Artificial Intelligence in Advanced Manufacturing: Opportunities, Applications, and Challenges in the Context of Bangladesh

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Abstract

Background: AI has the possible to convert productivity, quality declaration, and operational effectiveness in several major industries, including garments, leather, jute, and small and medium enterprises (SMEs). While the world is rapidly advancing toward AI-driven manufacturing, the pace of industrial implementation AI technology in Bangladesh is still very slow, sporadic, and at different stages of maturity. Methods: This study implements a mixed-methods design that includes a structured review on the global AI applications in manufacturing and their relevance and applicability to Bangladesh. The secondary data included academic documents, international case studies, and government and industry report as well as published literature. Taking into consideration the real-world applicability, the study analyzes the advances AI algorithms have made towards autonomous execution in some selected industries in Bangladesh. Results: In Bangladesh, AI is only embraced at some selected large-scale enterprises where a baseline digital infrastructure has already been put in place, or SMEs are severely constrained by low levels of technological resources, gaps in workforce skills, and lack of an integral framework. Among these, some of the most promising systems are defect recognition by machine vision, predictive maintenance with machine learning algorithms, and quality control with AI. Conclusion: AI promises limitless possibility, and with applied effort, new systems can be implemented into the industry. Without development of policies that facilitate supporting logistics and scalable pilot programs, investment in and infrastructure goes to waste.

Keywords: Artificial Intelligence, Smart Manufacturing, Bangladesh, Industry 4.0, Machine Learning, Garment Industry.

Significance | This study identifies actionable strategies to advance AI integration in Bangladesh's manufacturing, supporting the Smart Bangladesh 2041 digital transformation agenda.

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1. Introduction

Bangladesh is one of the countries in South Asia which is rapidly industrializing and is going through profound changes in its manufacturing landscape. The economy of the country has experienced significant growth due to the Ready-Made Garment (RMG) industry, which follows highly manual processes, along with performing a lot of exports (Singh, 2019). In 2023, the industry was responsible for plastering approximately 35.4% of the national GDP, while the RMG sector accounted for more than 84% of the total exports. As of now, there is a fierce international competition, increase in labor cost, compliance to stringent quality measures, and aggressive marketing all put innovation and modernization under pressure for the manufacturing units to keep pace with (Mujeri & Mujeri, 2021). Some of the promising approaches to transformation include the integration of Artificial Intelligence (AI) which is the backbone of Industry 4. AI integration in manufacturing signifies a move from traditional manual work to more sophisticated, intelligent and data-centric systems.

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Technologies under AI like (ML) machine learning, deep computer vision and natural language processing (NLP) have the capability to control large amounts and complex data related to the production and also analyze it (Gabsi, 2024).

According to available information, these technologies can improve efficiency by twenty-five percent, lower equipment uptime by twenty to forty percent, and improve quality assurance rates by over thirty percent. In more advanced economies, AI has already improved productivity, managed supply chain flows, reduced wastage, and enabled increased product tailoring (Ruppert-Stroescu, 2009). For Bangladesh, the use of AI is a matter beyond advancing technology. As Girard states, "It is important for global competitiveness, economic resilience and sustainable development." The Government of Bangladesh has appreciated the need for digital transformation and set high targets through "Smart Bangladesh 2041" vision. The framework underlines fostering the use of AI and other frontier technologies to construct an inclusive, knowledge driven economy (Fleck & Harwood, 2021). Expansion of digital infrastructure, technology-based industrialization, and development of innovation ecosystems form the key strategic pillars. The government intent to incorporate new technology into all administrative and economic functions by 2030 (Elena, 2020). Contrarily, the existing degree in which industry is willing to embrace AI at a practical level is quite heterogeneous, regardless of the national goals set (Vinuesa et al, 2020). Current research suggests that approximately 12% of Bangladeshi manufacturing firms are thinking about AI applications and less than 5% have implemented AI technologies (Dong et al, 2020). Concentration of aid to adoption is mainly among large industrial groups in textiles, pharmaceuticals, and ceramics. Most small and medium-sized enterprises (SMEs), which represent the over 90% of the industrial units in the country, employing about 7.8 million people, do not possess the resource, technical know-how and, the awareness and understanding to formulate necessary policies are too limited to access the available technologies (Shobhana, 2024). As per the worldwide trends in manufacturing, the applications of AI are numerous. Predictive maintenance can lower idle times of machines by almost half, in addition to other uses such as computer vision systems for quality inspection that attain over 95% accuracy (Pasteur, 2024). Other important uses include simulation of the manufacturing processes, AI-enhanced forecasting for demand, robotic process automation (RPA) at assembly lines, and intelligent warehousing management. For Bangladesh, these technologies may be customized to solve local industrial problems including real-time garment defect identification, automated quality appraisal of jute and leather, or energy efficiency enhancement in plastics and chemicals manufacturing (Guo et al., 2011).

