Blockchain for Transparency: Tracking Zero-Waste Practices Across the Fashion Value Chain in Bangladesh

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ABSTRACT

The country's ready-made garment (RMG) industry is facing tremendous pressure for sustainable practices owing to rising environmental concerns and expectations from global buyers. The present study tries to see the possibility of blockchain technology in enhancing transparency, traceability and zero-waste practices throughout the clothing value chain of Bangladesh. The study uses mixed methods to examine the state of awareness, barriers to adoption, enablers and integration with the 5.0 technologies using a survey of 300 professionals from the sector and 22 interviews. The results suggest moderate levels of adoption, with large firms adopting the measure while SMEs face financial, technical and organizational constraints. The adoption of Blockchain enhances visibility of material flows along with operational efficiency, sustainability reporting, and its integration with Industry 5.0. The main enablers are sustainability requirements driven by buyers, operational benefits as well as technological partnerships. The main barriers are high costs, skill deficits, and resistance to change. This research adds to the theory of blockchain for sustainable supply chain management in an emerging economy and provides implementation recommendations for practitioners, policymakers, and international buyers. Bangladeshi RMG firms can achieve zero waste production, operational transparency, and global competitiveness through the adoption of blockchain and Industry 5.0 integration.

Keywords: Blockchain Technology, Fashion Supply Chain, Transparency and Traceability, Zero-Waste Practices, Sustainability

INTRODUCTION

The Ready-Made Garment (RMG) sector, which accounts for more than 80 per cent of total export earnings, is the backbone of Bangladesh's economy. It also employs millions of workers (Miraz, Sharif, & Hassan, 2018; Textile giant Bangladesh pushed to recycle more waste, 2025) The sector, although economically important, is facing increasing pressure to adopt greener practices. This is due to the increasing environmental concerns, global awareness by the consumers and regulatory frameworks (Al Amin & Rahman, 2025; Khan & Rahman, 2023). One of these issues is textile waste: waste that is generated at various stages of production and distribution and ultimately in coming back to its life cycle after consumer use (Yadav & Singh, 2020; Investigating the impact of sustainable SCM, 2024). It is essential to minimize this waste while maintaining supply chain efficiency to ensure we stay in line with the circular economy as well as the Sustainable Development Goals (SDGs) (Saberi, Kouhizadeh, & Sarkis, 2019; Lin & Chen, 2021).

The decentralized, immutable, and real-time traceable nature of blockchain technology can enable organizations to overcome the supply chain challenges (Badhwar, Islam, & Tan, 2023; Chowdhury, 2018). In the fashion and textiles industry, blockchain allows transparent and open visibility of the entire supply chain. It allows all

stakeholders right from raw material suppliers up to final consumers to track the product and its waste stream (Agrawal & Pal, 2019; Tan et al., 2022). Studies show that Blockchain technology adoption within supply chains has the potential to improve operational efficiencies, reduce fraud and improve sustainability by verifying documentation of environmentally friendly practices (Devising a Mechanism, 2022; Sarker & Uddin, 2024). In order to enhance competitive advantage and achieve compliance with global standards of sustainability, integrating blockchain into Bangladesh where the RMG industry is a major player based on global supply, would be beneficial (The Role of Supply Chain Transparency, 2025; Hussain & Karim, 2022).

Fashion industry as a whole in Bangladesh has not widely adopted blockchain. Senior-level export-oriented companies are doing pilots with blockchain technology to trace their production, materials, and waste management practices (Digital Transformation in Bangladesh's RMG Supply Chains, 2025; Implementing Blockchain Technology, 2024). Nonetheless, SMEs face obstacles with high costs for implementation, lack of technical know-how, regulatory ambiguity and resistance to change (Devising a Mechanism, 2022; Supply Chain Management for Garments Industries, 2018). Studying these adoption aspects will certainly help us in formulating scalable and effective blockchain integration strategies to encourage zero-waste practices throughout the fashion value chain (Investigating the technological impact, 2025; Ahmed & Hossain, 2024).

Also, the implementation of blockchain with Industry 5.0 principles will enhance sustainability because Industry 5.0 seeks to establish the role of humans, together with AI and machine learning, in optimization for cyber-physical systems and data-based decisions (Radanliev et al., 2020; Blockchain Technology and Industry 5.0, 2024). RMG companies can enhance the use of resources, forecast demand for materials, and reduce production waste by combining blockchain with IoT, AI and predictive analytics (Tao & Qi, 2019; Venkatesh et al., 2020). This approach is in line with the international trends as several fashion brands are embedding digital technologies to achieve (Park et al., 2020; Yang & Li, 2021) transparency, traceability, and ethical compliance while staying competitive.

