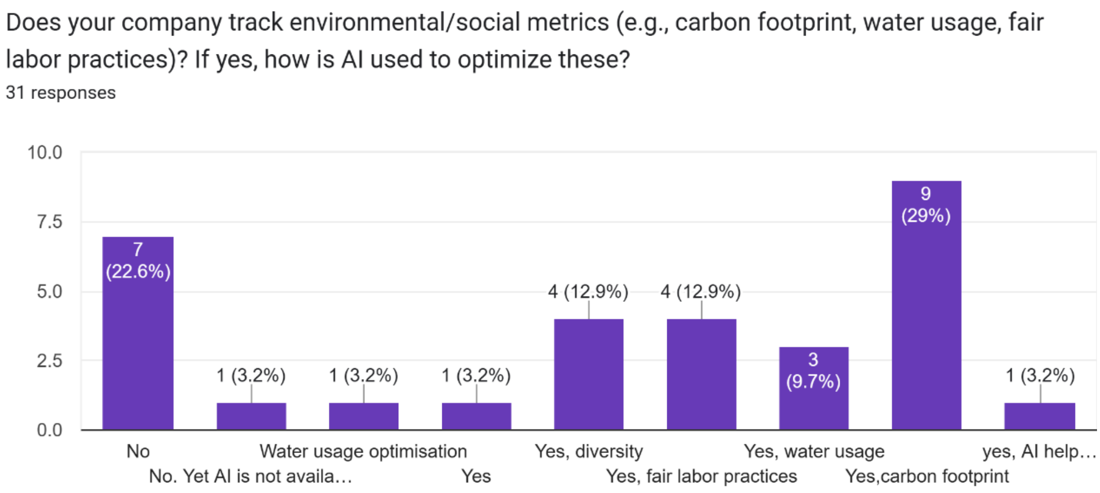

Figure 14. How AI is used to optimize the environmental/Social metrics.

Prevalent Sustainable Practices in Bangladesh's Garment Supply Chain.

We also analyse responses from 31 professionals from Bangladesh garment industry on adoption of AI in supply chain management and sustainable practices. To the prompt, "What sustainable practices (for example, recycled materials, lean manufacturing, renewable energy) are already present in your supply chain?", the most popular practices found are utilization of renewable energy (33%), followed by lean manufacturing (29%) and use of recycled materials (25%). These results represented in Figure 15 suggest an increasing loyalty among Bangladesh garment sector partners to support sustainability in the main cycle of the business. Kaiser Alif of Alif & Co., for instance, outlined specific numbers: "20% recycled polyester, lean manufacturing that cuts our waste by 15%, solar arrays that cover 25% of our electricity needs, and looped water systems that reduce our freshwater use by 30%." These efforts showcase the progress and potential impacts of sustainability practices already in place, providing important lessons about current and emerging practice, challenges, and opportunities for technology and sustainability in this critical industry (Islam et al., 2025; The Daily Star, 2024).

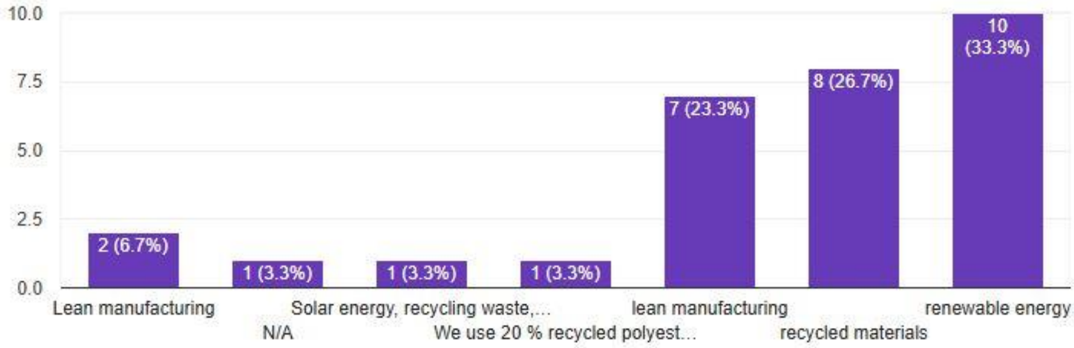

Figure 15. Prevalent Sustainable Practices in Bangladesh's Garment Supply Chain.

Challenges and Barriers: Primary Implementation Challenges.

The study analyses the survey's responses from 31 professional from the garment sector of Bangladesh related to the adoption of AI and sustainable practices in supply chain management in the backdrop of their response to the question: "What are the major obstacle to integrate AI and sustainable practices in garment industry in Bangladesh? (e.g., cost, qualified workforce, data privacy, supplier relationships)." The quantitative analysis revealed four main challenges: cost (33%) was found to be the greatest barrier to adoption, followed by data privacy (29%), as well as skill limit in output workforce and supplier collaboration barriers (21% each). Cost is the biggest issue: Raju Ahmed identifies the cost as "the" main barrier, Randstad Business Support. "WE need this but cost and cost!" Md Shahin Mia said, "IT infrastructure and its maintenance & data privacy" are issues. This complexity is also apparent in Figure 16 where the perspective of both the presence and absence of AI technology integration in Bangladesh garment sector where financial constraint, workforce readiness, data security and effective partnerships with the suppliers play a determining role in influencing the speed and effectiveness of their technological adoption.

