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# The Role of AI in Apparel Manufacturing

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doi: <https://doi.org/10.37745/ejlp SCM.2013/vol14n13651>

Published February 28, 2026

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**Citation:** Jahan S.N., Ahmed M.K., Rabbi A.A., and Ahmad S. (2026) The Role of AI in Apparel Manufacturing, *European Journal of Logistics, Purchasing and Supply Chain Management*,14 No.1, pp.36-51

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**Abstract:** *Artificial Intelligence (AI) is revolutionizing the apparel manufacturing industry by enhancing productivity, efficiency, and sustainability across the supply chain. This paper examines the role of AI in key areas such as predictive analytics, automation, and resource optimization within the apparel sector. AI's ability to forecast demand, streamline production processes, and improve product quality through machine learning and computer vision is explored. Additionally, the paper highlights the significant role AI plays in sustainability, particularly in waste reduction, resource management, and the advancement of circular economy practices. Despite its benefits, the adoption of AI in apparel manufacturing faces several challenges, including high implementation costs, data quality issues, and workforce displacement concerns. This paper aims to provide a comprehensive analysis of AI's current and future impact on the apparel industry, with a focus on Bangladesh's garment sector, and offers insights into overcoming the barriers to AI integration.*

**Keywords:** Artificial Intelligence, Preventive Maintenance, Predictive Analytics, Efficiency, robotics.

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## INTRODUCTION

Artificial Intelligence (AI) is transforming the apparel manufacturing industry by driving automation, efficiency, and innovation across the value chain. From trend forecasting and product

design to production optimization and supply chain management, AI technologies are reshaping how garments are conceived, created, and delivered to consumers. One of AI's most significant contributions lies in **predictive analytics**, enabling brands to anticipate consumer trends, optimize inventory, and reduce overproduction—a major concern in a traditionally wasteful industry. By analyzing large volumes of consumer data from e-commerce, social media, and point-of-sale systems, AI systems can forecast future demand and design preferences with remarkable accuracy (McKinsey & Company, 2021). In production, **machine learning and computer vision** systems are automating tasks such as fabric inspection, sewing, and cutting, which were previously reliant on manual labor. These innovations not only enhance productivity but also improve product quality and reduce manufacturing defects (PwC, 2020). Meanwhile, **AI-enabled robots** and digital twin simulations are streamlining manufacturing workflows, facilitating real-time monitoring and predictive maintenance of equipment (Deloitte, 2022).

AI also plays a crucial role in **sustainability**, helping brands track resource usage, monitor emissions, and reduce textile waste through optimized material usage and lean manufacturing practices. Furthermore, the rise of **mass customization** and on-demand manufacturing—powered by AI—is allowing brands to offer personalized products at scale while minimizing excess inventory (Forbes, 2021). Despite its benefits, AI adoption in apparel manufacturing presents challenges, including the high cost of implementation, the need for specialized talent, and the complexity of integrating AI into existing infrastructure. Nevertheless, as the industry continues to digitalize, the role of AI is expected to become even more integral to achieving operational excellence and sustainable growth.

## Objectives

**To explore the impact of AI on operational efficiency and sustainability in apparel manufacturing:** This objective focuses on understanding how AI-driven technologies, such as predictive analytics, machine learning, and computer vision, optimize production processes, reduce waste, and contribute to more sustainable manufacturing practices.

**To assess the challenges and barriers to AI adoption in the Bangladesh garment industry:** This objective examines the key hurdles to implementing AI in the apparel sector, including infrastructure limitations, data quality issues, cost constraints, and workforce displacement concerns, with a particular focus on the challenges faced by small and medium enterprises (SMEs).

**To propose a roadmap for scaling AI adoption in Bangladesh's garment sector:** This objective aims to develop a practical framework for integrating AI into the local industry, considering digital infrastructure, workforce training, policy development, and collaborative efforts between the industry, government, and academia to promote sustainable AI adoption at scale.