The study addresses the following objectives.

1) To explore the potential applications of blockchain in tracking material flows and waste management in the Bangladeshi fashion industry.
2) To examine the barriers and enablers influencing blockchain adoption among RMG firms, with particular attention to SMEs.
3) To evaluate how the union of blockchain with Industry 5.0 technologies can enable sustainable circular human-centred manufacturing.

The current study has been conducted with the specific objectives as mentioned below. Together, there will be potential contributions to academic knowledge on sustainable fashion supply chains and implications for practitioners and policy makers interested in promoting green manufacturing in developing countries (Li & Wang, 2020; Shah & Ahmed, 2021). The study sees blockchain not only as a technological advancement but also as a strategic enabler for adopting the circular economy in Bangladesh's RMG sector, operational transparency, and zero-waste production (Xu et al., 2019; Zhao et al., 2020). All in all, the introductory part notes that the RMG industry of Bangladesh needs sustainability measures on an urgent basis. It also mentions that blockchain is a solution for zero-waste management. Moreover, it scopes this study in the technological and sustainability frame.

THEMATIC LITERATURE REVIEW

1. Blockchain Technology and Supply Chain Transparency

Blockchain technology is a distributed, secure, and immutable ledger that can empower supply chain stakeholders to maintain verifiable records of production, logistics, and material consumption (Badhwar, Islam, & Tan, 2023; Agrawal & Pal, 2019). According to studies of fashion supply chains, blockchain ensures that there is transparency along the end-to-end supply chain. Moreover, it allows firms to track their raw materials and production batches as well as finished products in real-time (Tan et al., 2022; Park et al., 2020). Transparency is fundamental to checking sustainability claims, tracking supplier behavior, and giving customers truthful product

information (The Role of Supply Chain Transparency, 2025, Yazıcılar Sola, Güzel, 2025). In Bangladesh, export-oriented RMG enterprises have tested the capability of blockchain technology, proving it helps reduce information asymmetry, improves accuracy of reporting, and instills greater trust among international buyers. (Digital Transformation in Bangladesh's RMG Supply Chains, 2025, Hussain & Karim, 2022) Nevertheless, limited adoption is due to high set up costs, lacking technical expertise and fragmented supply chains especially for SMEs (Devising a Mechanism, 2022; and Miraz, Sharif, & Hassan, 2018). This indicates that the government, technology suppliers, and gradual adoption are possible solutions to these barriers (Ahmed & Hossain 2024; Supply Chain Management for Garments Industries 2018).

Table 1. Summary of Key Literature on Blockchain Adoption in the Textile and Fashion Industry

Author(s)	Year	Focus Area	Key Findings
Badhwar et al.	2023	Blockchain transparency	Systematic review confirming traceability as central to sustainability
Saberi et al.	2019	Sustainable SCM	Blockchain enables trust and accountability in supply networks
Khan & Rahman	2023	Zero-waste fashion	Digital tools optimize fabric utilization
Li & Chen	2021	Textile circularity	Blockchain supports closed-loop recycling systems
Islam & Hossain	2023	Bangladesh RMG	Blockchain adoption remains low due to cost and skill barriers

As summarized in *Table 1*, prior studies reveal that blockchain applications in the textile and fashion sectors primarily emphasize traceability, supplier visibility, and waste minimization (see Table 1; Badhwar et al., 2023; Saberi et al., 2019).

2. Zero-Waste Practices

Zero-waste clothing design seeks to eliminate as much waste as possible during the cutting and production phases (Yadav & Singh, 2020; Investigating the impact of sustainable SCM, 2024). According to Li & Wang (2020) and Pournader et al (2020), blockchain can track the flow of material through every step of the production. Defective products and fabric offcuts may be recorded on the ledger of the blockchain, which will enable firms to trace the recycling and repurposing of products (Saberi, Kouhizadeh, & Sarkis, 2019; Shah & Ahmed, 2021). Research shows that with the help of IoT sensors, blockchain can improve material traceability and minimize post-production waste (Lin & Chen, 2021; Zhao et al., 2020). Using real-time waste generation allows companies to modify cut patterns and optimize batch sizes while also applying the circular economy strategy to lower impact (Xu et al, 2019, Tan et al, 2022). In Bangladesh, many RMG companies have started pilot projects to log their production waste on blockchain platforms to make it visible to the buyers and help them standardize their operations as per international sustainability protocols (Digital Transformation in Bangladesh's RMG Supply Chains, 2025; Investigating the Technological Impact, 2025). However, obstacles still remain due to restricted digital literacy and reluctance to automation by small manufacturers. (Ahmed & Hossain 2024, Devising a Mechanism 2022)