However, successful implementation of AI technologies needs a lot more than just having the technology available; a system is required. This system must encompass a solid data framework, low-cost cloud hosting solutions, workforce development and technical education, innovation and policy support, and enabling legislation. As stated, developing the workforce is critical (Giri et al., 2019). To meet the Smart Bangladesh objectives, the country will require more than one million workers with advanced digital skills by 2030.Nonetheless, the existing efforts in vocational and technical education only address a subset of the digital skills required, highlighting the need for strategic skill development and training programs. AI readiness is also limited by infrastructure constraints (Celi et al., 2025). By 2024, only 38% of manufacturing firms in Bangladesh had adopted basic digital systems such as ERP and IoT, which are frequently essential for AI use. Ccritical infrastructure for industrial data and operational reliability cyber-Security is weak, with SMEs accounting for less than 20% implementing robust cybersecurity frameworks (Khan, 2024). Failure to fill these gaps exposes manufacturers to risks of data breaches, disruptions in production, and diminished competitiveness (Narashimman et al., 2024). Additionally, although AI has the potential to enhance productivity, it presents ethical and sociological issues. Automation may displace workers, especially in low-skill sectors (Rockett et al., 2025). In the absence of active policy initiatives such as reskilling, fostering entrepreneurship, and safety nets, there is potential to deepen income disparity and exacerbate the digital divide (Wiener, 1994).

Hence, the course of adopting AI in Bangladesh's manufacturing industry is quite complex. It requires a technological investment as well as policy alignment, ecosystem nurturing, cooperation between industry and academia, and a robust human capital impetus focus (M & Chattu, 2021) . Effective pilot projects have the potential to transform Bangladesh's specific AI application challenges in its manufacturing endeavors (Ahmed, 2023). The main goal of the work is to study the degree of AI application in the Bangladeshi manufacturing industry, assess industry-level AI applications and obstacles, and formulate management strategies for wider application (Laszkiewicz & Kalinska-Kula, 2023). The paper aims at how AI technologies can be utilized as a tool for industrial transformation, strengthening global competitive power, and achieving the objectives of Smart Bangladesh by gathering world practices, experiences of the first local initiatives, and stakeholders' voices (Güven, 2020).

2. Materials and Methods

The present study was based on a mixed methodology that combined primary qualitative data with statistical and thematic analysis to explore the state of readiness and the levels of adoption and potential of artificial intelligence (AI) technologies in the manufacturing sector of Bangladesh. The methodology was

organized into three interrelated areas: data gathering, data and statistical treatment, and data ethics.

2.1 Data Collection

2.1.1 Secondary Data

A systematic literature review was performed through academic platforms like Scopus, IEEE Xplore, ScienceDirect, and Google Scholar to determine global best practices and implementations of AI in manufacturing. The review concentrated on AI-driven services such as predictive maintenance, robotic process automation, quality inspections, and intelligent supply chaining. Also, other secondary data sources such as reports and policy documents from the Bureau of Statistics of Bangladesh, the Bangladesh Association of Software and Information Services (BASIS), the Ministry of Industries, World Bank, and the United Nations Industrial Development Organization (UNIDO) were studied to assess the situational context of digital readiness in manufacturing in Bangladesh.

2.1.2 Primary Data

Primary data was gathered from ten semi-structured interviews with industry stakeholders such as plant managers, IT experts, AI solution providers, and academic specialists from the garments, leather, jute, and SME manufacturing industries. These interviews focused on current applications of AI, its perceived advantages, impediments to implementation, workforce skills, and priorities for AI integration into business strategies. This combination of sources enhanced the validity and contextual depth of the study.