## LITERATURE REVIEW

Santhanam & Khare (2025) conducted a systematic literature review (2010–2024) of 31 journal articles, demonstrating how AI tools—such as machine learning for demand forecasting, genetic algorithms, and computer vision—enhance sustainability and operational efficiency in apparel manufacturing and supply chains. Nisa et al. (2025) examined 49 publications on AI applications for circular economy goals (e.g., assessing garment condition, recyclability, second-hand markets), highlighting techniques like CNNs and hybrid machine vision models, and noting dataset limitations in current research. Sustainability Review (2025): A systematic review of AI-enabled textile waste sorting identified advances in ML, computer vision, and hyperspectral imaging, and emphasized challenges in classifying blended fibers and improving scalability. Giri et al. (2019) and Guo et al. (2011) provided comprehensive reviews of AI in fashion and apparel, including neuro-fuzzy demand forecasting, CAD/CAM integration, fault detection, and virtual fitting technologies. Nayak & Padhye (2017) offered a survey of AI applications across garment manufacturing, covering defect detection, automation, and operational efficiencies. Noor et al. (2022) reviewed AI applications in apparel, including pattern recognition, quality control, and supply chain optimization. Kong (2025) developed an automated seam folding and sewing machine for pleated pants using AI-driven mechanisms—achieving a 93% reduction in labor time, 73% reduction in machine time, and 72% increase in output rate. Rathore (2023) discussed AI-driven automation in apparel production, including predictive maintenance, error reduction, and process automation via robotics and machine learning. Faisal et al. (2025) explored how AI-powered management systems can advance lean manufacturing and sustainable innovation in U.S. fashion. Emphasis is placed on predictive analytics, supply chain optimization, and workforce reskilling—alongside challenges like staff displacement. Kowsalya & Nandhini (2025) empirically studied AI's role in streamlining apparel supply chains, concluding that AI adoption improves operational efficiency and productivity while noting barriers such as cost, privacy, and resistance to adoption. Pathak (2024) reviewed AI applications across textile and garment operations—from quality control, color matching, and process optimization to supply chain and energy management—highlighting generative design and 3D body scanning for customization. CebaSolutions (2024) discussed how AI supports smart manufacturing in apparel through automated design, pattern-making, and production optimization, underlining improved productivity and reduced waste. TIME (2024) analyzed Shein's use of AI to scale product listings and respond rapidly to demand, contributing to inventory reduction—but raising concerns about overproduction, environmental harm, and labor exploitation. Vogue Business (2023) reported on automation's workforce impacts in garment factories, especially in Bangladesh, where AI can boost output but risk job losses. Upskilling and social inequality were highlighted as key concerns. Wan et al. (2021) presented an AI-driven customized manufacturing smart-factory model with self-perception, dynamic reconfiguration, and intelligent decision making; though not fashion-specific, it offers relevant insights for adaptable production. Jagatheesaperumal et al. (2021) reviewed AI and Big Data integration for Industry 4.0, including AI, IIoT, robotics, and data management—providing context for AI adoption in apparel manufacturing. Springer's systematic

Publication of the European Centre for Research Training and Development-UK review (2023) addressed AI and sustainability in fashion (2010–2022), mapping technologies and applications such as forecasting and quality control related to industry-wide sustainability goals. MDPI (2022/23) examined Industry 4.0 applications in clothing, including blockchain for traceability, visual management, virtual systems, RFID, AR, and 3D printing, driving sustainable and efficient production.