3. Industry 5.0 Principles

Industry 5.0 emphasizes human-centric, sustainable, and resilient manufacturing, complementing the digital capabilities of blockchain (Radanliev et al., 2020; Blockchain Technology and Industry 5.0, 2024). By integrating blockchain with IoT, AI, and predictive analytics, firms can achieve proactive waste management, optimize resource allocation, and ensure sustainable supply chain operations (Tao & Qi, 2019; Venkatesh et al., 2020).Research highlights that blockchain-enabled Industry 5.0 systems allow dynamic inventory management, real-time waste reduction, and enhanced product traceability, fostering transparency for regulators and end consumers (Park et al., 2020; Yang & Li, 2021). In Bangladesh, integrating blockchain with smart manufacturing

systems could support circular economy adoption, enhance compliance with global standards, and increase competitiveness (Soni & Ramesh, 2021; Hussain & Karim, 2022).

4. Barriers and Facilitators of Blockchain Adoption

Although blockchain has several potential uses, its adoption is hindered by technological, organizational, and regulatory barriers (Devising a Mechanism, 2022; Supply Chain Management for Garments Industries, 2018). One of the major challenges in Bangladesh is the high cost of implementation and fragmented supply chains (Ahmed & Hossain, 2024). Moreover, there is a lack of skilled personnel (Miraz, Sharif, & Hassan, 2018). Moreover, as a result of inadequate infrastructure (Implementing Blockchain Technology, 2024; Niloy, 2024), resistance to change is more likely in SMEs. Several study suggest (Sarker & Uddin, 2024; Al Amin & Rahman, 2025) identify the challenges of policy interventions, financial incentivize and training. Working with technology providers, international buyers and NGOs has also been found to be effective for adoption (The Role of Supply Chain Transparency, 2025; Hussain & Karim, 2022). Buyer-driven compliance requirements, rising consumer demand for transparency, and evidence of operational efficiency gains are some of the facilitators (Tan et al. 2022; Sola & Güzel 2025). Pilot implementations of blockchain technology have reduced the material losses, improved stakeholder trust and enhanced sustainability reporting (Digital Transformation in Bangladesh's RMG Supply Chains, 2025; Investigating the Technological Impact, 2025), as case studies indicate. In addition, integrating blockchain with Industry 5.0 technologies offers a scalable way to embed zero-waste practices into everyday workings (Radanliev et al, 2020; Blockchain Technology and Industry 5.0, 2024). Use of data-driven insights enables firms to optimise production, reduce energy consumption, and be more compliant with environmental standards (Park et al., 2020; Lin & Chen, 2021).Thematic review indicates Bangladesh's Readymade Garment sector can enhance transparency and traceability of products and ensure zero-waste willingness through blockchain application and Industry 5.0. I see barriers to adoption, especially for SMEs, requiring policy, and training, and tech assistance. The literature indicates that the blockchain and principles of circular economy can be successfully combined for sustainability to help manufacture eco-friendly products in developing economies (Xu et al., 2019; Zhao et al., 2020; Ahmed & Hossain, 2024).

Table 2. Summary of Thematic Clusters in Literature Review

Theme	Representative Studies	Summary of Findings
Blockchain and Traceability	Park et al. (2020); Badhwar et al. (2023)	Enhances supplier visibility and data security
Zero-Waste Fashion Systems	Shah & Ahmed (2021); Khan & Rahman (2023)	Encourages recycling and digital waste mapping
Circular Supply Chain Integration	Lin & Chen (2021); Tan & Li (2021)	Blockchain integrates with circular economy principles
Adoption Barriers	Devising a Mechanism (2022); Ahmed & Hossain (2024)	Cost, policy gaps, and lack of digital literacy
Bangladesh Context	Miraz et al. (2018); Niloy (2024)	Potential but fragmented implementation of blockchain

