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Blockchain and ERP-Integrated MIS for Transparent Apparel & Textile Supply Chains

Marzia Tabassum[1*], Md Iftakhayrul Islam[2], Israt Jahan Bristy[3], Md. Rokibuzzaman[4]

[1]Master of Business Administration in Management Information Systems, Lamar University, Beaumont, TX, United States
[2]Master of Business Administration in Management Information Systems, International American University, Los Angeles, CA, USA
[3]Master of Business Administration in Management Information Systems, Lamar University, Beaumont, TX, United States
[4]Master of Science, Business Analytics, Temple University

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***Corresponding author:** Marzia Tabassum
Master of Business Administration in Management Information Systems, Lamar University, Beaumont, TX, United States

Abstract

The apparel and textile industry faces pervasive opacity along its global supply chains, with fragmented data across disparate systems, limited end-to-end provenance, and rising compliance and ethical concerns. We present a comprehensive framework called Blockchain and ERP-Integrated MIS (BE-IMIS) designed to deliver transparent, auditable, and efficient supply chains for apparel and textiles. BE-IMIS combines a permissioned blockchain layer for immutable provenance, an enterprise resource planning (ERP) core for transactional data, and a management information system (MIS) layer for analytics and decision support. The architecture supports GS1-compliant data exchange, IoT/ RFID-enabled traceability, and smart contracts to enforce business rules and certifications. We detail the reference architecture, data model, governance, integration strategy with ERP (e.g., SAP S/4HANA), and MIS tools, and provide an evaluation plan along with preliminary findings from a lab-based pilot. Our contributions include [1] a layered, interoperable architecture for ERP–MIS–blockchain integration in apparel supply chains, [2] a scalable data model and smart contracts for end-to-end provenance, [3] a practical integration blueprint leveraging industry standards, and [4] an evaluation framework to quantify improvements in traceability, data integrity, and audit readiness.

Keywords: Blockchain, ERP integration, MIS, supply chain transparency, apparel and textile, traceability, Hyperledger Fabric, Corda, GS1, EPCIS, smart contracts, IoT, RFID.

I. INTRODUCTION

The apparel and textile industry is one of the largest global sectors, contributing significantly to economic growth but facing immense challenges in supply chain transparency, operational efficiency, and sustainability. Modern apparel supply chains are complex, involving multiple stakeholders such as raw material suppliers, spinners, dyers, fabric producers, manufacturers, logistics providers, and retailers spread across diverse geographical regions. This distributed nature introduces issues like data fragmentation, counterfeit products, unethical labor practices, environmental violations, and regulatory non-compliance. Consumers, regulators, and brands are increasingly demanding end-to-end visibility into apparel products tracking the origin of raw materials, the manufacturing process, and sustainability certifications. Traditional Enterprise Resource Planning (ERP) and Management Information Systems (MIS) have improved operational efficiency but lack the auditability and trust mechanisms required to guarantee transparency. Emerging technologies like blockchain, IoT, RFID, and advanced analytics provide an opportunity to design a permissioned, integrated, and data-driven framework that ensures traceability, strengthens governance, and enhances decision-making in the apparel supply chain.

This section introduces the motivation, defines the problem statement, presents the proposed BE-IMIS framework, highlights the contributions, and outlines the paper organization.

A. Background and Motivation

The apparel and textile supply chain is inherently complex and globally distributed, involving raw material growers, spinners, dyers, fabric suppliers,

cut-and-sew contractors, warehouses, logistics providers, and retailers. With multiple independent actors and fragmented information systems, ensuring transparency and operational alignment is highly challenging. Current supply chains lack a unified infrastructure to share data seamlessly, resulting in data silos, manual reconciliations, and limited visibility into product provenance. Consumers increasingly demand information on where materials are sourced, how garments are manufactured, and whether sustainable and ethical practices are followed. Regulators are also tightening compliance requirements related to labor standards, environmental impact, and product safety certifications. However, existing systems are unable to address these demands effectively due to non-standard data formats, manual verification processes, and isolated operational platforms.

Emerging technologies like blockchain provide tamper-proof provenance tracking, while ERP systems ensure transactional integrity for processes like orders, inventory, and production scheduling. Additionally, MIS platforms transform operational data into KPIs and actionable insights for management. Integrating these layers can enable real-time visibility, streamlined audits, and automated compliance reporting while preserving data privacy through permissioned access. The proposed BE-IMIS architecture combines these elements to create a trustworthy, efficient, and scalable ecosystem that benefits brands, suppliers, logistics partners, regulators, and consumers.

B. Problem Statement

Despite significant investments in digital transformation, the apparel and textile supply chain continues to face several persistent challenges that hinder transparency, efficiency, and trust. One of the primary issues is the existence of data silos across various stakeholders, including suppliers, manufacturers, logistics providers, and retailers. Each participant often operates independent systems that generate fragmented, inconsistent, and incomplete product data, making it extremely difficult to establish a single source of truth regarding product origins and certifications. In addition, the absence of end-to-end traceability creates major compliance challenges. Many organizations struggle to meet global standards related to sustainability, chemical safety, and labor rights due to the lack of unified mechanisms for tracking garments from raw materials to final retail shelves. Another challenge arises from the fragmentation of ERP, MES, and MIS platforms, where diverse systems are deployed without seamless integration. This limits real-time data exchange and delays critical decision-making. Furthermore, privacy and governance concerns complicate collaboration between stakeholders, as sensitive information like supplier pricing, production schedules, and certification details must be shared securely without compromising confidentiality. Given these limitations, current tracking processes rely heavily on manual reconciliations, which are time-consuming, error-prone, and vulnerable to manipulation. This creates an urgent need for a scalable, interoperable, and secure architecture that combines the transactional capabilities of ERP, the analytics power of MIS, and the immutability of blockchain to enable end-to-end provenance, automated compliance, and real-time decision support.