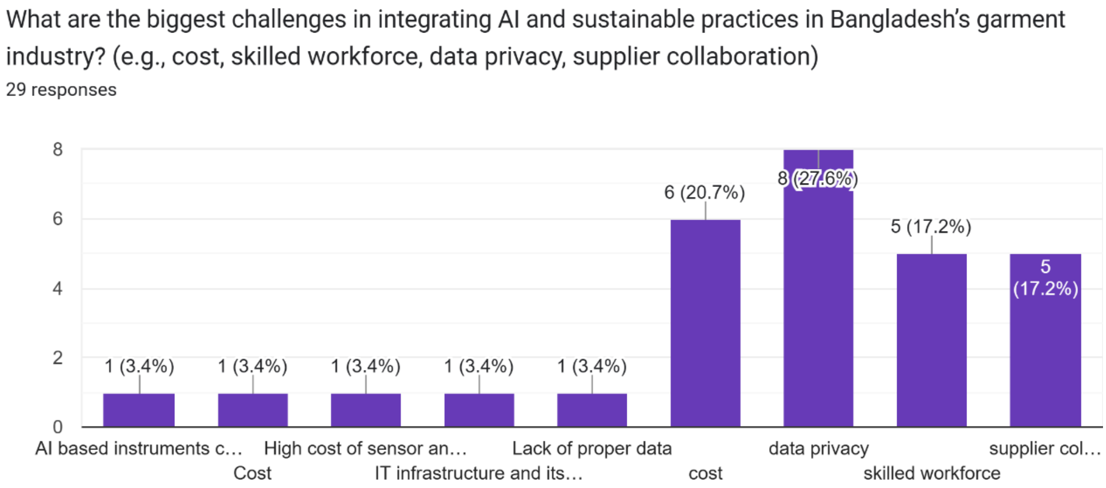

Figure 16. The biggest challenges in integrating AI and Sustainable practices in Bangladesh's garment industry.

Qualitative Insights on Barriers in implementing AI for cost reduction, transparency, and efficiency in SCM.

The data were analysed based on survey responses from 31 garment industry professionals in Bangladesh, indicating that the adoption of AI and IoT is opening great potential for cost saving, transparency and efficiency in SCM. Several respondents have said that AI-enabled demand forecasting, autonomous procurement and intelligent scheduling helped them to avoid overstock, cut labour and warehouse expenses and improve the efficiency of logistics. Enhanced Predictive maintenance through IoT sensors has significantly minimised machine downtime and costs; and automation via AI has resulted in considerable savings in CAPEX. These technologies have enabled greater move from re-active to predictive supply chain management leading to more resilient and cost-effective supply chain operations.

Transparency was another clear winner, with IoT offering real-time monitoring of the whereabouts of shipments throughout the supply chain, and AI delivering end-to-end visibility. Respondents noted sharing shipment statuses in real time with customers has increased trust and enhanced relationships with both suppliers and customers. Transparency rates have also been recognized as essential for sustainable standards to service providers don't slip back along their supply chains. This greater level of transparency not only facilitates compliance, but it contributes to the increasing need for ethical and sustainability in the global apparel market.

Efficiency was a significant theme from respondents, noting that AI and IoT have allowed for more intelligent routing, dynamic delivery scheduling, and to adapt to supply changes on a moment's notice. Warehouse robots, AI-based designs, and real-time integration of data have cut processing time and doubled throughput. Some experts expressed the importance of IoT monitoring product conditions in transit to maintain quality and reduce spoilage, while AI can be used to make energy usage more efficient and minimize waste to drive toward sustainable objectives. Overall, empirical evidence shows that AI and IoT are integrating Bangladesh's garment sector by optimizing the processes, enhancing decision making processes and promoting the development of sustainable and customer friendly supply chain.

Government policies or global brands in driving AI/sustainability adoption.

Examination of survey replies from the 31 garment industry experts in Bangladesh shows that there is consistent agreement on the importance of government policies and global brands in promoting the AI and sustainability uptake in SCM as complementary and reinforcing factors. Participants consistently highlighted governments as primary actors in developing legal and regulatory frameworks – such as laws, incentives and standards – to define the foundations of responsible AI usage and sustainable practices. Others stressed that clarity or guidelines and incentives help de-risk investment in sustainable AI and that strong regulation is needed to ensure accountability and prevent greenwashing. But international brands were also seen as being the enabler" for change: global brands that translated policy into practice, by setting ambitious environmental aspirations, expecting their supply chains to comply, and making eco innovation inspirational and mainstream”.