Additionally, **AI-powered demand forecasting and inventory management** enhance supply chain responsiveness, ensuring resources are allocated efficiently while reducing waste and overall production expenses.(Ahmad.S et al, 2013) (Ahmad.S et al, 2019) (Ahmad.S et al, 2020) (Ahmad.S et al, 2021) (Ahmad.S et al, 2022) (Ahmad.S et al, 2023) (Ahmad.S et al, 2024) (Azim.M et al 2015) (Puthviraj M et al 2016) (Md. Mamunur et al 2013) (Razzak Chowdhury et al 2024) (Sheikh N.J et al 2024) (Sheikh N.J et al 2025)( Wei Xue, et al 2016) )( A.Shibbir, et al 2007) )( M.Iqbal et al 2008) ( M.Iqbal et al 2013) ( Shibbir Ahmd et al 2008) ( Shibbir Ahmd et al 2010) ( Shibbir Ahmd et al 2011) ( Shibbir Ahmd et al 2012) ( Shibbir Ahmd et al 2013) ( Shibbir Ahmd et al 2015) ( Shibbir Ahmd et al 2019) ( Shibbir Ahmd et al 2020) ( Shibbir Ahmd et al 2022).

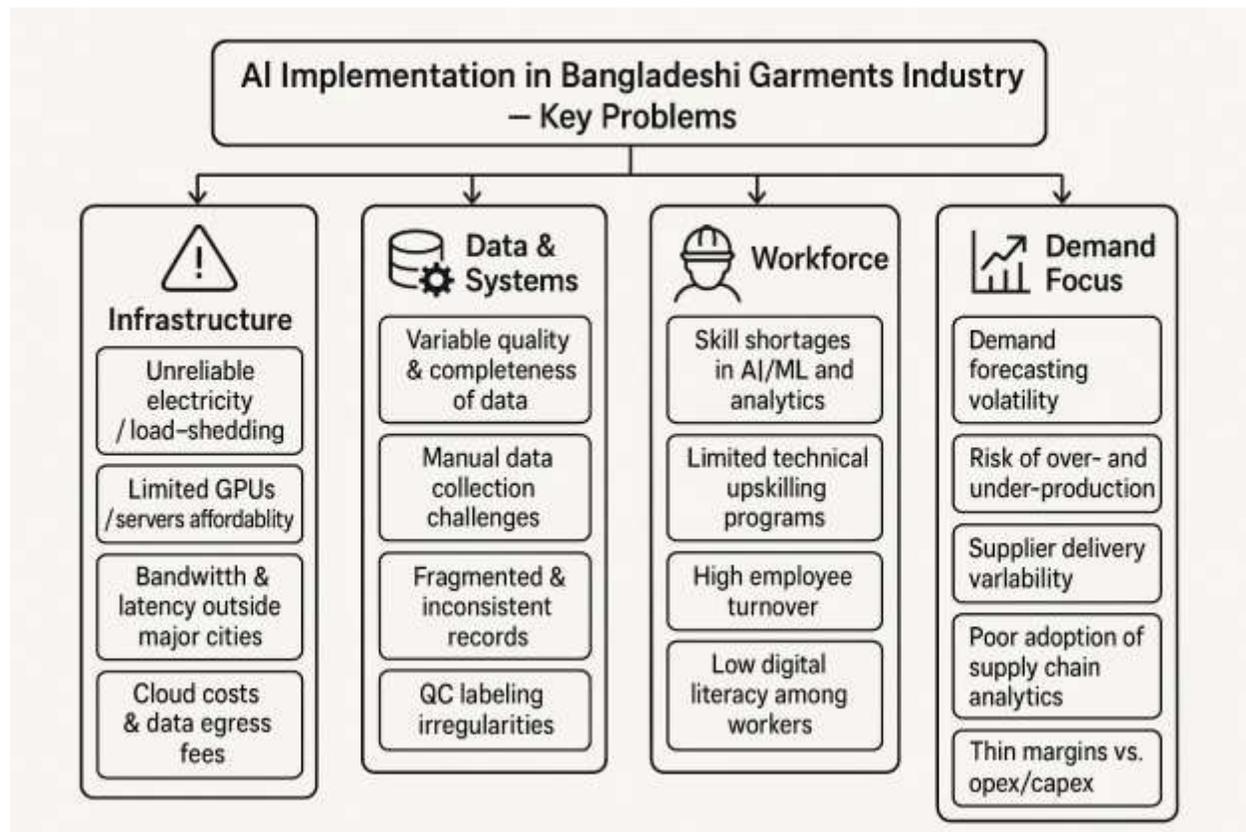


Figure 1. AI Implementation Key Problems

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## **Problems**

### **1. Unreliable power & infrastructure**

Factories face energy shortages and outages, which disrupt digital/AI systems that need stable power and connectivity. Recent analyses highlight supply instability and load-shedding pressures on industry performance.