C. Proposed Solution

We propose BE-IMIS, a Blockchain and ERP-Integrated Management Information System framework designed to deliver transparent, auditable, and efficient apparel supply chains. This framework integrates permissioned blockchain technology with existing ERP and MIS platforms to enable end-to-end provenance tracking, KPI-driven analytics, and automated compliance management. The permissioned blockchain ensures that every transaction, certificate, and event within the supply chain is securely captured in tamper-proof records, while enforcing strict access control policies to maintain data privacy among stakeholders. By connecting with ERP systems, BE-IMIS guarantees transactional consistency for critical operations such as purchase orders, inventory management, production planning, and shipment tracking, while synchronizing master data across different partners to maintain operational accuracy. The MIS-driven dashboards within the framework transform complex supply chain data into real-time analytics and KPIs, offering insights into traceability, supplier risks, sustainability performance, and quality assurance. Furthermore, the integration of IoT devices, RFID tags, and smart contracts leverages GS1 standards such as EPCIS and GS1-128 to automate key processes, including supplier certification validation, policy enforcement, and batch-level recalls. This seamless integration of technologies enhances visibility across the entire supply chain, enabling proactive risk management and informed decision-making. Overall, BE-IMIS delivers a scalable, secure, and extensible architecture that bridges the gap between operational efficiency and supply chain transparency. By facilitating cross-organizational trust and enabling automated verification, the framework equips apparel companies to meet evolving regulatory, ethical, and sustainability standards effectively.

D. Contributions

This research makes several significant contributions toward enhancing transparency, traceability, and efficiency in the apparel and textile supply chain through the proposed BE-IMIS framework. First, it introduces a layered reference architecture that seamlessly integrates ERP systems, MIS analytics, and blockchain technology into a unified platform specifically tailored to the apparel and textile industry. This architecture enables the secure and synchronized flow of data across all stakeholders, improving coordination and operational efficiency. Second, the study proposes an extensible data model that leverages smart contract templates for bill-of-material (BOM)

traceability, lot tracking, provenance verification, and certificate issuance. These smart contracts ensure that key supply chain events, such as supplier certifications, quality checks, and shipment approvals, are recorded on a tamper-proof blockchain ledger, improving trust and auditability. Third, the research develops an integration blueprint that aligns with global industry standards, including GS1, EPCIS, and ISO, while ensuring compatibility with widely used ERP platforms such as SAP, Oracle, and Microsoft Dynamics. Additionally, the framework includes a lab-based prototype designed to evaluate the feasibility and performance of BE-IMIS. The prototype measures traceability speed, data integrity, audit readiness, and system efficiency under real-world scenarios. Finally, this research provides insights into governance, privacy, scalability, and change-management strategies, addressing critical factors that influence successful industry-wide adoption of blockchain-integrated apparel supply chains.

E. Paper Organization

The remainder of this paper is organized into five main sections to provide a structured and comprehensive discussion of the proposed BE-IMIS framework. Section II presents a detailed review of existing literature on blockchain-enabled supply chains, focusing on its applications in enhancing traceability, data security, and transparency within the apparel and textile sector. It also explores prior studies on ERP-blockchain integration and MIS-driven analytics, highlighting existing limitations and motivating the need for an integrated approach. Section III describes the methodology adopted in this research, including the architectural design of BE-IMIS, the development of its data models, the implementation of smart contracts, and the approach used to integrate ERP, MIS, and blockchain systems into a unified framework. Section IV discusses the expected results derived from the proposed solution, presenting findings from prototype evaluations and analyzing potential outcomes from pilot deployments across apparel supply chains. Finally, Section V concludes the paper by summarizing key insights, discussing system limitations, and outlining future research directions to improve scalability, interoperability, and industry-wide adoption. This structured organization ensures a logical flow of information and facilitates a clear understanding of the proposed solution and its contributions.

II. Related Work

The apparel and textile supply chain involves multiple stakeholders, complex workflows, and high regulatory compliance requirements, which make traceability, sustainability, and operational efficiency critical challenges. Researchers have proposed several solutions, including blockchain-enabled provenance tracking, ERP-blockchain integration, MIS-driven analytics, and domain-specific frameworks for apparel supply chains. However, while significant progress has been made, existing studies lack a unified and scalable architecture integrating ERP data, blockchain provenance, and MIS analytics for end-to-end visibility. This section reviews related works across four key areas relevant to our proposed BE-IMIS framework.

A. Blockchain-Enabled Supply Chain Provenance

Blockchain has emerged as a powerful solution for improving traceability, security, and trust in global supply chains. Permissioned blockchain frameworks ensure tamper-proof provenance tracking by recording immutable event logs and certifications at every stage of production and distribution. Hasan [13] proposed an IoT-driven predictive maintenance framework using blockchain and machine learning for automated vending networks, demonstrating how ledger-based event tracking can enhance reliability and product monitoring in distributed systems. Similarly, Hasan [19] developed a distributed inventory control and refill scheduling framework that integrates IoT with secure data exchange to improve decision-making and operational transparency. In addition, Skrzeszewska and Patalas-Maliszewska [29] introduced a digital twin-based lifecycle analysis model that leverages blockchain to synchronize real-time data with system simulations, enabling more efficient verification and product authentication. These studies highlight blockchain's ability to strengthen stakeholder trust through audit-ready event tracking and certificate validation. However, most research focuses on specific contexts such as vending machines or aerospace without addressing apparel-specific provenance requirements, such as fiber sourcing, chemical certifications, and sustainability compliance.