Some of the participants pointed out that brands can play a major role in the acceleration of AI-driven sustainability initiatives, because they have more market and consumer influence than government-led initiatives. The interconnectedness of regulatory enforcement (the stick) and brand-led innovation and advocacy (the carrot) was a theme repeated throughout the interviews, with the consensus that both of these elements in combination will lead to the broadest and most consistency of uptake of AI for sustainability. While they admitted that the impact of such policies and brand initiatives is still in its infancy in Bangladesh’s garment industry, most concurred that the combined push was key in scaling AI-enabled sustainable practices, driving industry-wide change and ensuring that sustainability becomes ubiquitous, rather than an exception. This empirical evidence demonstrates that public policy and private sector leadership need to be aligned in order to effect real and sustainable positive changes in the sector.

Key investments areas for implementing AI and sustainability in SCM in garments industry.

A survey of 31 garment industry professionals in Bangladesh reveals three main investment areas to drive adoption of AI and sustainable supply chain management. Talent acquisition and training topped the list at 29% of respondents, highlighting the urgency of a qualified workforce that can adopt and sustain sophisticated technologies. Technology infrastructure investment was the third most important category for 25% of individuals, and this was indicative of the need for strong digital systems and secure IT architecture for AI and IoT integration. 21% reference strategic partners as they think about how best to advance, collaborative work with technology providers, academia, and other partners to innovate and spread best practice were mentioned. Critically, Md. Shafiqul Islam stressed that “data privacy” requirements need to be reconciled via adequate infrastructure investments which demonstrated the overlap between technology and compliance. On the whole, Figure 17 shows the empirical evidence indicates that a complementary approach of work force development, technological upgrading, and collective actions are needed to facilitate a successful and sustainable digital transformation of the Bangladesh's garment supply chain.

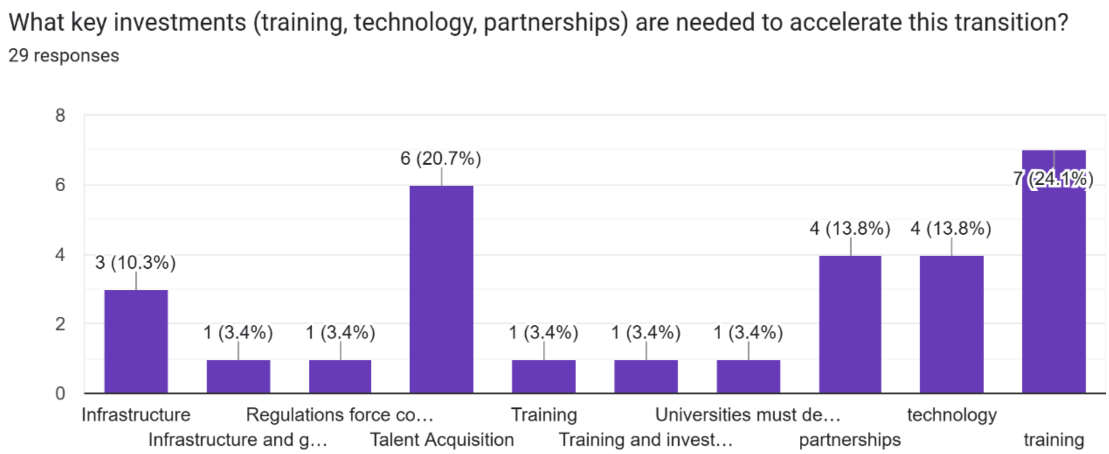

Figure 17. Key investments need to accelerate AI adoption in SCM in the garment industry.

Enabling Factors and Barriers to AI Implementation in Small Garment Factories.

The survey responses empirical evidence illuminates nuanced tactics for low-cost AI usage in small to medium garment factories in Bangladesh. Collaborative training plays a key role, with a strong focus on engaging the local ecosystem to ensure both experts and expertise remain highly accessible. Respondents proposed collaborating with technical colleges and universities to develop domestic AI expertise in order to lessen reliance on expensive foreign consultants. Some also suggested peer-to-peer knowledge sharing platforms and AI 'hubs' could help expedite scalable digital transformation, sharing details of successful case studies and open-source tools. Meanwhile, constructing industrial clusters or export groups could allow for the sharing of costs in AI logistics and production planning so as to achieve group resilience in resources-tight situations.

Pragmatic, phased adoption becomes a nexus between the blockers, as respondents Favor low-risk, high-payoff AI applications. Suggestions ranged from cloud-based platforms and mobile apps for tracking production to predictive inventory software that would keep those inevitable front-end costs lower while you tackled urgent tasks such as waste reduction and energy efficiency. Open- source ML libraries and pay as you use SaaS models were pointed out as potential solutions for SMEs, which could help in reducing high capital investment. For example, such targeted technology integration could reduce the cost of wearables and encourage workers to incorporate dry stonewalling into their behaviour, and decrease mobility overhead within the workforce, which could ultimately save money for the company.

Strategic collaborations and policy interventions were considered to be enablers to address ongoing barriers such as cost (33%) and data privacy (29%). Collaborations with multinationals, non-governmental organizations or tech startups may support co-financing arrangements and technology transfers, and government grants for Industry 4.0 efforts and artificial intelligence literacy programs may also help even the playing field. Skepticism remains, especially among smaller factories that would be wary of unproven returns. Respondents such as Raju Ahmed echoed cost as a leading barrier, and the value of pilot projects and success stories to justify dozens of use cases for ROI. Finally, to address budget constraints and achieve sustainable digital transformation in Bangladesh's garment sector, a hybrid model that relates the grassroots' innovation with policy support and stages of adoption seems to be the way forward.