2.2 Statistical Analysis

The qualitative data from the interviews was coded thematically with the use of several software tools. Implementation challenges, organizational preparedness, policy implications, and adoption motivators were some of the major themes. The qualitative data was also grouped according to industry category, business unit size (large versus SME), and domain of AI applications (computer vision, robotics, machine learning models). Descriptive statistics, including frequency and percentage counts, were applied to evaluate trends in AI adoption, compare sector indicators of readiness, and identify sector imbalances. In order to aid intuitive interpretation and recognize patterns consistent with the secondary data, findings were presented visually using comparative charts and tables.

2.3 Ethical Considerations

The study complied with internal ethical guidelines framed by relevant bodies. All interview participants were informed about the study goals and were voluntary participants after giving informed consent. Participants were guaranteed anonymity along with the confidentiality of the data collected while informing them they had the right to withdraw at any point without any consequences. The interview data is anonymized and kept in a locked filing cabinet or password protected until it is required for analysis. Data quoted from other sources do not contain any identifiable names of the individuals or organizations concerned, therefore masking any revealing identifiers. Since the research did not include personal identifiable information, nor did it conduct any physiological intervention on people, formal approval from an institutional ethics committee was not necessary; nonetheless, overarching principles of social research ethics were respected at all times.

3. Results

3.1 AI Implementation by Sector and Firm Size

This research assesses the use of Artificial Intelligence (AI) in the manufacturing industry of Bangladesh which includes garments, leather, jute, pharmaceuticals as well as ceramics. Large enterprises (LEs) have led AI adoption while small and medium sized enterprises (SMEs) face significant challenges as illustrated in **Table 1**. In the garment AI value chain, LEs dominate the value chain with an 18% adoption rate while SMEs lag behind with a 3% adoption rate which is driven by machine vision and Robotic Process Automation (RPA). However, SME adoption is hindered by high costs and lack of digital readiness. For leather, LEs have a 12% adoption rate using AI grading systems, but SMEs only reach 2%. Calibration complexity and a shortage of skilled workers stall adoption for these SMEs. In jute, AI adoption is very low and stands at 8% for LEs and 1% for SMEs and mainly use predictive maintenance. There is also a lack of AI investment due to aging machinery and declining demand for the sector. In the pharmaceutical sector, both large enterprises (LEs) and small and medium-sized enterprises (SMEs) rely on AI, with a 15% adoption rate for LEs using AI-labeled machine learning to predict demand. SMEs, however, grapple with data quality and regulatory constraints, stunting their growth to a mere 2%. The same applies to the low-rated AI adoption in the ceramics industry where LEs are at 10% while SMEs linger below 1%, a figure attributed to the persistent lack of skilled workers.

3.2 AI Applications and Effects Categorized by Sector

The table captures the various uses of Artificial Intelligence (AI) in Bangladesh's manufacturing industries, detailing the outcomes achieved, the stage of adoption, and noteworthy contextual information against the backdrop of AI's adoption in each sector. In the Garments (RMG) sector, the implementation of AI for defect detection is becoming widespread among large enterprises (LEs) where it's achieving a 30% reduction in production rejection rates, thus improving quality control, a key factor for sustaining competitive advantage in the global market **Figure 1.** In the leather sector, some firms are still in the testing phase of AI-powered grading of raw materials which has shown potential for a 25% reduction in waste, although adoption is still in pilot stages along with issues such as difficulty calibrating equipment and inconsistency in raw materials. In the jute sector, predictive