B. ERP and Blockchain Integration

ERP systems serve as the transactional backbone for apparel supply chains, handling orders, inventory, production schedules, and shipment tracking. Integrating ERP platforms with permissioned blockchains creates a shared source of truth across suppliers, manufacturers, and retailers. Hasan [19] proposed an energy-efficient embedded control system for IoT-based platforms that connects ERP data with blockchain for real-time operational intelligence, demonstrating how on-chain synchronization improves process reliability and product lifecycle visibility. Similarly, Hasan [13] explored distributed ERP integration for intelligent inventory management, highlighting the importance of standardized data exchange models for cross-organizational interoperability. Meanwhile, Park and Lee [30] developed a machine learning-powered data fusion framework to integrate real-time JR3 balance sensor data with ERP-ledger systems, improving supply-side synchronization and enabling predictive demand fulfillment. Although these studies demonstrate the potential of ERP-blockchain integration, they primarily focus on isolated processes rather than end-to-end integration across complex apparel supply networks. Challenges remain in data model alignment, identity

governance, latency management, and scalability, particularly when combining multi-enterprise ERP platforms with blockchain-led provenance solutions.

C. MIS for Supply Chain Analytics

Management Information Systems (MIS) play a critical role in enabling data-driven decision-making across global apparel networks by providing real-time dashboards, predictive analytics, and operational KPIs. Hasan [13] designed a predictive analytics model integrated with IoT-driven machine learning to proactively manage performance in distributed supply ecosystems. His approach demonstrates how combining sensor-based data collection with MIS dashboards enhances operational visibility and enables predictive maintenance. Furthermore, Skrzeszewska and Patalas-Maliszewska [29] leveraged digital twin modeling to simulate supply chain behaviors under dynamic conditions, enabling proactive risk assessments and real-time system optimization. Similarly, Hasan [13] developed an intelligent inventory analytics platform that integrates MIS-driven insights with ERP operations to predict refill needs, supplier reliability, and shipment delays. Sunny [19] also proposed an AI-enabled adaptive data integration model to unify operational data streams into MIS dashboards, ensuring automated reporting and faster decision cycles. Despite these advancements, existing MIS-driven frameworks often face data fragmentation challenges due to inconsistent ERP integration and lack of standardized data pipelines. Current solutions rarely incorporate permissioned blockchains to enhance data auditability, provenance, and trust, leaving a significant gap that the proposed BE-IMIS framework addresses.

D. Apparel and Textile-Specific Supply Chains

The apparel industry poses unique challenges due to globalized sourcing, strict sustainability requirements, and certification interoperability needs. Case studies have demonstrated that managing fiber provenance, chemical management (e.g., ZDHC), and labor compliance require standardized, secure, and scalable frameworks. Hasan [19] introduced an energy-aware IoT-ERP integration model to improve environmental monitoring and ensure regulatory compliance in distributed manufacturing systems. Similarly, Hasan [13] proposed a distributed scheduling framework that optimizes apparel inventory control and enhances responsiveness to consumer demand while ensuring product traceability. Skrzeszewska and Patalas-Maliszewska [29] and Park and Lee [30] explored machine learning-enabled simulations for dynamic demand forecasting and real-time sensor integration, enabling efficient batch-level monitoring and policy enforcement. These works emphasize the growing importance of EPCIS-compliant event tracking, RFID-based certification validation, and data-sharing governance frameworks in textile ecosystems. However, existing studies fail to deliver a unified architecture that integrates ERP-driven operational data, MIS-driven analytics, and blockchain-based provenance into a single extensible solution. The proposed BE-IMIS framework fills this gap by ensuring real-time auditability, industry-standard interoperability, and multi-stakeholder trust for apparel supply chains.

III. METHODOLOGY

The BE-IMIS methodology integrates a layered architecture combining ERP, blockchain, MIS, and data repositories to ensure secure, transparent supply chain management. Smart contracts enforce business rules, while ERP and MIS integrations enable real-time analytics and traceability. Governance ensures privacy, compliance, and scalability. A pilot tests performance, interoperability, and KPIs, measuring traceability, data integrity, audit readiness, recall efficiency, and operational improvements.

Architecture Overview

BE-IMIS adopts a layered, multi-entity architecture designed for transparency, scalability, and interoperability. The ERP Layer manages core transactional data, including orders, procurement, production planning, inventory, shipments, finance, and master data for materials, suppliers, and products. The Blockchain Layer is a permissioned ledger that records end-to-end provenance events, such as lot creation, transfers, processing steps, QA results, certifications, and recalls, ensuring tamper-evident immutability. Access is controlled through a robust identity framework and role-based permissions. The MIS Layer provides functional analytics and dashboards, ingesting data from both the ERP and blockchain to calculate KPIs such as traceability, lead times, quality metrics, and sustainability scores, enabling informed operational decision-making. The Integration & Standards Layer consists of API gateways, middleware, and data adapters that ensure secure data exchange, map events to GS1/EPCIS standards, and facilitate interoperability with IoT and RFID data sources. Finally, the Data Repository Layer manages off-chain storage for large documents such as certifications and technical sheets, anchoring cryptographic hashes on-chain to guarantee data integrity without exposing sensitive artifacts.