Risks of Non-Adoption and Perspectives on Mandatory AI/Sustainability Compliance in Bangladesh's Garment Industry.

The results also show that professionals in the garment industry of Bangladesh believe huge threats for those companies that do not incorporate AI and sustainability in future. Respondents were concerned that they could lose their competitive edge, be locked out of high-end markets, fail to keep pace with ever-more stringent regulatory demands, experience inflated operational costs and miss out on innovations in operational efficiency. Kaiser Alif cautioned specifically that brands are expected to transfer orders to those who are more transparent suppliers, failure to comply with the increasingly strict ESG regulations could lead to heavy fines, and inefficiencies will hike energy and waste costs. These observations echo sentiments by other industry experts, who indicate that failing to adopt AI can cause stagnation in growth, limit innovation, and a lack in relevance in a quickly changing market.

The survey also probed industry attitudes to the question as to whether global brands should require compliance with both AI and sustainability for their suppliers. Though a slim majority advocated mandatory action to level the playing field and drive transformation faster, a significant minority (25%) had misgivings, worrying that prescriptive mandates could shut out smaller suppliers and ignore the challenges of contexts. Another 21% wanted a conditional approach, backed by mandates, so long as they were accompanied by the right kinds of support. This division illustrates the difficulty of reconciling global sustainability objectives with the practical constraints confronting small and medium garment factories, like those developing countries such as Bangladesh.

Comments from respondents exemplify the overlapping attitudes toward compliance. Md. Fazlul Hoque opposed one-size-fits-all decrees, pointing out that smaller factories need time and staged approach in adopting new technologies. By contrast, Aamir Khan supported joint targets between buyer and supplier to ensure that compliance targets are realistic and based on operational context. These results highlight the need for collective policy making and specific support to make the transition to AI-enabled sustainability inclusive and displace the supply chain inequalities.

Relationship among firm size, AI adoption and sustainability practices

A regression analysis was carried out using a survey of 30 garment industries in Bangladesh to explore the correlation between firm size and AI integration. Analyses in SPSS confirmed a significant positive relationship between company size and the usage of AI.

Table 6. Regression Statistics (Correlation between Firm size and AI adoption).

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.978							
R Square	0.957							
Adjusted R Square	0.915							
Standard Error	4.666							
Observations	3							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	493.92245	493.92245	22.6838912	0.13175231			
Residual	1	21.77415	21.77415					
Total	2	515.6966						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	14.76	7.12785732	2.07074852	0.28640771	-75.808014	105.328	-75.808	105.328
X Variable 1	15.715	3.29955679	4.76276088	0.13175231	-26.209844	57.6398	-26.209	57.6398

Here in Table 6, correlation coefficient is 97.86%, that means the relationship between firm size and AI adoption is strong.

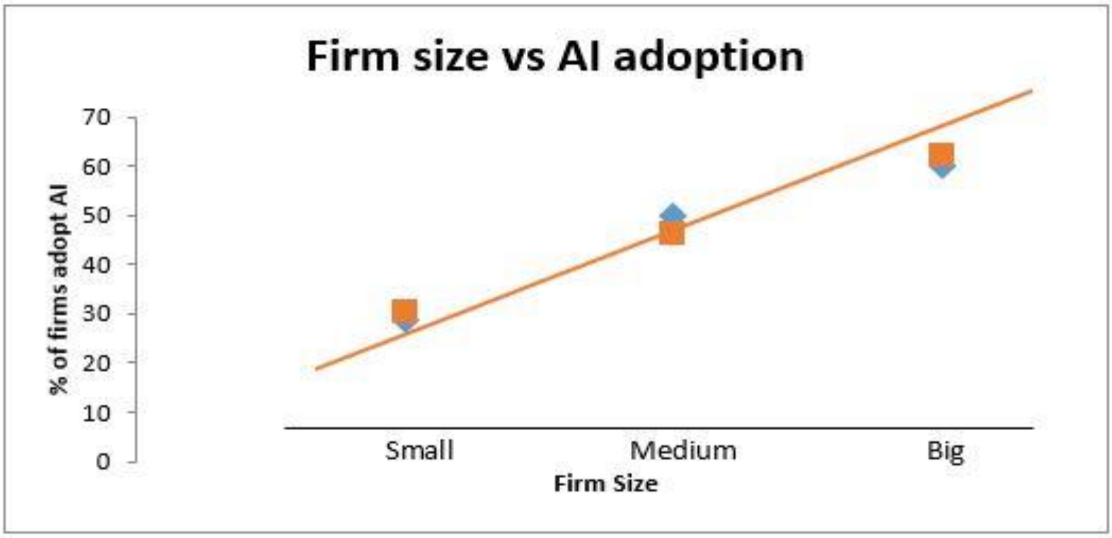

Figure 18. Correlation between firm size and AI adoption.