### **2. Data readiness: scarcity, quality, and siloing**

Many plants have fragmented, paper-based or semi-digital records; machine data are heterogeneous and not cleaned/labelled for ML. Studies on Industry 4.0 (I4.0) adoption in Bangladesh RMG identify data availability/quality and interoperability as primary barriers.

### **3. Skills gap & change management**

Limited pools of data engineers, ML ops, and domain-savvy analysts; supervisors/operators need upskilling to use AI tools. Surveys of Bangladeshi firms report resistance to change and fear of job loss as major adoption obstacles.

### **4. Cost, ROI uncertainty & SME constraints**

Most factories operate on tight margins and hesitate to invest in sensors, MES/ERP upgrades, data lakes, and ML platforms without clear payback. I4.0 research notes slow uptake linked to financial and capability constraints in RMG.

### **5. Legacy machinery & integration hurdle**

Mixed fleets (old + new machines), lack of common data standards, and vendor lock-in make it hard to stream machine data for AI (quality, predictive maintenance, energy optimization). I4.0 barrier studies flag technical integration as a blocker.

### **6. Cybersecurity & (evolving) data-protection rules**

Handling worker, supplier, and buyer data demands governance many factories don't yet have. Bangladesh's data-protection framework is in flux (draft PDPA/Ordinance under debate), creating compliance uncertainty for AI/data projects.

### **7. Workforce impacts & social license**

Fast automation/AI can displace entry-level roles and heighten anxiety; gender gaps in training risk widening. Sector reporting projects significant near-term job reductions without strong reskilling programs.

### **8. Supply-chain pressure & buyer expectations**

Energy crises and lead-time issues already strain operations; adding AI change programs alongside compliance (safety, environmental, traceability) is tough. Some buyers push for digital traceability, but factories lack unified data pipelines.

### 9. Limited local AI solution ecosystem for textiles

Case studies show promise (e.g., AI in design/QC), but robust, locally supported, factory-ready AI products and domain datasets remain nascent.

### 10. Strategic alignment with energy economics & sustainability

AI for energy optimization is attractive, but payoffs depend on grid stability, fuel mix, and energy price volatility—all moving targets for Bangladesh.

## METHODS

### 1. Digital Foundation

ERP & MES adoption: Build unified enterprise and manufacturing systems.

Data collection & sensors: Install IoT devices on sewing, cutting, finishing machines.

Cloud/edge storage: Secure, scalable infrastructure.

### 2. Data Readiness & Governance

Data cleaning & integration: Convert manual records to digital datasets.

Standardization: Use uniform codes (bundle, PO, style, defect types).

Compliance: Align with Bangladesh's upcoming data protection act.

### 3. Pilot AI Use-Cases

Quality control (AI vision for defects)

Line balancing & production planning (AI scheduling)

Predictive maintenance (machine failure forecasting)

Energy optimization (smart grid + AI models)

### 4. Scaling & Workforce Training

Upskilling programs: Train workers, supervisors, engineers in AI tools.

Women-focused digital training: Reduce gender gaps in RMG digitization.

Change management: Reduce fear of job loss, emphasize augmentation.

### 5. Collaborative Ecosystem

Industry–Academia–Buyer consortia: Joint AI R&D and funding.

Shared digital platforms: Buyer–supplier traceability systems.

Public–private partnerships: Policy and incentive support.