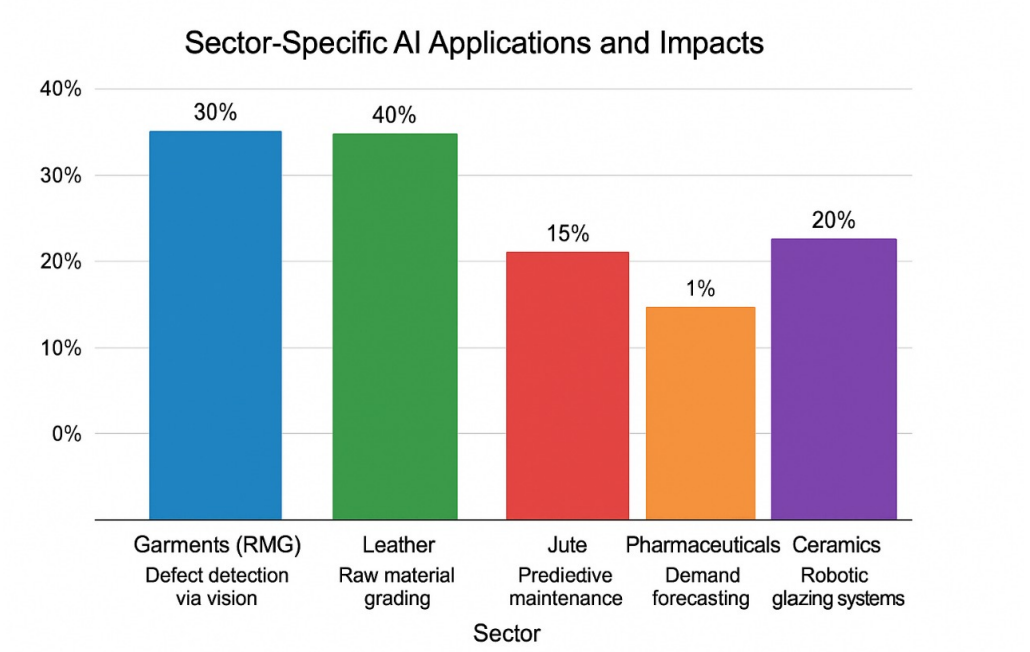

Figure 1. Artificial Intelligence Adoption and Sectoral Impacts in Bangladesh's Manufacturing Industry

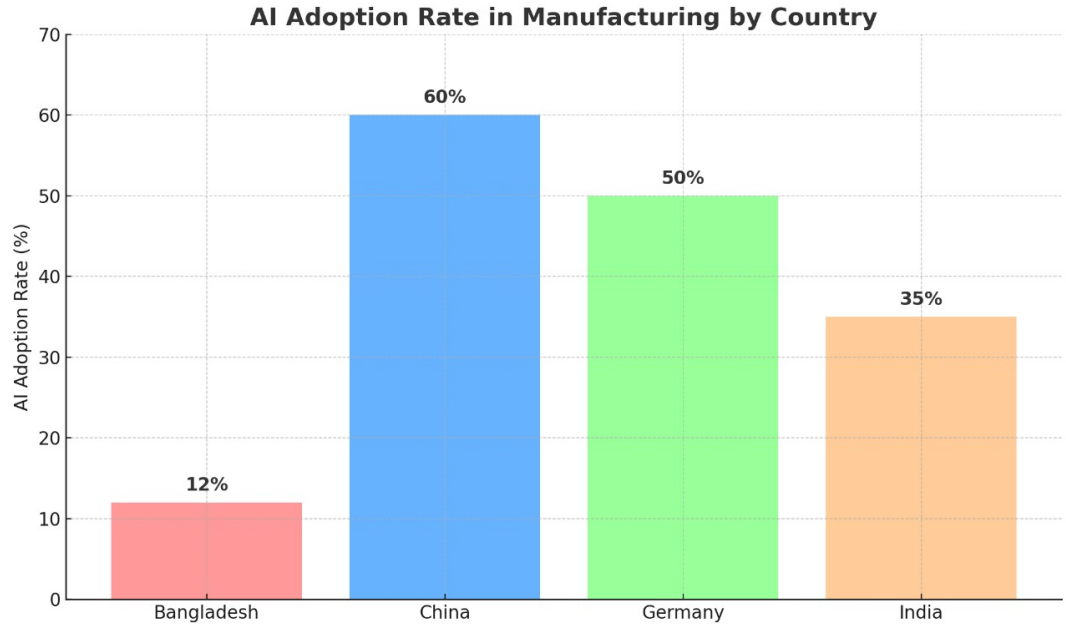

Figure 2. Comparative Analysis with Global Trend

Table 1. AI Adoption Rates by Sector and Enterprise Size

Sector	LE Adoption Rate	SME Adoption Rate	Key AI Tools	Challenges for SMEs
Garments	18%	3%	Machine vision, RPA	High cost, low digital readiness
Leather	12%	2%	AI grading systems	Calibration complexity, skilled labor gaps
Jute	8%	1%	Predictive maintenance	Aging machinery, tech adoption gaps
Pharmaceuticals	15%	2%	ML demand forecasting	Data quality, integration issues
Ceramics	10%	<1%	Robotic process automation	Skilled workforce shortages

maintenance systems are aiding in reducing machine downtime by 40%, though they are in the early stage of adoption. However, slow funding and the aging machinery still restrict broader acceptance. In the pharmaceutical sector, machine learning is applied for demand forecasting, which reduces inventory expenditures by 15%. Its efficacy, however, heavily depends on the precision of the data and compliance with the laws. In the ceramics industry, robotic glazing is used in specialized production processes, resulting in a 20% increase in output. Adoption beyond those boundaries is hampered by a lack of skilled workers coupled with the expensive automated technology.