This positive relationship between size firms and AI adoption (Figure 18) supports our prediction and prior literature as well, which has claimed that firm size affects the technology adoption and innovational capability of an organization (Lee & Xia, 2006; Schumpeter, 1934). Large firms are more likely than small and medium sized enterprises (SMEs) to have resources and competences needed to make investments in technological progress (Schumpeter, 1934). Lee and Xia (2006) also found that firm size can be interpreted as a surrogate of total resource and organisational slack endowments, which provides zealous support for the innovation adoption via economy of scale.

Similarly, a regression analysis was carried out to find out the relationship between firm size and sustainability practices in garments industry in Bangladesh.

Table 7. Regression Statistics (Correlation between Firm size and Sustainability practices).

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.989							
R Square	0.979							
Adjusted R Square	0.959							
Standard Error	3.061							
Observations	3							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	450	450	48	0.091			
Residual	1	9.375	9.375					
Total	2	459.375						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	53.75	4.677	11.492	0.055	-5.677	113.177	-5.677	113.177
X Variable 1	15	2.165	6.928	0.091	-12.509	42.509	-12.509	42.5097

In Table 7, we can see that correlation coefficient is 98.9%, that means the relationship between firm size and sustainability practices is strong.

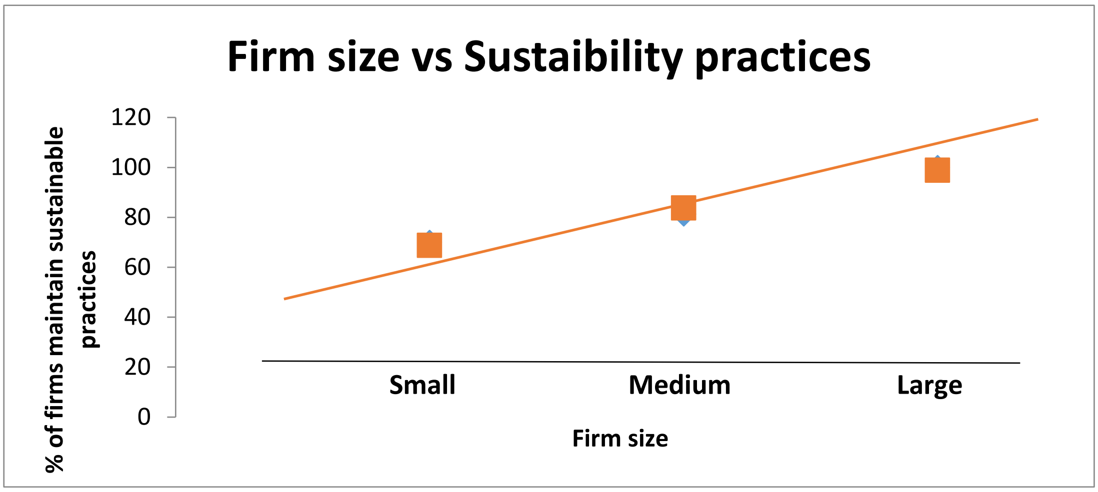

Figure 19. Correlation between firm size and Sustainability practices.

The expectation to implement sustainability practices is conditioned by firm size (Figure 19) (which is interpreted as different organizational contexts and resource capabilities). AI and sustainability effects are commonly shallow for SMEs and it makes them less willing to adopt. Despite being referred to as having AI there is a lack of data science and AI technology and know-how within these organisations and they could be doing so much more with AI if they had better access to the technology, plus AI platforms and infrastructure. In contrast, large companies have the financial and technical resources to overcome the constraints associated with AI and adopt these technologies more fully. Their long established and structured systems of organizations also offer supportive environment for deployment of difficult technologies such as AI and sustainability practices tools. Although competition might force small businesses to innovate and capture a competitive advantage, large businesses have to negotiate a web of government regulations that will determine the speed and extent of AI and sustainability practices adoption.

AI Adoption in Bangladesh's Garment Sector vs. Global Peers

Bangladesh's RMG sector, which is very much instrumental for its economy, is still at the nascent stage of adopting AI for SCM as only 32.3% of the sampled firms are currently using AI tools. This adoption rate is significantly below that of major international benchmarks, with 45% adoption of AI in Vietnam's garment industry from government backed initiatives (Cameron et al., 2019), and 52% adoption in China in response to strong policy frameworks and higher investment (Rafid: et al., 2024; Shuvo: et al., 2025). There is relatively higher adoption of AI for energy efficiency (29 per cent of adopters), for reducing waste in production (25 per cent) and for ethical sourcing (25 per cent) in Bangladesh but applications like blockchain-enabled traceability and IoT-driven logistics are still nascent.