Thematic clusters identified during the literature synthesis are presented in *Table 2*, which highlights five dominant research streams: blockchain traceability, zero-waste systems, circular integration, adoption barriers, and the Bangladesh context (Table 2; Lin & Chen, 2021; Niloy, 2024)

RESEARCH GAP

As blockchain technology is gaining popularity for use in supply chains, a literature review shows a number of critical gaps in the context of Bangladesh's fashion and RMG industry. To begin with, many blockchain studies claim that it can enhance transparency and traceability. However, not very few empirical studies conducted zero

waste practices in the Bangladeshi RMG sector. Ahmed and Hossain (2024) and Digital Transformation in Bangladesh's RMG Supply Chains (2025) may prove to be exceptions in this regard. Most of the research work so far is conceptual or based on international case studies. Thus, these studies do not reflect the operational, regulatory and socio-economic conditions of Bangladesh (Miraz, Sharif and Hassan, 2018; Supply Chain Management for Garments Industries, 2018).

In addition to supply chain buying and selling efficiency and transparency, as well as enhanced product authenticity, there is little research that examines how blockchain may be integrated with zero-waste or circular economy strategies in the context of developing countries (Yadav in addition to Singh, 2020; Xu et al, 2019). There is a major gap in our knowledge on this matter. This is particularly true as Bangladesh is one of the biggest apparel exporters in the world and faces major environmental pressures from textile waste and resource-hungry production (Investigating the impact of sustainable SCM, 2024; Shah & Ahmed, 2021).

The application of Industry 5.0 technologies—human-centric automation, IoT, and predictive analytics—for blockchain-driven sustainability has also not yet received much attention. Most of the research investigates technologies to be adopted in isolation. There are not many studies that analyze how human-machine collaboration and data-driven decision-making can improve zero waste practices (Radanliev et al, 2020; Blockchain Technology and Industry 5.0, 2024).

SMEs adoption in a developing country like Bangladesh is troubled with financial, technical and organiational barriers. However, these barriers are yet explored to test the effect on practical blockchain adoption on zero-waste tracking (Devising a Mechanism, 2022; Ahmed & Hossain, 2024).

Finally, it is noted that sustainability expectations are being shaped by consumers and buyers. However, in Bangladesh, there is little evidence on the role of Stakeholder trust, Regulatory facilitation, and Transparency requirement, in the Blockchain adoption for sustainability (Sola & Güzel, 2025; Hussain & Karim, 2022).

This study addresses the following research gaps.

1. Empirical investigation of blockchain-enabled zero-waste practices in Bangladesh's fashion value chain.
2. Combining blockchain technology with Industry 5.0 technologies to increase sustainability results.
3. Identification of barriers and facilitators for blockchain adoption among SMEs and large RMG firms.
4. Assessment of stakeholder trust, regulatory influence, and buyer requirements in driving adoption.

METHODOLOGY

1. Research Design

The combination of qualitative and quantitative methods has been adopted in this research study to examine blockchain adoption for zero-waste practices in the fashion industry in Bangladesh. For this study, mixed-methods research is appropriate because it allows for triangulation. In other words, it captures what is happening on the ground in the industry as well as measurable patterns of adoption. (Cohen, Manion, & Morrison, 2018; Braun & Clarke, 2021).

The exploratory and empirical research aims to find out the technological, organizational, regulatory blocks that could affect the implementation of blockchain and its effectiveness in tracking zero waste. The research analyzes how Industry 5.0 integration boosts sustainability and transparency outcomes of the supply chain.

2. Population and Sampling

The target population consists of RMG firms of Bangladesh including large export oriented enterprises and SMEs. Using the Bangladesh Garment Manufacturer and Exporter Association (BGMEA) data, there are almost five thousand registered firms in the country. Those who have first-hand experience or decision-making power in supply chain management, sustainability, or digital technology adoption will be selected as participants using a purposive sampling technique. Firms were selected to ensure diversity across.

- The size of a company.
- Location (Dhaka, Chittagong, Gazipur).
- Various types of products: woven, knits, denim.

For our quantitative survey, we targeted a sample size of 300 supply chain managers, sustainability officers, and IT managers. The sample size is adequate for structural equation modeling and regression analysis as per Hair et al. (2019).

The qualitative phase involves conducting about 20–25 in-depth interviews with key stakeholders, such as executives, supply chain managers and technology providers. This sample will allow to achieve saturation in data and get clear insights on the barriers, facilitators, and operational issues faced due to the adoption.

3. Data Collection Methods

3.1 Quantitative Survey

A structured questionnaire was designed to measure.

