

AI-Based Garments Manufacturing

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Abstract

Artificial Intelligence (AI) is transforming the apparel manufacturing industry by improving productivity, efficiency, and sustainability throughout the supply chain. This paper explores how AI contributes to key areas such as predictive analytics, automation, and resource optimization within the apparel sector. It discusses AI's capacity to forecast market demand, optimize production workflows, and enhance product quality through technologies such as machine learning and computer vision. The study also emphasizes AI's growing role in promoting sustainability, particularly through waste reduction, improved resource management, and support for circular economy practices. However, the implementation of AI in apparel manufacturing also presents several challenges, including high adoption costs, issues related to data accuracy and availability, and concerns about workforce displacement. This paper provides a comprehensive analysis of the current and potential future impact of AI on the apparel industry, with particular attention to Bangladesh's garment sector, and offers recommendations for addressing the barriers to successful AI integration.

Keywords

Artificial Intelligence, Total Quality Management, Total Productive Management, Efficiency, Predictive Analytics

1. 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 [1]. 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 [2]. Meanwhile, AI-enabled robots and digital twin simulations are streamlining manufacturing workflows, facilitating real-time monitoring and predictive maintenance of equipment [3]. 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 [4].

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.

In this research, some terms will be used repeatedly which is defined as follows: The adoption of artificial intelligence (AI) in Bangladesh's ready-made garment (RMG) sector increasingly depends on the integration of digital systems such as Enterprise Resource Planning (ERP), defined as integrated software platforms used to manage core business processes including inventory, production, finance, and human resources, and Manufacturing Execution Systems (MES), which are real-time monitoring and control systems that track and optimize production activities on the factory floor.

A critical prerequisite for successful AI implementation is data readiness, referring to the availability, quality, consistency, and accessibility of data required for analytics and machine learning applications. Many factories in Bangladesh still face challenges in ensuring structured and reliable datasets, which limits the effectiveness of AI-driven decision-making.

Advanced concepts such as digital twins, defined as virtual replicas of physical production systems that enable simulation, monitoring, and optimization of manufacturing processes in real time, are also gaining attention in smart manufacturing environments. These technologies allow manufacturers to test process improvements and predict system behavior without disrupting actual production.

In addition, AI plays an important role in supporting circular economy princi-

ples, which refer to an economic system aimed at minimizing waste and maximizing resource efficiency through reuse, recycling, remanufacturing, and sustainable product design. In the context of the garment industry, this includes applications such as textile recycling, waste sorting, and lifecycle tracking of garments.

This paper is a narrative and conceptual review that synthesizes existing research and industry reports on the role of AI in apparel manufacturing, with a particular emphasis on implications for Bangladesh's garment sector. The review method involved searching scholarly databases such as Scopus, Web of Science, and Google Scholar, as well as industry publications (e.g., McKinsey, Deloitte, PwC, and Forbes). Search terms included "Artificial Intelligence", "apparel manufacturing", "Bangladesh garment industry", "Industry 4.0", and "sustainable production". The search covered publications from 2015 to 2023. Sources were selected based on their relevance to AI applications in the apparel value chain, their empirical or conceptual contributions, and their focus on industrial transformation in emerging economies such as Bangladesh.

Objectives

- 1) To explore the impact of AI on operational efficiency and sustainability in apparel manufacturing.
- 2) To assess the challenges and barriers to AI adoption in the Bangladesh garment industry.
- 3) To propose a roadmap for scaling AI adoption in Bangladesh's garment sector.

2. Literature Review

Santhanam & Khare [5] conducted a systematic study, 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. 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 [6]. AI-enabled textile waste sorting identified advances in ML, computer vision, and hyperspectral imaging, and emphasized challenges in classifying blended fibers and improving scalability. It provided comprehensive reviews of AI in fashion and apparel, including neuro-fuzzy demand forecasting, CAD/CAM integration, fault detection, and virtual fitting technologies [7] [8].

Nayak and Padhye [9] offered a survey of AI applications across garment manufacturing, covering defect detection, automation, and operational efficiencies. It reviewed AI applications in apparel, including pattern recognition, quality control, and supply chain optimization [10]. It 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 [11]. AI-driven automation in apparel production, including predictive maintenance, error reduction, and process automation via robotics and machine learning [12]. AI-powered management systems can advance lean manufacturing and sustainable innovation in U.S. fashion [13]. Emphasis is placed on predictive analytics, supply chain optimization, and workforce reskilling—alongside challenges like staff displacement. A study showed 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 [14]. It 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 and discussed how AI supports smart manufacturing in apparel through automated design, pattern making, and production optimization, underlining improved productivity and reduced waste [15]. The 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. It 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 [16].