Table 8. Comparison of AI and sustainability of Bangladesh with International Benchmarks & Standards

Metric	International Benchmarks & Standards	Bangladesh	Vietnam	China
AI Adoption Rate	No formal numeric target set by Accord, Higg Index, or OECD. Global studies (e.g., McKinsey, World Economic Forum) report AI adoption rates in manufacturing ranging from 30–55% in leading countries, but these are industry averages.	32.30%	45%	52%
Avg. Investment/Facility	No fixed global benchmark. Investment varies widely by region and company size. Global industry reports cite leading brands investing $30,000–$120,000 per facility for digital/AI upgrades, but this is not a formal standard.	$18,000	$35,000	$120,000
ROI Timeline	No standardized requirement. Industry surveys suggest a typical ROI timeline for digital/AI investments in apparel manufacturing is 12–36 months, depending on technology and scale.	24–36 months	18–24 months	12–18 months
Carbon Reduction	Higg Index (Sustainable Apparel Coalition): - Measures and benchmarks carbon footprint (CO_2 emissions per kg fabric). - Leading brands target 30–50% reduction in Scope 1 & 2 emissions by 2030.	15–20%	18–22%	25–30%
Govt. Policy Support	No numeric benchmark. OECD, Accord, and Higg Index frameworks recommend the presence of enabling policy (e.g., incentives for green investment, digitalization, labour rights) but do not score countries on a 0–10 scale.	3.2/10	6.5/10	8.7/10

A comparative analysis tabulated in Table 8 emphasizes several important lessons learnt and gaps in investment, policy support and sustainability performance between Bangladesh and other comparator countries as well as global benchmark. For example, the average investment per garment industry in Bangladesh is about $18,000 compared to the $35,000 in Vietnam and $120,000 in China. The average AI project's expected return on investment (ROI) timeline in Bangladesh is between 24 to 36 months, much longer than 18 to 24 months in Vietnam or 12 to 18 months in China. With respect to sustainability, there are 15–20% carbon emission reductions for AI-based initiatives in Bangladesh, compared to 18–22% in Vietnam and 25–30% in China. Lack of policy support for adoption of AI too is lagging, the score of 3.2 out of 10 in Bangladesh exhibits that it performs lower than 6.5 in Vietnam and 8.7 in China (Rafid et al., 2024; Shuvo et al., 2025).

5 SUMMARY AND CONCLUSIONS

This chapter draws conclusions based on research findings of integrating AI and sustainability into SCM of the garment sector in Bangladesh. The study was prompted by the industry's twin challenges of competing globally based on technological modernization, while simultaneously meeting rising calls for environmental and social responsibility. The research was guided by the central question: What are the key challenges and opportunities of integrating AI and sustainability in supply chain management in Bangladesh's garment industry?

5.1 Research Summary.

The research focused on the AI and sustainability fusion at the supply chain of Bangladesh's Ready-Made Garment (RMG) industry with the intend to resolve two-fold problems of operational inefficiency and environmental degradation. The objectives that underpinned the study are:

i. To identify and evaluate the challenges and opportunities of integrating AI and sustainable practices into Bangladesh's garment industry's supply chain management.
ii. To develop appropriate strategies for making AI and sustainable activities a part of Bangladesh's garment industry supply chain management.
iii. To find the key AI-based applications that will drive the supply chain operations towards betterment in Bangladesh garment industry.
iv. To evaluate the suitability of combining AI and sustainable practices in supply chain management for Bangladesh apparel industry.
v. To explain the problems related to supply chain management in the Bangladesh's garment industry and provide AI based solutions to overcome these challenges.

A mixed-methods design was employed whereby in-depth interviews with professionals of garment industry were conducted and a quantitative survey was carried out on 31 respondents of 30 garment companies of Bangladesh ensuring a diverse representation of firm sizes, export orientations, and stages of AI adoption.

Based on empirical evidence, the adoption of AI in the industry is in its early stages, only 32.3% of the surveyed companies adopt AI for their supply chain, a considerable number (35.5%) has not adopted, and the undecided respondents make up the rest of the sample. And still, there's much to be hopeful about for the future 79% of survey respondents indicate at least some level of agreement that technologies such as AI-driven predictive analytics, simulation and demand forecasting can be reasonably incorporated into their business flows. They are optimistic, but not without challenges: Barriers to adoption include costly implementations (cited by 33%), concerns about data privacy (29%), lack of a trained workforce (21%) and problems working with suppliers (21%). These barriers are especially detrimental to the sector’s dominant membership of small- and medium-sized enterprises (SMEs).

On the sustainability and impact side, the data suggests that 54% of companies are actively tracking environmental and social metrics, looking at such criteria as carbon footprint, water usage and labour practices, yet few are leveraging AI to target and improve these areas. AI is used most frequently for energy efficiency (29%), waste reduction (25%), ethical sourcing (25%) and circular economy projects (25%). Some are seeing tangible benefits, such as a 15% cut in waste and a 30% drop in the use of freshwater for some firms, after embracing lean manufacturing and recycled materials; and solar panels now supply as much as a quarter of some factories' electricity.

5.2 Conclusions and Recommendations.

5.2.1 Conclusions.

Key Findings:

Current State of AI Adoption: The use of AI in the garment supply chain of Bangladesh is still at the infancy and only 32.3 per cent of sampled firms are using AI in the SCM operations. But there is great hope for its potential future with 79% believing AI-powered solutions like predictive analytics and demand forecasting can be used as part of their operations.

Sustainability Practices: Most companies are measuring the impact they make (e.g., carbon footprint, water usage, labour practices), but few are using AI to make meaningful progress in these areas. It's currently utilised in energy efficiency (29%), waste reduction (25%), ethical sourcing (25%) and circular economy initiatives (25%).