1. Understanding and seeing benefits of blockchain technology for transparency, traceability, zero waste monitoring.
2. Adoption barriers (financial, technical, regulatory, organizational).
3. Collaboration with Industry 5.0 tools such as IoT, AI and predictive analytics.
4. Stakeholder pressure (buyer requirements, consumer expectations, regulatory mandates).

The items were assessed using a five-point Likert scale rated from 1 (“strongly disagree”) to 5 (“strongly agree”). Fifteen industry professionals were pre-tested to ascertain clarity, relevance and reliability of the survey**.**

3.2 Qualitative Interviews

Semi-structured interviews were conducted to study the participants’ experience, challenges, and best practices behind the blockchain adoption for zero-waste practices. Questions covered-

- Understanding and knowledge of blockchain and Industry 5.0 Applications.
- Conditions Facilitating Adoption and Implementation
- How sustainable and efficient do you think it is?
- The buyer’s expectations, regulatory pressures, and collaboration across the industry.

Interviews took place either in person or via Zoom for 45–60 minutes each and were recorded with permission from the participants.

4. Data Analysis

4.1 Quantitative Analysis

Survey responses were analyzed using SPSS.

- Statistics summarizes age, sex, education, awareness and benefit estimation.
- The researcher verified reliability and validity with the Cronbach’s alpha (>0.7) and confirmatory factor analysis (CFA).
- A structural equation modeling methodology to study the relationships between independent variables (barriers, Industry 5.0 integration, stakeholder pressure)and dependent variable (blockchain adoption for zero-waste practices.)
- Regression analysis identified which predictors mattered most to adoption levels.

4.2 Qualitative Analysis

Thematic analysis was applied to the interview transcripts (Braun & Clarke, 2021). The process included.

1. Familiarization with the data.
2. Initial coding of text segments.
3. Identification of themes and sub-themes (for example, technological barriers, operational enablers, and regulation).
4. Integration of findings with quantitative results to provide a triangulated understanding.

We managed and coded qualitative data using NVivo software.

5. Ethical Considerations

Participants were.

- Updated on the aims of the study.
- You can trust that it will be kept private and secret.
- Individuals were given the right to withdraw their consent at any stage.

The interview was recorded to maintain data integrity by using safe digital procedures. Further, once the interview was transcribed, the recording was deleted.

6. Validity and Reliability

1. The survey instrument adopted had 60 references from the existing literature which ensured construct validity.
2. All scales were verified using Cronbach's alpha to show internal consistency.
3. The usage of more than one method of data collection for the study enhanced credibility and reduced bias (Cohen, Manion, & Morrison, 2018).

7. Limitations of Methodology

- The findings might not apply to sectors beyond Bangladesh’s RMG sector.
- Responses from a survey that require self-reporting could cause social desirability bias.
- Advances in technology can cause delay in the findings.

5.Findings and Discussion.

The chapter presents the findings of the study that was conducted using the mentioned instruments in the methodology chapter. It integrates the survey from 300 respondents and qualitative data from 22 in-depth interviews. The analysis focuses on-

1. Current awareness and adoption of blockchain for zero-waste practices.
2. Adoption barriers and enablers, including firm size, technological capability, and stakeholder pressure.
3. Use of Industry 5.0 tech in supply chain operations
4. Perceived impact on operational efficiency, sustainability, and supply chain transparency.

The context of the findings will be elaborated relative to blockchain adoption, zero-waste fashion and digital transformation in emerging countries.

Bangladesh's RMG Sector's Awareness and Adoption of Blockchain.The report revealed that only 42% of respondents are aware of examples of blockchain in fashion supply chains while just 21% reported partial adoption for material tracking or sustainability (Table 1) Fifty-five percent of large export-oriented firms were aware of and adopted the technologies. This figure is higher than that of SMEs at eighteen percent. This confirms that large firms are more technologically ready than SMEs (Ahmed and Hossain, 2024; Devising a Mechanism, 2022).

Benefits that respondents perceived from applying blockchain-

- Improved tracking and transparency (Mean = 4.21, SD = 0.63).
- Improved waste tracking and zero-waste compliance (Mean = 4.05, SD = 0.71).
- Strengthened buyer trust and increased compliance with sustainability standards (Mean = 4.17, SD = 0.68).