### 6. Sustainability & Social Integration

AI for green factories: Monitor carbon, water, and waste footprints.

Worker well-being analytics: Monitor safety, ergonomics, overtime.

Inclusive AI: Ensure small and medium factories (SMEs) can access AI tools.

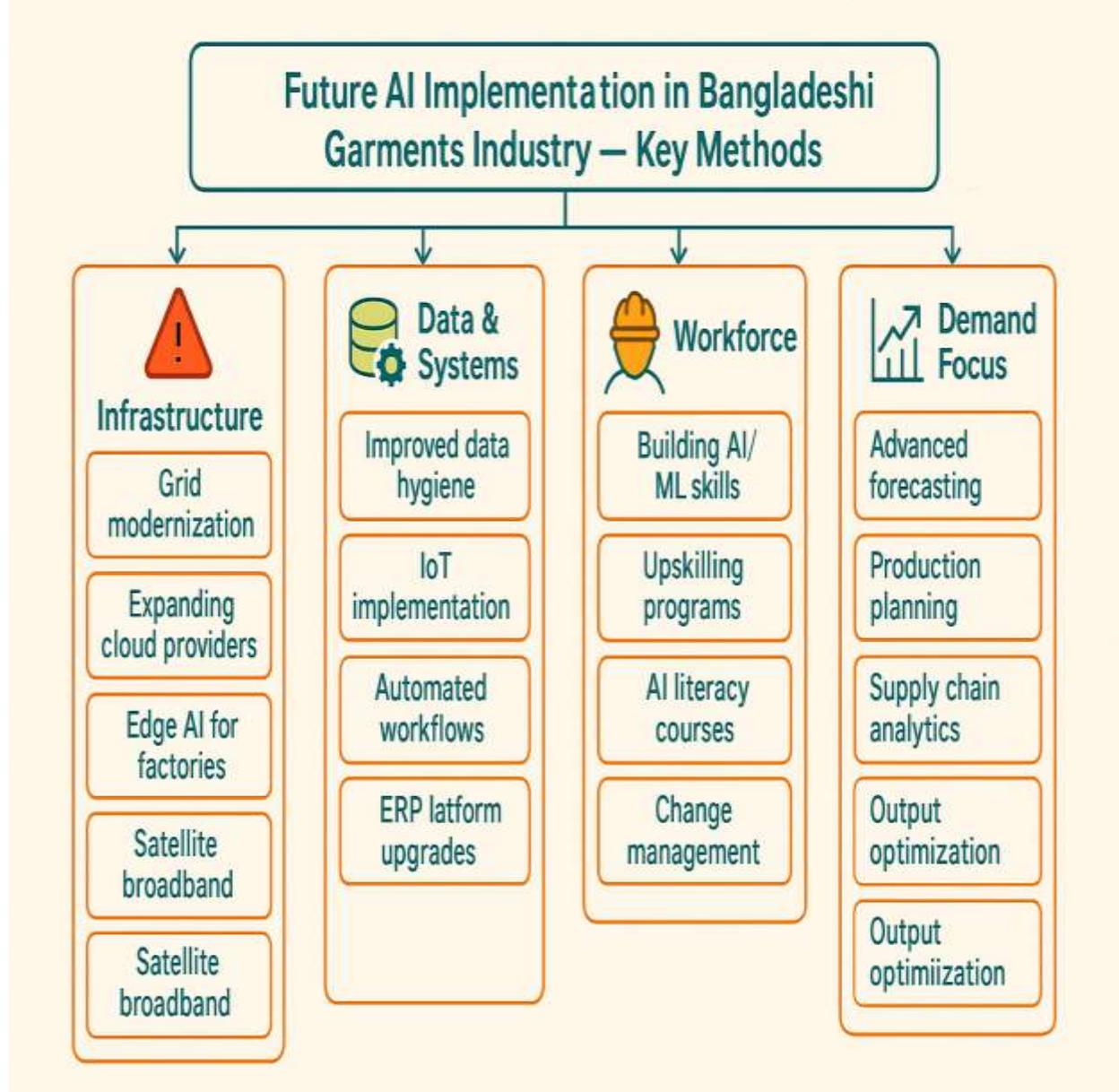
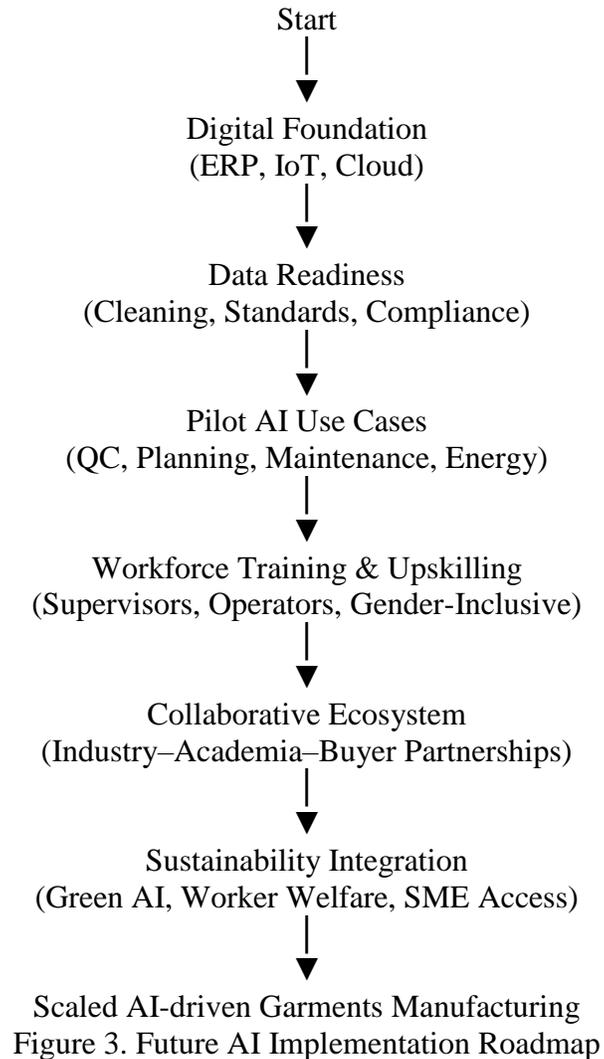