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 [17]. Jagatheesaperumal reviewed AI and Big Data integration for Industry 4.0, including AI, Industrial Internet of Things (IIOT), robotics, and data management—providing context for AI adoption in apparel manufacturing [18]. Springer's systematic 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 [19].

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 [20].

Additionally, AI-powered demand forecasting and inventory management enhance supply chain responsiveness, ensuring resources are allocated efficiently while reducing waste and overall production expenses [21]-[49]. AI-driven demand forecasting can help Bangladesh's RMG sector reduce overproduction, improve order planning, and enhance responsiveness to global fast-fashion markets. AI-based quality inspection systems can significantly reduce defect rates in Bangladesh's garment factories, improving export quality and compliance with international standards. Predictive maintenance and automation can help Bangladeshi factories reduce machine downtime, increase productivity, and transition toward smart manufacturing systems. AI-driven sustainability solutions can help Bangladesh meet international environmental and traceability standards, which

are increasingly required by global buyers. AI-enabled supply chain optimization can enhance coordination between buyers and suppliers in Bangladesh, reducing lead times and improving global competitiveness.

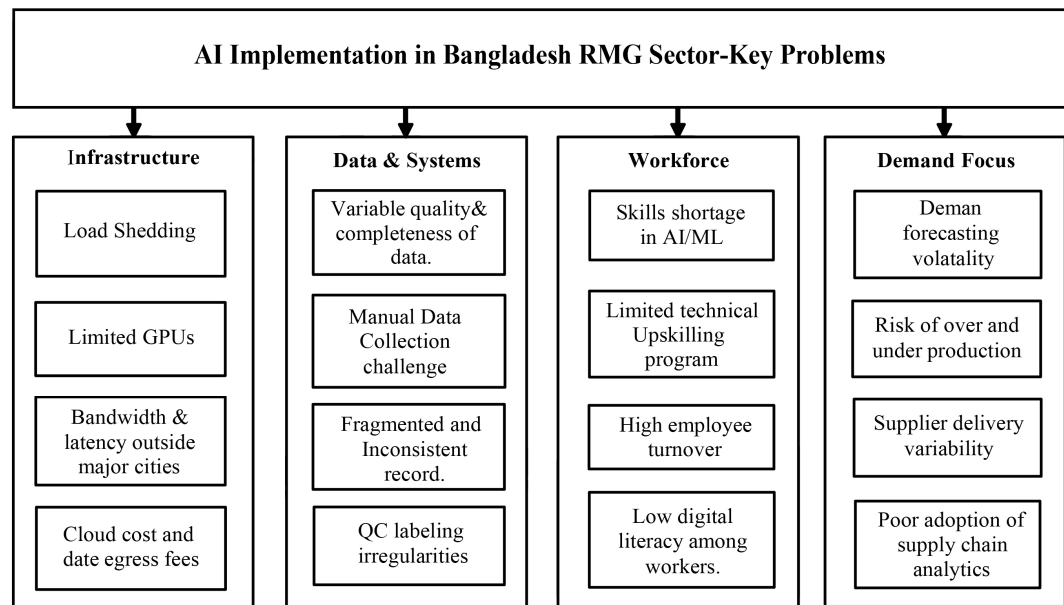


Figure 1. AI implementation key problems.

3. Problems

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|---|---|--|
| 1 | Unreliable Power and Infrastructure | Frequent power outages and energy shortages in factories interrupt the operation of digital and AI-based systems that require consistent electricity and stable network connectivity. These disruptions negatively impact industrial productivity. |
| 2 | Data Readiness: Limited Availability and Poor Quality | Many garment factories still rely on fragmented, paper-based, or partially digital record systems. Machine-generated data are often inconsistent, unstructured, and not properly prepared or labeled for machine learning applications. |
| 3 | Skills Gap and Change Management Issues | There is a shortage of professionals skilled in data engineering, machine learning, and AI system management. Additionally, factory managers and workers require training to effectively use AI technologies, while fear of job loss and resistance to change hinder adoption. |
| 4 | High Costs and Uncertain Return on Investment | Due to narrow profit margins, many factories are hesitant to invest in AI-related infrastructure such as sensors, upgraded ERP/MES systems, data platforms, and machine learning tools without clear financial benefits. |