The results of the study were similar to other studies that have been done internationally indicating how blockchain can be used as a tool to achieve transparency in supply chain and sustainable operations (Badhwar, Islam and Tan, 2023; Park et al., 2020; Li and Wang, 2020). Interviews reinforced these findings. A senior supply chain manager in Dhaka stated. Blockchain technology helps us keep track of the production waste and each batch of fabric. Shoppers are now looking for evidence of sustainability and this technology helps us do that. Nevertheless, SME respondents showed a lack of awareness and technical know-how, preferring to use manual means of tracking rather than tracking digitally (Sarker & Uddin, 2024; Implementing Blockchain Technology, 2024).

Barriers to Blockchain Adoption

According to the regression analysis, financial constraints, skills scarcity, and organizational inertia were significant barriers to adoption (β = -0.42, -0.36, -0.31, respectively, $p < 0.01$). SMEs faced difficulty around the world because of limited capital and low infrastructure. Cited as a moderate barrier was regulatory uncertainty $\beta=-0.21$, $p<0.05$. These findings align with global studies on blockchain adoption, which suggests that cost, complexity, and fragmented supply chains are limitations to widespread implementation (Devising a Mechanism, 2022; Queiroz et al., 2019).

Interviewees emphasized three primary barriers-

1. Small businesses cannot afford the high implementation costs of blockchain platforms which use IoT or predictive analytics.
2. The limited training and staff knowledge about blockchain leads to a skills gap.
3. Traditional management practices and perceived complexity make resistance to change difficult.

A technology officer explained. The reason SMEs are hesitant is because they think Blockchain is hard and expensive. Adoption will remain limited when unsupported. This shows that there were previous researches which shows the necessity of training, awareness programs, and government support for effective diffusion of blockchain (Ahmed & Hossain, 2024; Al Amin & Rahman, 2025).

Table 3. Empirical Data Coding Scheme

Code	Theme	Example Quote	Frequency
T1	Transparency	“Blockchain helps us verify raw cotton origin.”	17
T2	Waste Management	“Digital logs reduce leftover fabric waste.”	15
T3	Circular Practice	“Recycling firms want verified digital proof.”	12
B1	Barriers	“Lack of skilled workforce limits adoption.”	19

The coding of interview data revealed recurring themes related to transparency, circular practice, and adoption barriers (see Table 4; Braun & Clarke, 2021).

Survey analysis revealed that stakeholder pressure, perceived operational benefits, and Industry 5.0 integration were key enablers

- Buyer-driven sustainability requirements (Mean = 4.32)
- Operational efficiency gains (Mean = 4.14)
- IoT and AI integration for predictive waste management (Mean = 4.08)

SEM results indicated that Industry 5.0 integration positively moderated the relationship between perceived benefits and adoption ($\gamma = 0.28$, $p < 0.01$), demonstrating that firms leveraging human-centric and automated systems are more likely to implement blockchain effectively. Interviews highlighted that successful adoption is often driven by:

1. **Buyer requirements:** International brands demand traceability and proof of zero-waste practices.
2. **Technology partnerships:** Collaborations with IT vendors enable SMEs to access affordable blockchain solutions.
3. **Operational improvements:** Firms that integrate blockchain with IoT or ERP systems reported **reduced material loss and faster reporting**.

An RMG executive commented:

“We now know exactly how much fabric is wasted in each process. Blockchain combined with IoT gives us actionable insights that were impossible before.”

This aligns with literature emphasizing that blockchain is most effective when integrated with complementary technologies for circular economy and sustainability objectives (Radanliev et al., 2020; Tan et al., 2022).

Blockchain and Zero-Waste Practices

- Average reduction in untracked material loss: 18%
- Increase in recycled or repurposed fabric: 12%
- Enhanced compliance with sustainability reporting: 25%

These results suggest that blockchain not only provides traceability but also drives operational changes that reduce environmental impact, consistent with prior studies (Yadav & Singh, 2020; Shah & Ahmed, 2021; Xu et al., 2019).This confirms that blockchain supports zero-waste objectives when combined with operational monitoring and human oversight, reinforcing the Industry 5.0 framework (Radanliev et al., 2020; Tao & Qi, 2019).Survey data indicated that IoT devices, predictive analytics, and AI algorithms significantly enhance blockchain’s effectiveness for zero-waste tracking ($\beta = 0.28$, $p < 0.01$). Firms combining real-time monitoring with predictive decision-making achieved higher reductions in fabric waste and improved compliance reporting. Interviews revealed practical applications of Industry 5.0 technologies:

- IoT sensors track production stages and waste streams automatically.
- AI algorithms predict material usage and optimize cutting patterns.
- Predictive dashboards help managers adjust processes proactively.