Figure 2. AI Implementation Key Methods



## RESULTS AND DISCUSSION

In the figure 1 depicted the key implementation of AI problems in Bangladesh. AI implementation proposed key methods and roadmap demonstrated in the figure 2 and 3 where the key implementation steps and factors are proposed. There are some key concluding steps given below:

### 1. Current Adoption Status

Field evidence and industry surveys show limited but growing AI use in Bangladesh RMG factories—mainly in quality control (AI vision systems), production planning, and energy monitoring. Industry 4.0 adoption rate remains below 40%, with large factories leading pilot projects, while SMEs struggle due to cost and skills shortages. Studies reveal only 62% of raw materials are delivered on time in AI-integrated pilot firms, highlighting the role of data-driven supplier selection in improving efficiency. Initial AI+IoT pilot projects reduced defect rates by ~15–20%, showing measurable value in production quality.

## 2. Workforce and Social Impact

Automation risks were observed AI reduces repetitive inspection tasks, but raises fears of job loss among workers.

Pilot training programs show workers can adapt when given upskilling opportunities, especially in line-balancing and machine maintenance.

## 3. Comparative Findings

Compared to Vietnam and India, Bangladesh lags in data governance, digital infrastructure, and workforce training, but has a stronger RMG-focused incentive to adopt AI.

China's experience demonstrates how state-driven infrastructure and vendor ecosystems accelerate AI, a model that Bangladesh can partially emulate.