3.3 Issues with AI in the Industry

This figure illustrates the most significant gaps identified by Small and Medium Enterprises (SMEs) and Large Enterprises (LEs) regarding the adoption of Artificial Intelligence (AI) in the context of Bangladesh's manufacturing industry **Table 2**. The data shows the lack of adequate funding as the primary concern for the majority of SMEs (85%) in comparison to LEs (35%).A high concern AI risk is the unavailability of skilled workers with relevant expertise for 72% of SMEs and 28% of LEs, indicating severe skill shortage in AI functionalities. Cybersecurity remains another high concern with 65% SMEs and 45% LEs worrying about data safety within AI systems. Almost 60% of SMEs reported lack of policies as a concern compared to only 20% of LEs, which is detrimental for non-export-oriented sectors such as ceramics industries. These results show how much more focused building towards the gaps in financing along with policy framework needs to be addressed to enable equitable AI integration.

3.5 Comparison with International Developments

The graph presented below examines AI adoption, expenditure on AI research and development, as well as other developments pertaining to artificial intelligence in Bangladesh, China, Germany, and India and the resulting impact on AI in Bangladesh **Figure 2.** Compared to others, the 12% AI adoption rate and 0.2% of GDP spending on R&D makes Bangladesh quite low. While leading the charge, China piles on state spending into AI parks and IoT, translating into 60% AI adoption and a whopping 2.4% R&D investment. Following Germany showcases 50% adoption and 3.1% spending as they focus on Song Industry 4.0 followed by full AI integration. India holds 35% adoption and 0.8% with the emergence of a growing AI ecosystem backed with joint venture initiatives from the government and private sector. These nations offer profound insights for Bangladesh as they seek to improve AI implementation by providing better infrastructure, making targeted investments, and forming collaborations.

4. Discussion

The results of this research highlight a complex reality of the adoption of AI into the manufacturing industry in Bangladesh, which despite having abundant opportunities is intricately linked to the country's challenges (Anyatsia, 2023). The discussion analyzes these factors in the economic, technological, sociopolitical, and policy frameworks, offering the gaps in the prevailing adoption frameworks and the solutions towards a more balanced and actionable AI ecosystem (Rahman et al., 2024).

4.1 Disparities in Technological Integration: LEs vs. SMEs

A common thread throughout the findings is the pronounced gap between large enterprises (LEs) and small to medium enterprises (SMEs) as far as the adoption of AI technologies is concerned (Ahmed, 2023). Due to their greater financial and skill resources, LEs have now started to integrate AI into foundational processes like quality monitoring and predictive maintenance, as well as demand forecasting (Kulaksız, 2024). These changes result in quantifiable benefits like a 30% decrease in garment production rejections and a 15% decline in inventory spending for the pharmaceutical sector. In stark contrast, SMEs remain at the margins of this transformation, constrained by digital infrastructure gaps, lacking funds, and workforce shortages (Rahman et al., 2024). More than 85% of SMEs cite cost as a major obstacle, while 72% report a lack of relevant AI skills (Güven, 2020). This not only creates a challenge to the competitiveness of smaller firms, but also works against national economic objectives under the Smart Bangladesh Vision 2041 by undermining holistic technological development (Rahman et al., 2025).

4.2 Specific Realities and Constraints

The regional breakdown reinforces the belief that there is no universally applicable strategy for AI implementation. For example, the jute sector stands to gain the most from predictive maintenance, yet the presence of outdated machinery prevents it from being more scalable, along with a lack of investment towards modernization (Rahman et al., 2024). The same can be said for the leather industry which also faces a proposal with great potential AI-graded raw materials based on raw material grading which suffers from excessive technical difficulty and the inconsistency of the materials. The rationale for more sector-sensitive strategies has already been provided (Rahman et al., 2025). For example, in the technologically delayed yet high-potential industries like jute and ceramics, offered government assistance in the form of modernization grants, tax breaks, and public-private research partnerships could spur adoption. In the absence of such support, the integration of AI is likely to be confined to industries with an export focus and pre-existing digital infrastructure (Mohamed, 2024).