These findings underscore that blockchain alone is insufficient; the full potential for sustainability is realized through integration with advanced digital tools, confirming prior literature (Venkatesh et al., 2020; Lin & Chen, 2021; Park et al., 2020).The findings confirm the theoretical and practical benefits of blockchain for transparency, traceability, and zero-waste practices (Badhwar, Islam, & Tan, 2023; Li & Wang, 2020). The study extends previous research by providing empirical evidence in Bangladesh, a context that has been underexplored in prior literature (Ahmed & Hossain, 2024; Investigating the Technological Impact, 2025).

Barriers identified—cost, skill gap, resistance to change—align with global adoption studies (Devising a Mechanism, 2022; Queiroz et al., 2019), while enablers such as buyer pressure and technology integration highlight context-specific factors that facilitate adoption in emerging economies.

1. **Empirical validation:** Confirms blockchain's role in reducing waste and enhancing transparency in RMG supply chains.

2. **Integration framework:** Demonstrates that Industry 5.0 technologies (IoT, AI, predictive analytics) significantly moderate adoption effectiveness.

3. **SME perspective:** Highlights adoption constraints and enablers for smaller firms, contributing to literature on technology adoption in developing economies.

CONCLUSION

This study was conducted to investigate how the fashion value chain of Bangladesh can leverage blockchain to ensure transparency, proper traceability, and zero waste practices. A combination of quantitative surveys of 300 industry professionals and 22 interviews provided insight into present adoption trends, barriers, enablers, and integration with Industry 5.0 technologies. The report indicates that financial, technical and organizational barriers are pervasive. However, the adoption is led by large exporters, while SMEs face a moderate awareness of blockchain. Worldwide buyers will push for sustainability. Also, profits from efficiency will go higher. Thus, both will use sustainability. The adoption of blockchain technology facilitates the real-time tracking of materials, minimises waste, and enhances sustainability reporting, therefore, aiding zero-waste and circular economy objectives. Crucially, the research highlights the joint role that Industry 5.0 gadgets play in boosting the effectiveness of block chain technologies. Firms that employed technologies showed reduced waste, improved compliance, and greater transparency in operations. Using blockchain is most effective when incorporated into an ecosystem that is human-centric and technology-enabled.

In general, the study contributes to theory by providing empirical evidence of blockchain's role in sustainability from the perspective of an emerging economy which extends the existing literature that has largely been conceptual or global cases. For operating organizations, it provides actionable strategies that explain the adoption of technology. The research shows that policymakers must provide support mechanisms, regulatory clarity and capacity-building initiatives to help SMEs leverage blockchain for sustainable supply chain management.

RECOMENDATIONS

Based on their research findings, the scholar suggests that the impact of blockchain technology combined with Industry 5 on the fashion value chain of Bangladesh. The efficiency of this impact will be ensured by integrating transparency, traceability, and zero waste. Although there are many barriers to the adoption of Technology in Business, particularly for the SMEs, pressure from stakeholders, operational benefits and integration capabilities are key facilitate factor. Findings of the study will enhance academic knowledge as well as the practical usefulness for firms, public policy makers, and technology providers for developing sustainable, circular and digital supply chains in the emerging economy. The following recommendations are proposed:

For Industry Practitioners.

- Start tracking selected production flows and waste flows with small scale, carefully designed pilot projects; scale up based on learnings.

- Using tools from Industry 5.0 which include the Internet of Things, Artificial Intelligence and Predictive analysis.
- To boost technical skills and become familiar with blockchain, conduct regular workshops for staff members.
- Partnering with technology players and international partners to drive down costs, increase effective implementation

For Policymakers and Regulators.

- Governments can provide grants, tax breaks or low-interest loans to SMEs for implementing blockchain and Industry 5.0 solutions.
- Setting up orgnaized plans for making sustainability more effective for data sharing and traceability and framework for RMG sector.
- Help pay for programming that raises digital skills and technical skills across an entire industry.

For International Buyers and Stakeholders.

- Include contract clauses to require proof of zero-waste and sustainability from your suppliers.
- Assist Suppliers with Enabling Compliance Technical Network.

These recommendations seek to effect sustainable change across the Bangladeshi fashion value chain, promoting zero-waste while remaining competitive in global markets.

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