Continued

5	Legacy Machinery and Integration Difficulties	Many factories operate with a combination of old and modern machines that lack standardized data interfaces. This creates challenges in integrating systems and collecting real-time machine data needed for AI-driven applications like predictive maintenance and quality control.
6	Cybersecurity and Data Protection Concerns	The use of AI requires proper management of sensitive information related to employees, suppliers, and buyers. However, many factories lack strong data governance frameworks, and evolving national data protection regulations add uncertainty.
7	Workforce Impact and Social Concerns	The rapid introduction of automation and AI technologies may lead to job displacement, particularly for low-skilled workers. Without proper reskilling initiatives, this could increase workforce anxiety and widen training gaps.
8	Supply Chain Pressure and Buyer Demands	Factories already face challenges related to energy shortages, strict delivery timelines, and compliance standards. Implementing AI systems while meeting buyers' expectations for sustainability and digital traceability adds further pressure.
9	Limited Local AI Technology Ecosystem	Although AI has shown potential in areas such as product design and quality inspection, locally developed AI solutions and specialized datasets for the textile industry remain limited.
10	Alignment with Energy Economics and Sustainability Goals	AI applications for energy optimization can improve efficiency, but their effectiveness depends on factors such as energy price fluctuations, fuel availability, and the stability of the national power grid.

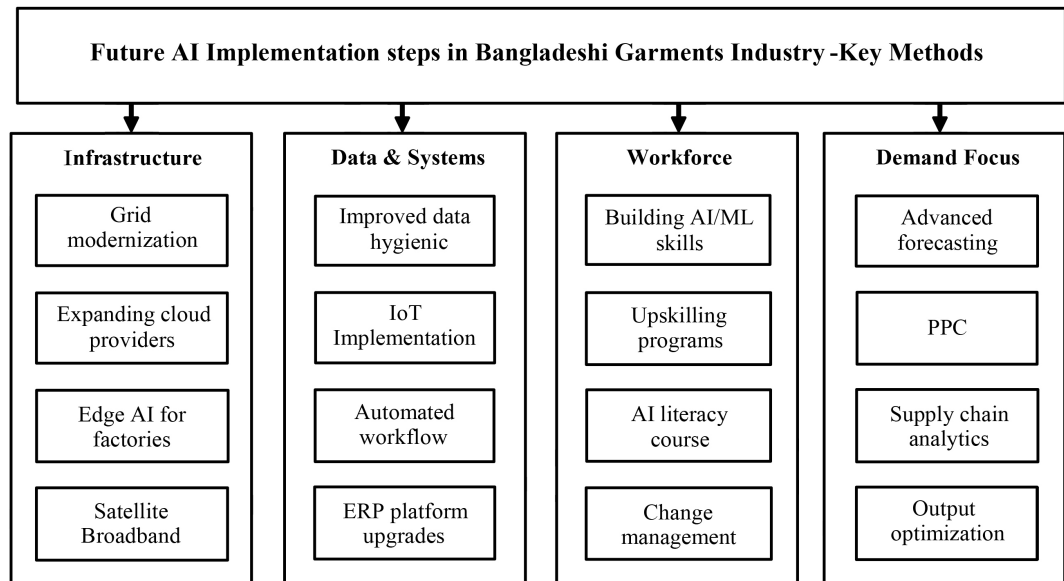


Figure 2. AI implementation key methods.