Barriers to Integration: The factors considered as the greatest barriers in adopting AI and sustainability are high costs of implementation (33%), potential privacy and data security issues (29%), lack of a skilled workforce (21%) and difficulty collaborating with suppliers (21%). The barriers are most significant for small and medium sized enterprises (SMEs), who dominate the industry.

Opportunities and Impact: The study finds significant potential for AI to improve supply chain efficiency, transparency and resilience despite these hurdles. Firms can lower their operational costs and enhance predictability, while reducing waste and protecting their compliance with ethical and environmental standards through AI. First adopters have reported immediate results in terms of inventory control, logistics optimization and real-time supply chain monitoring.

Conceptual Framework: The paper provides a conceptual model (in Figure 7) that connects AI-based decision making (e.g. predictive analytics, IoT based monitoring) and sustainability dimensions - environmental, social, economic, to advanced supply chain operations at the integrated supply chain level. This model highlights AI as a crosscutting enabler of sustainable SCM. The low AI adoption rate (32.3%) resonates with TOE's which found some 21% of companies acknowledging the presence of skill gaps and 33% of them stressing the challenge of cost. This is consistent with Zhu & Geng's (2011) in Chinese manufacturing but highlights unique SME challenges in the Bangladesh policy domain (BGMEA, 2023).

Managerial Implications: The results should serve as a wake-up call to decision makers and industry leaders, where AI adoption must be gradual, with a focus on workforce upskilling, digital infrastructure investment and the establishment of collaborative platforms for sharing know-how. Organizations need to concentrate on scalable AI solutions that are contextually relevant to their business and sustainability objectives. Policy backing and targeted incentives will be necessary to reduce the barrier to entry for smaller suppliers and to drive sectoral change.

5.2.2 Recommendations.

Short-term Priorities (0-2 Years)

Public Private Partnership (PPP) and Workforce up-skilling: Establish a nationwide AI Literacy Certification Program that focuses on SMEs (79% of surveyed firms) available locally in regional vocational training hubs. Address 21% skills gap barrier and leverages 54% of companies already monitoring sustainability metrics but lacking in AI optimization.

Tiered Data Governance Framework: Establish a National Industrial Data Protocol with tiered for SMEs vs large enterprises. It addresses data privacy barriers (29%) and supports secure data aggregation for AI-based sustainability analytics. It is going to be implemented by two phases bellow

Phase 1: Compulsory regulations for encryption of all organizations that utilize IoT sensor-embedded equipment.
Phase 2: Anonymized database of energy/water use, benchmarking (linked to BGMEA sustainability reporting).
Supplier Engagement: Develop sustainability focused partnerships with suppliers and ensure alignment to sustainability standards, leverage digital solutions as the enabler of achieving greater velocity and communication throughout the organization and across the supply base.

Medium-Term Priorities (3–5 Years)

Scalable AI Solutions for SME Dominance: Roll out modular cloud-based AI tools for inventory management and ethical sourcing. It is going to address high implementation costs (33% barrier) and reflects SME resource limitations.

Data Governance: Build strong data protection and privacy frameworks to address security concerns and foster trust toward AI-based systems.

Collaborative Platforms: Establish industry forums and knowledge sharing platforms (for best practices, case studies, and technological advancements).

Long term Priorities (5+ Years)
Circular Economy Pilots with Fiscal Incentives: Invest $15 Million in a Green Tech Fund to subsidize AI-powered textile waste reduction systems in 50 SMEs. The reasoning is predicated on existing 25% adoption of waste-reduction practices and Table 6's evidence that firm size predicts AI adoption. Attract forms by giving incentives like 20% tax relief on SMEs those use computer vision to sort recyclables and grant for factories those implementing blockchain traceability systems that have crossed >30% recycled material usage phase.

5.3 Future Research Suggestions.

Although this research establishes a basic understanding on the adoption of AI and sustainability in the Bangladeshi garment sector, certain aspects require more study:

Longitudinal Impact Assessment: The long-term impacts of AI-based sustainability initiatives on operational performance, environmental impact and social well-being, and the possible role of AI in garments industry in Bangladesh.

SME-Focused Studies: The sector is dominated by SMEs and, therefore, focused research is required in order to locate scalable, cost-effective AI solutions that are applicable to smaller companies. Align with Bangladesh's National Action Plan for Sustainable Garment Industry (2025) and EU's Circular Economy Action Plan.

Use Probability sampling method: In this research I use convenience sampling method, which is inferior to probability sampling method in terms of research quality. So future research needs to be done similar to this by adapting probability sampling to get rid of certain limitations of this research.

Advanced AI Applications: Investigation of new AI technologies like blockchain for traceability, advanced robotics, and explainable AI (XAI) and their impact on supply chain transparency and ethical compliance.

Policy and Regulatory Analysis: Detailed analyses of how policy interventions, regulatory regimes and public-private cooperation help to create digital and sustainable transformation.