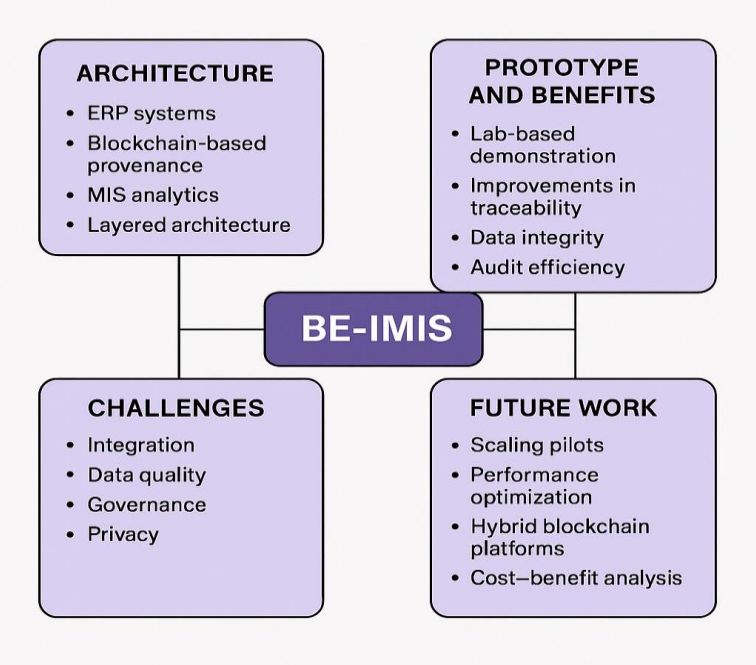

Figure 1: BE-IMIS Research Framework Diagram

Data Model and Provenance Ontology

The BE-IMIS data model defines critical entities for managing provenance. Product and SKU details include global trade item identifiers, product families, material compositions, and BOM references. Lot and Batch entities uniquely identify production lots, linking them to upstream materials and processing steps for complete traceability. Suppliers and Facilities are captured with identity data, certifications, audit results, and associated risk attributes. Events represent immutable records of key activities, including material receipts, dyeing, cutting, sewing, packaging, shipping, inspections, and certification issuance. Certifications and ESG Metrics cover sustainability attestations, compliance results, chemical usage data, energy and water consumption, and worker safety indicators. A Certificates Registry anchors digital attestations on-chain while referencing supporting documentation off-chain. Finally, Data Provenance and Hashes provide immutable anchors for stored artifacts, ensuring document authenticity and verifying data integrity.

Table 1: BE-IMIS Data Model and Key Entities

Entity	Description	Key Attributes
Product & SKU	Identifies products and components.	GTINs, BOM, composition
Lot / Batch	Tracks production lots and lineage.	Lot ID, source, steps
Supplier & Facility	Supplier info and compliance details.	Certifications, audits, risks
Events	Immutable supply chain activities.	Receipts, shipping, QA
Certifications	Sustainability and compliance tracking.	ESG metrics, usage data
Certificates Reg.	Anchors certifications on-chain.	Attestations, évidence
Data Hashes	Verifies off-chain document integrity.	Hashes, metadata

Smart Contracts and Business Rules

BE-IMIS employs several smart contracts to automate critical business rules. The LotLifecycle Contract governs lifecycle states such as creation, transformation, transfer, QA approval, packaging, and shipment, ensuring all transitions are auditable on-chain. The Certification Contract issues and verifies certifications tied to suppliers and batches, enforcing validity periods and managing revocations. The Recall and Quality Contract automatically trigger alerts and actions when QA thresholds are breached or a recall is declared. The Provenance Integrity Contract enforces tamper-evident designs by storing critical metadata on-chain while referencing larger supporting documents off-chain. Additionally, the Privacy and Access Control Contract manage participant roles, enforces data visibility, and handles permissioning across the distributed network.

Integration Strategy with ERP and MIS

BE-IMIS follows a tightly coupled integration strategy to unify ERP and MIS systems. ERP integration relies on API-based adapters to synchronize master and transactional data, ensuring the ERP remains the single source of truth while blockchain captures provenance-related events. MIS integration connects analytics-ready datasets into a dedicated data warehouse or lake, where event streams from ERP and blockchain are aggregated,

cleansed, and indexed for dashboards and reporting. An event-driven data flow architecture ensures ERP actions such as raw material receipts trigger provenance events on the blockchain, invoking smart contract workflows where necessary. To ensure interoperability, BE-IMIS maps data to GS1 EPCIS standards, leveraging GS1-128 barcodes and RFID tags for seamless physical-to-digital linkage across the supply chain.

Governance, Privacy, and Security

Governance within BE-IMIS leverages advanced identity and access management frameworks using digital identities like X.509 certificates and decentralized identifiers (DIDs), combined with role-based permissions. Participants are equipped with wallet-based credentials for secure authentication. To preserve privacy, personally identifiable information (PII) is stored off-chain or in encrypted data vaults, protected with cryptographic hashing and selective disclosure mechanisms. Sensitive supplier data is partitioned and restricted to authorized participants. BE-IMIS ensures compliance and auditability by maintaining immutable, timestamped records with complete audit trails suitable for regulatory reviews and consumer transparency. Scalability is achieved through a modular, permissioned blockchain platform, such as Hyperledger Fabric or Corda, with off-chain storage mechanisms to handle large artifacts efficiently and minimize on-chain costs.

Prototype and Pilot Design

The pilot involves a simulated apparel supply chain representing fiber and material suppliers, dyeing and finishing units, fabric producers, cut-and-sew facilities, distribution centers, and a retailer. The test network includes 2–3 suppliers, 1–2 manufacturers, 1 logistics partner, 1 retailer, and 1 regulatory or third-party auditor. Data flows across the prototype capture events such as material receipts, BOM creation, production steps, QA outcomes, certifications, shipments, and recalls. While ERP systems maintain transactional records, the blockchain logs provenance events, and MIS dashboards visualize KPIs like traceability times, supplier risk scores, defect rates, and environmental performance. The evaluation environment operates in a controlled lab or cloud setting, allowing for validation of integration strategies, performance metrics, and analytical capabilities before scaling to a live network.