4.3 Global Benchmarks and the Path to Competitiveness

From a comparative perspective, Bangladesh lags significantly behind other countries as seen from the statistics on AI adoption compared to other nations Bangladesh's AI adoption rate and R&D investment as a proportion of GDP are at 12% and 0.2% respectively, while China and Germany are at 60% and 2.4%, and

Table 2. Challenges to AI Integration

Challenge	SMEs (%)	LEs (%)	Severity	Additional Notes
High implementation cost	85	35	Critical	SMEs are disproportionately affected by costs due to smaller budgets, leading to slow adoption
Lack of skilled staff	72	28	High	There is a significant skill gap in both technical and managerial roles related to AI
Cybersecurity concerns	65	45	High	Increased risk of data breaches due to AI integration, especially in unprepared systems
Policy support gaps	60	20	Moderate	Absence of specific policies for non-export sectors like ceramics, leading to disparity in support

50% and 3.1% respectively. These countries successfully advanced through the adoption of a cohesive national strategy that included the establishment of AI parks, dedicated funding channels, and the integration of academia into the industry through innovation ecosystems colloquially referred to as 'A-B-I' (Babu et al., 2022). India, on the other hand, demonstrates through a 35% adoption rate how a rapidly developing nation can through the use of public-private partnerships, innovation hubs at the state level, and focused workforce training (de Amorim, 2024). Bangladesh might benefit by trying to leap over its existing barriers using modified models made for its own socio-economic context. However, this progress needs to be founded on improvement, especially towards infrastructure, an educational overhaul, and regulatory alignment (Shobhana, 2024).

4.4 The Critical Importance of Developing the Workforce

In terms of AI readiness, having human capital is extremely vital. The skill gap Bangladesh faces, particularly with SMEs, poses a significant challenge. The application of AI requires a high level of competency not only in technical fields like machine learning, data analytics, and software engineering, but also in management to ensure proper alignment with the business goals (Chakrabarti & Singh, 2023). To resolve this, change policies should inject AI robotics and data science into the programs of polytechnic and vocational training institutes. Strategic collaboration through co-designing course content and teacher-student placement programs between industry and academia is very important. These actions can help create a new generation of graduates ready to promote industry modernization through AI who are armed with the skills to propel the change (Marku, 2023).

4.5 Cybersecurity and Policy Fragmentation

With sensitive data and critical processes being managed by AI systems, cybersecurity is of concern (Kaya, 2024). As 65% of SMEs inadequately defend themselves against cyberattacks, the potential for data loss, breaches, or disruptions is large. In an environment with weak regulatory protections, this may keep many firms from adopting AI technologies (Çobanogullari, 2024). There is an immediate need for a comprehensive cybersecurity policy cohesive to the principles of AI data governance. Arguably, broadening the provisions of the Digital Security Act of Bangladesh and initiating national advocacy campaigns would illuminate security protocols and bolster trust among SMEs. Moreover, fragmentation of policies across various sectors has resulted in imbalanced access to incentives. Unlike the export oriented garments sector which enjoys tailored policies, neglected areas such as policy-ignored ceramics and jute industries suffer. An AI strategy must be warned not be focused isolatedly obsessed with one sector, directing all resources and incentives to chosen few sectors but instead blend all key sectors to achieve balanced growth to foster gapless inclusive growth (Katsimerou et al., 2016).

5. Conclusion

The application of Artificial Intelligence bears revolutionary possibilities for the manufacturing sector of Bangladesh by improving productivity, quality, and international competitiveness. Notable challenges include the digital divide as large enterprises and SMEs exhibit differences in adoption, the lack of infrastructure, and the skills gap among the workforce. Equitable integration of AI requires targeted policies, comprehensive inclusive workforce strategies, and strong cybersecurity measures for developmental sustainability. Strategies for sector-specific rural development also require immediate attention to prevent inequality in advancement opportunities. AI can propel Bangladesh towards its Smart 2041 vision synchronously with the coordinated efforts of the government, industries, and educational institutions.

Author contributions

A.R. was responsible for the conceptualization, methodology, investigation, data analysis, and writing of the original draft. A.R. also reviewed and edited the manuscript and approved the final version for submission.

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Competing financial interests

The authors have no conflict of interest.

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