4. Research Method

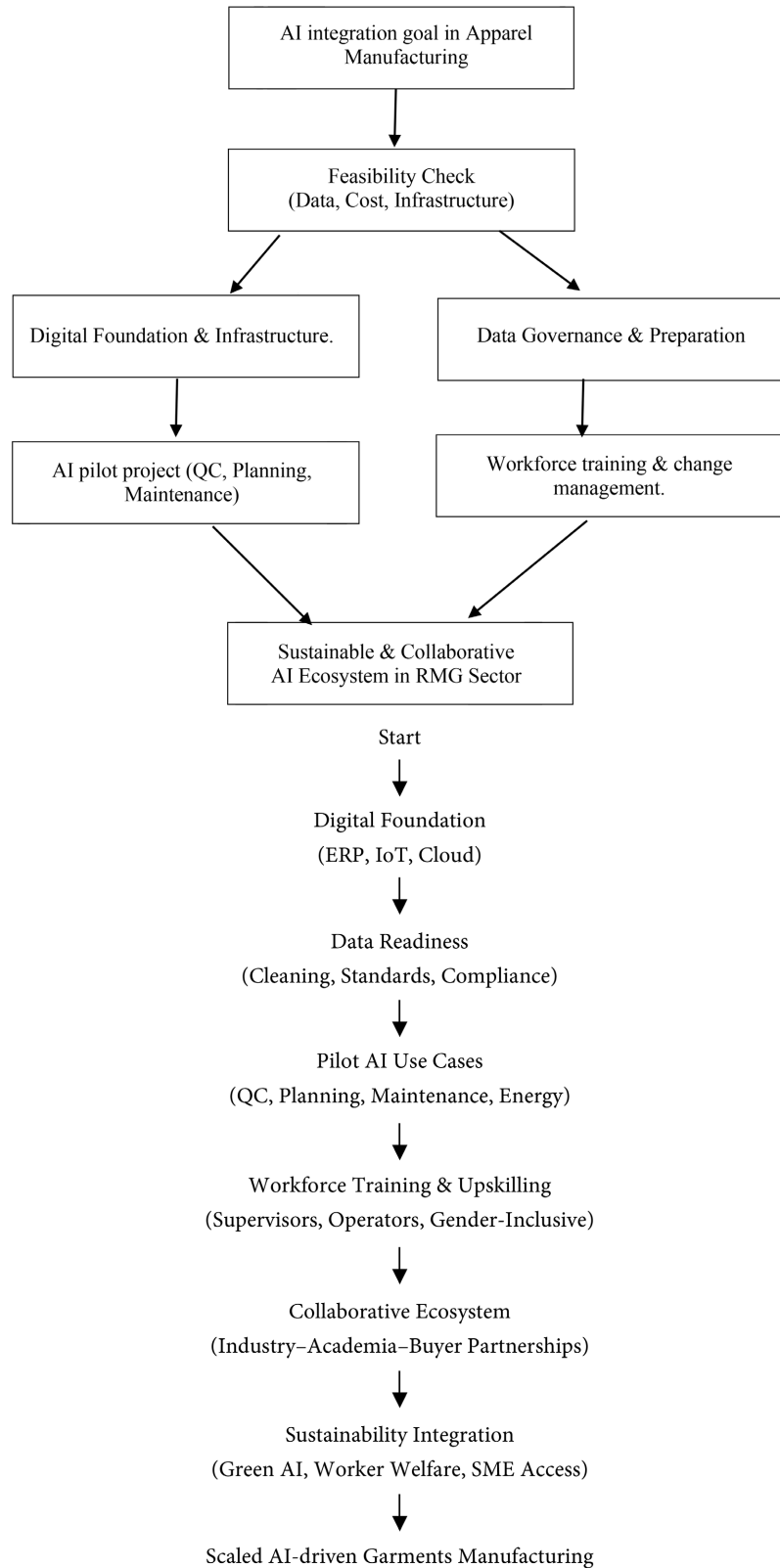


Figure 3. Future AI implementation roadmap.

5. Results & Discussions

The results and discussion indicate that the adoption of artificial intelligence (AI) in Bangladesh's ready-made garment (RMG) industry is still at an early stage but is gradually increasing. Current evidence from industry surveys and pilot projects shows that AI is mainly applied in areas such as automated quality inspection through computer vision, production planning, and energy monitoring. Although the overall adoption of Industry 4.0 technologies remains below 40% (e.g., based on recent industry surveys such as BGMEA reports or international assessments; precise source to be cited) [50], larger factories have begun experimenting with AI-driven systems, while small and medium-sized enterprises face barriers related to high costs and limited technical expertise. Key problems of AI depicted in **Figure 1**. The key implementation steps discussed at **Figure 2**. After the analysis problems and implementation steps a proposed future AI implementation roadmap demonstrated at **Figure 3**.

Early pilot implementations integrating AI and IoT technologies have demonstrated promising outcomes and improved operational efficiency through data-driven supplier selection. At the same time, the introduction of AI has raised concerns among workers regarding job displacement, particularly in repetitive inspection tasks; however, training and reskilling initiatives indicate that employees can adapt to new roles when provided with appropriate support, especially in areas such as line balancing and machine maintenance.

Compared with regional competitors such as Vietnam and India, Bangladesh still lags behind in digital infrastructure, data governance, and workforce development, although the country's heavy dependence on RMG exports provides a strong motivation to adopt advanced technologies. Experiences from China further illustrate how coordinated government policies and strong technology ecosystems can accelerate AI implementation, offering valuable lessons for Bangladesh.