Participatory and Mixed-Methods Approaches: Increased deployment of participatory action research and mixed-methods research to capture the views of workers, suppliers and other actors in receiving countries to ensure inclusive and context-specific response.

In conclusion, the adoption of AI and sustainable solutions for this industry in Bangladesh is a game changer and a positive disruptive measure by which Bangladesh garment industry will be taking a leap from operational efficiency, global competitiveness to long term sustainability. Unlocking this potential will require collaboration amongst industry, regulators, and the wider ecosystem to remove current barriers and effect real change.

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Appendices

Appendix 1. Invitation Letter for Companies.

Research Questionnaire

Dear Sir/Madam,

I hope this message finds you well. I am reaching out to invite you to participate in an academic research study aimed at assessing the readiness of organizations for the integration of Artificial Intelligence (AI) and Sustainable Practices in the Supply Chain of the Garment Industry in Bangladesh. The study examines the challenges and opportunities of Integrating AI and Sustainable Practices in the Supply Chain of the Garment Industry in Bangladesh.

Your participation in this online interview is completely voluntary and you may opt out of any question in the questionnaire. All of your responses will be kept confidential. They will only be used for research purposes and will be reported only in aggregated form. The completion of the questionnaire should not take more than 10-20 minutes of your time.

To participate, Please click on the following link: https://docs.google.com/forms/d/e/1FAIpQLSdoJ9g0Wb2f3-A8WdFI2pEb2H_R6IBNoaAEZ42R2VxMiVpMyQ/viewform?usp=sharing

If you have any questions about this questionnaire, or difficulty in accessing the link, please contact Sohag.ipe2010@gmail.com.

Thank you in advance for providing this important feedback.

Yours Sincerely,

Kazi Abdul Wadud Sohag (Master’s degree student)

Dept. of Industrial System Analytics

Faculty of Technology and Innovations

University of Vaasa

Vaasa, Finland

Supervised by: Prof. Dr. Emmanuel Ndzibah

Appendix 2. The online interview questions for the senior management.

1. Does your company currently use AI (Artificial Intelligence) in supply chain management (SCM)?
    - ❖ Yes
    - ❖ No
    - ❖ N/A
    - ❖ Other:
2. If no, on a scale of 1–5, how likely is your company to adopt AI-driven sustainability solutions in the next 5 years?

    1 (Not likely)
    - ❖ 2
    - ❖ 3 (Neutral)
    - ❖ 4
    - ❖ 5 (Very likely)
3. Do you agree that it is possible to implement the AI technologies in your company, in particular, AI-driven design, simulation, optimization, and demand forecasting into SC?
    - ❖ Strongly Disagree
    - ❖ Disagree
    - ❖ Not sure
    - ❖ Agree
    - ❖ Strongly Agree
4. How can AI help improve sustainability in the garment supply chain? (e.g., reducing waste, energy efficiency, ethical sourcing, circular economy)
5. Does your company track environmental/social metrics (e.g., carbon footprint, water usage, fair labour practices)? If yes, how is AI used to optimize these?
6. What sustainable practices (e.g., recycled materials, lean manufacturing, renewable energy) are already implemented in your supply chain?

7. What are the biggest challenges in integrating AI and sustainable practices in Bangladesh’s garment industry? (e.g., cost, skilled workforce, data privacy, supplier collaboration)
8. What opportunities do AI and IoT offer for cost reduction, transparency, and efficiency in your SCM?
9. How do you see the role of government policies or global brands in driving AI/sustainability adoption?
10. What key investments (training, technology, partnerships) are needed to accelerate this transition?
11. Any additional comments on the future of AI and sustainable SCM in the garment industry?
12. How can small and medium-sized garment factories in Bangladesh adopt AI affordably?
13. As an industry expert, what advice would you give to garment manufacturers in Bangladesh about AI and sustainability?
14. What are the risks of not adopting AI/sustainability in the next decade?
15. Should global fashion brands mandate AI/sustainability compliance for suppliers? Why/why not?

Appendix 3. Demographic of the respondents (N = 31).

Measure		Frequency	Percentage
Gender	Male	30	96.77%
	Female	1	3.23%
Age	30 ≤Age < 40	14	45.16%
	40 ≤Age < 50	9	29.03%
	50 ≤Age < 60	6	19.35%
	Age ≥60	2	6.45%
Designation	CEO	2	6.45%
	Chief Business Officer	1	3.23%
	Executive officer	2	6.45%
	Head of Department	1	3.23%
	Head of Group Strategic Planning	1	3.23%
	Head of Operations	1	3.23%
	Head of Planning	7	22.58%
	Managing Director	5	16.13%
	Planning Manager	4	12.90%
	Planning Officer	1	3.23%
	Principal	1	3.23%
	CFO	1	3.23%
	Head of supply chain	4	12.90%
Size of the company	Large (No. of workers ≥30000)	5	16.13%
	Medium (5001 ≤No. of workers < 30000)	16	51.61%
	Small (1000 ≤No. of workers < 5001)	10	32.26%
Working Experience	1≤ Years < 10	4	12.90%
	10≤ Years < 20	14	45.16%
	20 ≤ Years < 30	9	29.03%
	Years ≥30	4	12.90%