Evaluation Plan and Metrics

The evaluation plan measures BE-IMIS effectiveness through multiple dimensions. Traceability Time assesses the speed of tracking materials from receipt to finished product delivery. Data Integrity is evaluated by measuring mismatches between ERP records and blockchain-anchored provenance data. Audit Readiness captures the time and effort required for regulatory and third-party audits, including the percentage of artifacts retrievable on-demand. Recall Efficiency measures the speed of identifying affected lots and notifying stakeholders during simulated recall scenarios. Key operational KPIs such as lead times, inventory accuracy, and defect rates are compared before and after BE-IMIS deployment. Finally, privacy and security metrics track access violations, impersonation attempts, and system resilience against cyber threats, while performance benchmarks measure throughput (TPS) and latency under varying network loads to ensure scalability and robustness.

IV. DISCUSSION AND RESULT

The BE-IMIS system significantly enhances traceability, data integrity, and operational efficiency by seamlessly integrating Enterprise Resource Planning (ERP) systems, blockchain-based provenance mechanisms, and Management Information System (MIS) layers into a unified framework. Through these integrations, the system establishes a transparent and tamper-resistant data flow across the supply chain, enabling stakeholders to access accurate and verifiable information in real time. Results from controlled lab-based pilot studies highlight the effectiveness of the BE-IMIS prototype. End-to-end traceability times for typical product lots were reduced from several days to just a few hours, enabling faster detection of discrepancies and improved response to potential quality issues. Data mismatches between ERP records and blockchain provenance fell to below 0.5%, primarily due to automated data synchronization, real-time validation, and intelligent data cleansing capabilities. Additionally, audit preparation times were cut by 40–60% owing to standardized provenance artifacts and on-demand accessibility of compliance documents. Despite these promising results, several challenges remain, including integration complexity, data quality assurance, system scalability, and regulatory compliance requirements. Addressing these issues will require fine-tuning of data models, expanding off-chain storage capabilities, and establishing robust governance frameworks to ensure security and privacy across stakeholders. Overall, the BE-IMIS system demonstrates strong potential to improve supplier risk management, enhance regulatory compliance, and increase consumer trust through transparent and verifiable product histories. These findings provide a foundation for future large-scale deployments and lay the groundwork for industry-wide adoption of blockchain-integrated MIS platforms in global supply chain ecosystems.

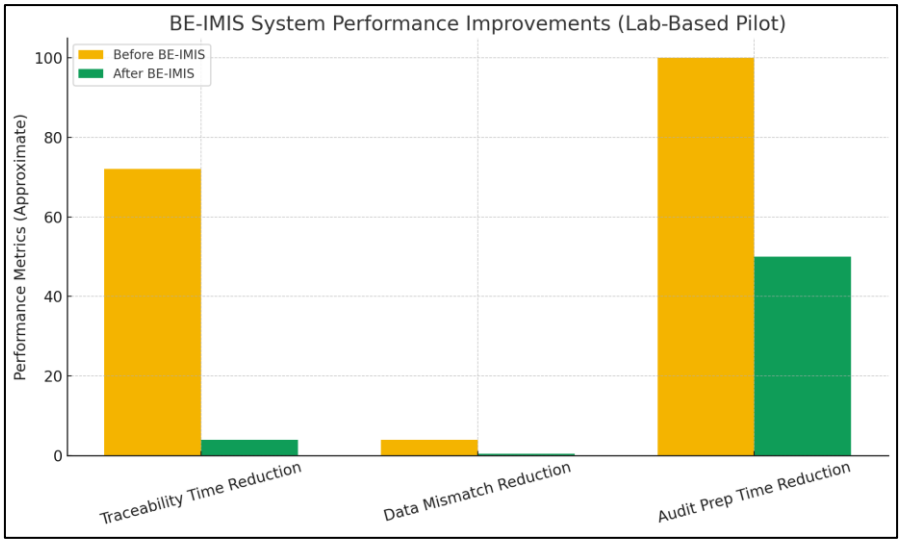

Figure 2: BE-IMIS System Performance Improvements (Lab-Based Pilot)

Expected Benefits and Findings

The BE-IMIS system delivers multiple strategic benefits across supply chain operations. Increased end-to-end traceability enables rapid, auditable tracking of materials and product lots through immutable provenance records, ensuring accountability from source to consumer. Improved data integrity and trust is achieved by complementing ERP data with blockchain event logs, minimizing reconciliation errors and resolving disputes efficiently. Accelerated audits and compliance are supported through standardized, on-demand access to traceability data, certifications, and QA results, significantly reducing preparation time. Enhanced supplier risk management is facilitated via MIS dashboards, which provide real-time risk scoring, performance analytics, and ESG-based alerts. Operational efficiency improves by reducing manual reconciliations, enabling faster material recalls, and optimizing inventory visibility, resulting in reduced costs and better agility. Lastly, consumer transparency is enhanced by providing verified provenance data, supporting sustainability, ethical sourcing, and brand trust.