The adoption of AI presents significant opportunities to enhance global competitiveness by improving product quality, ensuring timely delivery, and strengthening compliance with international sustainability and traceability requirements. Nevertheless, several challenges continue to limit large-scale implementation, including inconsistent data availability, inadequate ERP/MES integration, unreliable power supply, and cultural resistance to technological change among some factory managers. Policy initiatives such as the Draft National AI Policy and evolving data protection regulations provide a positive foundation, but effective implementation strategies and industry support mechanisms are required.

Furthermore, collaboration among buyers, suppliers, and policymakers could help reduce investment barriers for smaller factories through shared digital platforms and financing models. Ultimately, for AI adoption to be sustainable and socially responsible, it must be accompanied by comprehensive workforce development programs and inclusive training initiatives, particularly for women who represent a significant portion of the RMG workforce, ensuring that technological

advancement contributes not only to productivity but also to equitable social progress.

6. Conclusions & Recommendations

The findings of this study indicate that the adoption of artificial intelligence (AI) in Bangladesh's ready-made garment (RMG) sector is still in its early stages, with implementation mainly concentrated in larger factories experimenting with applications such as automated quality inspection, production scheduling, and energy management. Despite its limited spread, early pilot initiatives have demonstrated clear operational benefits, including reductions in defect rates by approximately 15% - 20% (based on pilot implementations and case-study evidence; exact sources should be cited or clearly identified as indicative estimates) [51], improved delivery reliability, and more efficient use of resources, highlighting the strong economic potential of AI for the industry.

However, several structural challenges continue to hinder wider adoption, including insufficient digital infrastructure, unreliable electricity supply, poor data management practices, and a shortage of skilled personnel capable of managing AI systems. These barriers particularly affect small and medium-sized enterprises (SMEs), which form the majority of the RMG sector but often lack the financial capacity and technical expertise required to implement advanced technologies.

In addition, the introduction of AI raises social concerns regarding possible job displacement among low-skilled workers, although existing evidence suggests that with appropriate training and reskilling initiatives, workers can transition into more technical or supervisory roles within increasingly digitalized production environments. When compared with regional competitors such as Vietnam, India, and China, Bangladesh remains behind in areas such as digital governance, industrial AI ecosystems, and policy implementation; nevertheless, the country's heavy dependence on RMG exports provides a strong motivation to accelerate technological transformation.

If AI adoption is strategically implemented through supportive government policies, collaborative industry partnerships, and comprehensive workforce development programs, it could significantly strengthen the global competitiveness and long-term sustainability of Bangladesh's garment sector. To achieve this transformation, policymakers should prioritize the effective implementation of the National AI Policy (2024) alongside the Data Protection Ordinance (2025) to establish a secure and transparent framework for industrial AI deployment.

Financial incentives such as tax benefits, subsidies, and low-interest financing should also be introduced to help SMEs invest in digital infrastructure, including IoT devices and integrated ERP/MES systems. Furthermore, investment in reliable power infrastructure and the development of shared digital platforms between buyers and suppliers would support standardized data exchange and uninterrupted AI operations.

Workforce development must also be a central component of this transition,

with national training initiatives focused on AI, IoT, and data analytics for supervisors, engineers, and factory managers, while ensuring inclusive participation for women who represent the majority of the RMG workforce. Encouraging industry collaboration through partnerships among manufacturers, global buyers, academic institutions, and organizations such as the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) can further accelerate AI innovation and reduce investment risks through shared pilot projects and co-financing mechanisms.

Finally, integrating AI-driven monitoring systems for supply chain traceability, carbon emissions, water consumption, and waste management can help Bangladesh align with evolving international sustainability standards, strengthening its position as a global leader in environmentally responsible garment manufacturing.

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Financial incentives such as tax benefits, subsidies, and low-interest financing should also be introduced to help SMEs invest in digital infrastructure, including IoT devices and integrated ERP/MES systems [55] (supported by recommendations from World Bank (2020) and McKinsey & Company (2021) on industrial upgrading and SME digitalization). Furthermore, investment in reliable power infrastructure and the development of shared digital platforms between buyers and suppliers would support standardized data exchange and uninterrupted AI operations (consistent with digital transformation frameworks discussed in World Economic Forum (2022)) [55].

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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