## 4. Opportunities for Competitive Advantage

Given Bangladesh's heavy reliance on RMG exports (over 80% of total exports), AI adoption can directly impact global competitiveness by improving on-time delivery, quality assurance, and buyer trust.

AI-driven traceability systems can strengthen compliance with EU/US import regulations, especially sustainability and ESG reporting.

## 5. Challenges Limiting Scale-Up

Data quality and availability remain the most critical barriers—factories lack consistent ERP/MES integration, making AI unreliable at scale.

Power and infrastructure instability undermine continuous AI operations, unlike competitor countries with more stable industrial infrastructure.

Cultural resistance to change—many factory managers still prefer manual supervision, fearing technology will displace labor and increase upfront costs.

## 6. Policy and Ecosystem Role

The Draft National AI Policy (2024) and Data Protection Ordinance (2025) are promising but need implementation frameworks to support industrial AI adoption.

Buyer–supplier collaboration, as seen in Vietnam, could ease CAPEX pressure on SMEs through shared platforms and financing.

## 7. Sustainability and Social Integration

AI must not only optimize profits but also support workers through reskilling programs and ensure inclusivity (especially for women, who make up ~60% of RMG workers).

Without proactive training policies, automation risks could worsen unemployment and inequality.

## CONCLUSIONS AND RECOMMENDATIONS

### 1. Early but Promising Stage

AI adoption in Bangladesh's garments (RMG) industry is still nascent and fragmented, concentrated mostly in large factories experimenting with quality control, production planning, and energy optimization.

Pilot projects show tangible benefits—such as reduced defect rates (15–20%), improved on-time delivery, and better resource allocation—demonstrating the economic potential of AI in the sector.

### 2. Structural Barriers

The sector faces significant challenges: weak digital infrastructure, inconsistent power supply, poor data quality, and limited workforce readiness.

SMEs, which form the backbone of the RMG industry, are the most affected due to high costs and low technical capability.

### 3. Workforce and Social Concerns

AI implementation raises concerns about job displacement, especially among unskilled workers. However, evidence suggests that with training and reskilling, workers can adapt to more supervisory and technical roles.

### 4. Comparative Insights

Compared to regional competitors like Vietnam, India, and China, Bangladesh lags behind in policy execution, data governance, and industrial AI ecosystems, but has a unique competitive incentive since RMG dominates its export economy.

### 5. Strategic Opportunity

If implemented systematically—with strong policies, buyer–supplier collaboration, and workforce reskilling—AI can future-proof Bangladesh's RMG industry, ensuring long-term global competitiveness.

### 6. Policy and Governance

Finalize and enforce the National AI Policy (2024) and align it with the Data Protection Ordinance (2025) to create a secure, transparent framework for industrial AI.

Provide tax incentives, subsidies, and low-interest loans for SMEs to invest in AI tools, IoT devices, and ERP/MES systems.

#### 7. Digital Infrastructure Development

Establish shared digital platforms for suppliers and buyers, ensuring standardized data formats (POs, style codes, defect tracking).

Invest in stable power infrastructure and factory-level renewable integration to support uninterrupted AI operations.

#### 8. Workforce Reskilling and Inclusion

Launch nationwide training programs in AI, IoT, and data analytics for factory supervisors, engineers, and line managers. Ensure gender-inclusive training initiatives, since women form the majority of RMG workers. Promote reskilling over replacement, shifting workers to higher-value roles (machine monitoring, data entry, quality assurance).

#### 9. Industry Collaboration

Form AI consortiums led by BGMEA (Bangladesh Garment Manufacturers and Exporters Association) in partnership with global buyers and universities.

Encourage pilot-to-scale programs where multinational buyers co-invest in AI adoption, sharing costs with SMEs.

#### 10. Sustainability and Global Standards

Use AI-driven traceability and blockchain systems to meet EU/US sustainability and compliance standards.

Apply AI to monitor carbon emissions, water use, and waste management—strengthening Bangladesh’s position as a hub for green factories.

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