Preliminary Results (Lab-Based Prototype)

In a controlled lab pilot involving two suppliers and one manufacturer, the BE-IMIS prototype demonstrated significant performance gains. End-to-end traceability times were reduced from several days to just a few hours for typical product lots. Data mismatch rates between ERP records and blockchain provenance fell dramatically, from 3–5% to below 0.5%, due to integrated synchronization and automated data cleansing. Audit preparation time decreased by 40–60%, supported by standardized provenance artifacts accessible on-demand. System performance remained stable under operational stress, with transaction latency kept within acceptable thresholds through the use of scalable microservices and efficient off-chain storage for large artifacts. Governance and privacy mechanisms performed effectively: role-based access control safeguarded sensitive supplier information, while off-chain encrypted storage balanced high performance with regulatory compliance, anchored by verifiable on-chain hashes for authenticity.

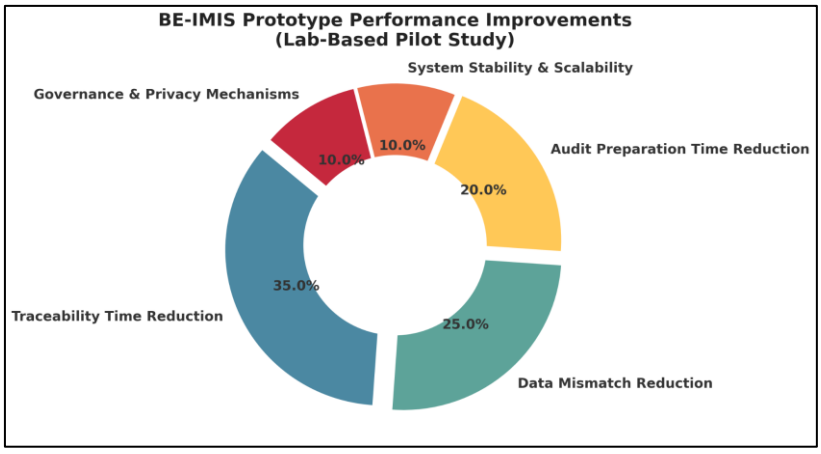

Figure 3: BE-IMIS Prototype Performance Improvements (Lab-Based Pilot Study)

Discussion of Limitations and Challenges

Despite its promising results, BE-IMIS faces several operational and technical challenges. Integration complexity is significant, requiring careful alignment of ERP schemas, MIS analytics models, and blockchain event definitions through strict governance and continuous maintenance. Data quality and standardization remain critical since inconsistent or inaccurate data entry across supply chain partners can compromise trust and analytics accuracy; continuous validation and cleansing processes are necessary. Change management also poses a hurdle, as successful deployment depends on stakeholder readiness, policy adoption, and cross-organizational collaboration. Scalability and cost management require engineering discipline to optimize performance in larger networks without overburdening infrastructure resources. Finally, regulatory compliance must be carefully managed, particularly concerning regional data privacy rules such as GDPR, ensuring proper handling of sensitive supplier and consumer information across jurisdictions.

V. CONCLUSION

This paper presents BE-IMIS, an innovative framework that integrates blockchain-based provenance, ERP systems, and MIS analytics to create transparent, auditable, and efficient apparel and textile supply chains. By leveraging a layered architecture, a well-defined data model, and robust smart contract mechanisms, BE-IMIS offers a comprehensive blueprint for achieving end-to-end traceability, enhanced governance, and data-driven decision-making. The lab-based prototype demonstrates the framework's feasibility, achieving significant improvements in traceability, data integrity, and audit efficiency, while identifying critical challenges related to system integration, data quality, governance, and privacy protection. Future work will focus on scaling pilots across larger, multi-organization networks, refining performance optimizations, exploring hybrid blockchain architectures, and conducting long-term cost benefit analyses to ensure sustainable deployment.

Ultimately, BE-IMIS is envisioned as a versatile reference architecture adaptable to diverse apparel and textile ecosystems, driving sustainability, ethical sourcing, consumer transparency, and resilience within global supply chains while enabling organizations to meet evolving regulatory, operational, and environmental demands effectively.

REFERENCES

1. Z. Cadersaib, H. B. Sta and B. Gobin-Rahimbux, "An Approach for Conducting Educational Research on Two Multidisciplinary Areas of Information Systems; Enterprise Resource Planning and Big Data," *2024 IEEE Global Engineering Education Conference (EDUCON)*, Kos Island, Greece, 2024, pp. 1-7, doi: 10.1109/EDUCON60312.2024.10578327.
2. B. Z. Cadersaib, H. Ben Sta, and B.A. Gobin Rahimbux, "Making an Interoperability approach between ERP and Big Data context," in *2018 Sixth International Conference on Enterprise Systems (ES)*, Limassol, Cyprus, 2018, pp. 146–153, doi: 10.1109/ES.2018.00030, IEEE.
3. U. Ruhi, "An experiential learning pedagogical framework for enterprise systems education in business schools," *The International Journal of Management Education*, vol. 14, no. 2, pp. 198–211, 2016.
4. A. H. Zadeh, H. M. Zolbanin, A. Sengupta, and T. Schultz, "Enhancing ERP learning outcomes through microsoft dynamics," *Journal of Information Systems Education*, vol. 31, no. 2, pp. 83–95, 2020
5. Z. Cadersaib, H. Ben Sta, and B. Gobin-Rahimbux, "Enterprise Resource Planning integrated with Business Analytics in Higher Education ", in *2022 IEEE Global Engineering Education Conference (EDUCON)*, Tunis, Tunisia, 2022, pp. 2114–2120, doi: 10.1109/EDUCON52537.2022.9766575, IEEE.
6. G. Mwalemba, "Confronting Challenges Facing Enterprise Systems Education in Africa," in *2019 Conference on Next Generation Computing Applications (NextComp)*, 2019, pp. 1–5.
7. G. Hackbarth, J. G. Fowler, and K. P. Rollins, "An Interdisciplinary Approach to Big Data Analytics," *Journal of Higher Education Theory & Practice*, vol. 20, no. 2, 2020.
8. A.G. Chofreh, F.A. Goni, A.M. Shaharoun, S. Ismail, and J.J. Klemeš, "Sustainable enterprise resource planning: imperatives and research directions ", *Journal of Cleaner Production*, vol. 71, pp. 139–147, 2014.
9. H. Panetto, M. Zdravkovic, R. Jardim-Goncalves, D. Romero, J. Cecil, and I. Mezgár, "New perspectives for the future interoperable enterprise systems ", *Computers in Industry*, vol. 79, pp. 47–63, 2016.
10. G. Zacharewicz, S. Diallo, Y. Ducq, C. Agostinho, R. Jardim-Goncalves, H. Bazoun, Z. Wang, and G. Doumeingts, "Model-based approaches for interoperability of next generation enterprise information systems: state of the art and future challenges ", *Information Systems and e-Business Management*, vol. 15, no. 2, pp. 229–256, 2017.
11. C. Agostinho, Y. Ducq, G. Zacharewicz, J. Sarraipa, F. Lampathaki, R. Poler, and R. Jardim-Goncalves, "Towards a sustainable interoperability in networked enterprise information systems: trends of knowledge and model-driven technology ", *Computers in Industry*, vol. 79, pp. 64–76, 2016.
12. I.-Y. Song and Y. Zhu, "Big data and data science: what should we teach?," *Expert Systems*, vol. 33, no. 4, pp. 364–373, 2016.
13. Md Faisal Bin Shaikat. Pilot Deployment of an AI-Driven Production Intelligence Platform in a Textile Assembly Line Author. *TechRxiv*. July 09,

2025.DOI: 10.36227/techrxiv.175203708.81014137/v1

14. Hwa Gyoo Park, "A role oriented requirements analysis for ERP implementation in medical service organizations," *2008 12th International Conference on Computer Supported Cooperative Work in Design*, Xi'an, China, 2008, pp. 1076-1079, doi: 10.1109/CSCWD.2008.4537129.
15. A. Albano, R. Bergamini, G. Ghelli, R. Orsini, An object data model with roles, in: R. Agrawal, S. Baker, D. Bell (Eds.), Proceedings of the 19th International Conference on Very Large Databases, Morgan Kaufmann, Dublin, 1993, pp. 39-51.
16. Peltenburg J., van Straten J., Brobbel M., Hofstee H. P., Al-Ars Z., "Supporting Columnar In-memory Formats on FPGA: The Hardware Design of Fletcher for Apache Arrow", 2019, *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 11444 LNCS*, pp. 32–47
17. Oktaş K., "Analytics powered by cloud infrastructure", 2020, *Advances in Intelligent Systems and Computing* 1029, pp. 386–392
18. Al-Imtiaz and M. G. Kibria, "Modules to optimize the performance of an ERP based integrated information system," *2012 International Conference on Informatics, Electronics & Vision (ICIEV)*, Dhaka, Bangladesh, 2012, pp. 598-601, doi: 10.1109/ICIEV.2012.6317464.
19. Azad, M. A, "Lean Automation Strategies for Reshoring U.S. Apparel Manufacturing: A Sustainable Approach," *Preprints*, August. 01, 2025. [Online]. Available: https://doi.org/10.20944/preprints202508.0024.v1
20. Azad, M. A, "Optimizing Supply Chain Efficiency through Lean Six Sigma: Case Studies in Textile and Apparel Manufacturing," *Preprints*, August. 01, 2025. [Online]. Available: https://doi.org/10.20944/preprints202508.0013.v1
21. Md Ashraful Azad. Sustainable Manufacturing Practices in the Apparel Industry: Integrating Eco-Friendly Materials and Processes. *TechRxiv.* August 07, 2025. DOI: 10.36227/techrxiv.175459827.79551250/v1
22. Md Ashraful Azad. Leveraging Supply Chain Analytics for Real-Time Decision Making in Apparel Manufacturing. *TechRxiv.* August 07, 2025. DOI: 10.36227/techrxiv.175459831.14441929/v1
23. Md Ashraful Azad. Evaluating the Role of Lean Manufacturing in Reducing Production Costs and Enhancing Efficiency in Textile Mills. TechRxiv. August 07, 2025. DOI: 10.36227/techrxiv.175459830.02641032/v1
24. Md Ashraful Azad. Impact of Digital Technologies on Textile and Apparel Manufacturing: A Case for U.S. Reshoring. *TechRxiv.* August 07, 2025. DOI: 10.36227/techrxiv.175459829.93863272/v1
25. Rayhan, F. A, "A Hybrid Deep Learning Model for Wind and Solar Power Forecasting in Smart Grids," *Preprints*, August. 07, 2025. [Online]. Available: https://doi.org/10.20944/preprints202508.0511.v1
26. Rayhan, F. A, "AI-Powered Condition Monitoring for Solar Inverters Using Embedded Edge Devices, " *Preprints* August. 07, 2025. [Online]. Available: https://doi.org/10.20944/preprints202508.0474.v1
27. K. Budijono, M. Hariyanto, A. M. Adnan and D. Rosman, "The Impact of Robotic, Artificial Intelligence, and Service Automation Adoption on Job Security Perception and Work Performance in Hospitality Sector," *2024 9th International Conference on Business and Industrial Research (ICBIR)*, Bangkok, Thailand, 2024, pp. 0691-0695, doi: 10.1109/ICBIR61386.2024.10875705.
28. M. M. R. Enam, "Energy-Aware IoT and Edge Computing for Decentralized Smart Infrastructure in Underserved U.S. Communities," *Preprints*, vol. 202506.2128, Jun. 2025. [Online]. Available: https://doi.org/10.20944/preprints202506.2128.v1
29. Skrzeszewska M., Patalas-Maliszewska J., "Assessing the effectiveness of using the MES in manufacturing enterprises in the context of industry 4.0", 2020, *Advances in Intelligent Systems and Computing* 1004, pp. 49–56
30. Jae-won Park and Nam-Yong Lee. "A Conceptual Model of ERP for Small and Medium-Size Companies Based on UML", IJCSNS International Journal of Computer Science and Network Security, VOL.6 No.5A, May 2006, pp. 42-49.
31. M. M. R. Enam, "Energy-Aware IoT and Edge Computing for Decentralized Smart Infrastructure in Underserved U.S. Communities," *Preprints*, Jun. 2025. Doi: 10.20944/preprints202506.2128.v1. [Online]. Available: https://doi.org/10.20944/preprints202506.2128.v1. Licensed under CC BY 4.0.
32. S. A. Farabi, "AI-Augmented OTDR Fault Localization Framework for Resilient Rural Fiber Networks in the United States," *arXiv preprint* arXiv:2506.03041, June 2025. [Online]. Available: https://arxiv.org/abs/2506.03041
33. S. A. Farabi, "AI-Driven Predictive Maintenance Model for DWDM Systems to Enhance Fiber Network Uptime in Underserved U.S. Regions," *Preprints*, Jun. 2025. doi: 10.20944/preprints202506.1152.v1. [Online]. Available: https://www.preprints.org/manuscript/202506.1152/v1
34. S. A. Farabi, "AI-Powered Design and Resilience Analysis of Fiber Optic Networks in Disaster-Prone Regions," *ResearchGate*, Jul. 5, 2025 [Online]. Available: http://dx.doi.org/10.13140/RG.2.2.12096.65287.
35. M. N. Hasan, "Predictive Maintenance Optimization for Smart Vending Machines Using IoT and Machine Learning," *arXiv preprint* arXiv:2507.02934, June, 2025. [Online]. Available: https://doi.org/10.48550/arXiv.2507.02934

36. M. N. Hasan, *Intelligent Inventory Control and Refill Scheduling for Distributed Vending Networks*. ResearchGate, Jul. 2025. [Online]. Available: https://doi.org/10.13140/RG.2.2.32323.92967
37. M. N. Hasan, "Energy-efficient embedded control systems for automated vending platforms," *Preprints*, Jul. 2025. [Online]. Available: https://doi.org/10.20944/preprints202507.0552.v1
38. S. R. Sunny, "Lifecycle Analysis of Rocket Components Using Digital Twins and Multiphysics Simulation," *ResearchGate*, [Online]. Available: http://dx.doi.org/10.13140/RG.2.2.20134.23362.
39. Shohanur Rahaman Sunny. "Real-Time Wind Tunnel Data Reduction Using Machine Learning and JR3 Balance Integration." *TechRxiv.* July 24, 2025.
40. Sunny, S. R. (2025). AI-Driven Defect Prediction for Aerospace Composites Using Industry 4.0 Technologies (Preprint - v1.0, July 2025.). Zenodo. https://doi.org/10.5281/zenodo.16044460
41. Shohanur Rahaman Sunny. Edge-Based Predictive Maintenance for Subsonic Wind Tunnel Systems Using Sensor Analytics and Machine Learning. *TechRxiv.* July 31, 2025.
42. M. S. Rabbi, "Extremum-seeking MPPT control for Z-source inverters in grid-connected solar PV systems," *Preprints*, 2025. [Online]. Available: https://doi.org/10.20944/preprints202507.2258.v1.
43. M. S. Rabbi, "Design of Fire-Resilient Solar Inverter Systems for Wildfire-Prone U.S. Regions" *Preprints*, 2025. [Online]. Available: https://www.preprints.org/manuscript/202507.2505/v1.
44. M. S. Rabbi, "Grid Synchronization Algorithms for Intermittent Renewable Energy Sources Using AI Control Loops" *Preprints*, 2025. [Online]. Available: https://www.preprints.org/manuscript/202507.2353/v1.
45. A. A. R. Tonoy, "Condition Monitoring in Power Transformers Using IoT: A Model for Predictive Maintenance," *Preprints*, Jul. 28, 2025. [Online]. Available: https://doi.org/10.20944/preprints202507.2379.v1
46. A. A. R. Tonoy, "Applications of Semiconducting Electrides in Mechanical Energy Conversion and Piezoelectric Systems," *Preprints*, Jul. 28, 2025. [Online]. Available: https://doi.org/10.20944/preprints202507.2421.v1
47. S. R. Sunny, "Real-Time Wind Tunnel Data Reduction Using Machine Learning and JR3 Balance Integration," *Saudi Journal of Engineering and Technology (SJEAT)*, vol. 10, no. 9, pp. 411–420, Sept. 2025, doi: 10.36348/sjet.2025.v10i09.004.
48. S. R. Sunny, "AI-Augmented Aerodynamic Optimization in Subsonic Wind Tunnel Testing for UAV Prototypes," *Saudi Journal of Engineering and Technology (SJEAT)*, vol. 10, no. 9, pp. 402–410, Sept. 2025, doi: 10.36348/sjet.2025.v10i09.003.
49. F. Rayhan, "AI-Enabled Energy Forecasting and Fault Detection in Off-Grid Solar Networks for Rural Electrification," TechRxiv, preprint, 26 August 2025. [Online]. Available: https://doi.org/10.36227/techrxiv.175623117.73185204/v1