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ARTÍCULOS

Arquitecturas de Blockchain de Consorcio para la Gobernanza Democrática impulsada por ESG y la resiliencia de la cadena de suministro en las cooperativas textiles

Sadurya G.
Karunya Institute of Technology and Science. Coimbatore (India)
Kavitha Selvaranee J.
Karunya Institute of Technology and Science. Coimbatore (India)

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ES **Resumen.** Este estudio explora la aplicación de la tecnología blockchain de consorcio como un mecanismo transformador para mejorar la transparencia, la rendición de cuentas y la gobernanza democrática en las cooperativas textiles de Tamil Nadu, India. La investigación se fundamenta en los principios del modelo de las 3P (Protección, Participación y Rentabilidad) de la gestión cooperativa, integrando la innovación digital con los valores tradicionales del cooperativismo. Mediante un estudio piloto realizado en cooperativas textiles seleccionadas, la investigación examina el potencial de blockchain para mejorar la viabilidad financiera, la trazabilidad operativa y la confianza de los miembros. Los resultados preliminares indican un incremento del 15 % en el valor actual neto (VAN) promedio, una reducción del 40 % en los errores de trazabilidad y una aceptación superior al 75 % por parte de los miembros respecto a la gobernanza basada en contratos inteligentes (*smart contracts*). Estos resultados demuestran que blockchain no funciona únicamente como una herramienta tecnológica, sino también como un recurso cooperativo compartido que refuerza la transparencia y la toma de decisiones participativa.

Asimismo, este estudio contribuye a la dimensión de gobernanza (G) de los marcos ambientales, sociales y de gobernanza (ESG), examinando cómo las redes cooperativas habilitadas por blockchain promueven la transparencia, la rendición de cuentas y la participación democrática. Al incorporar mecanismos de gobernanza en las infraestructuras digitales, las arquitecturas de blockchain de consorcio refuerzan el principio cooperativo de «un miembro, un voto», alineando así la innovación tecnológica con el desarrollo institucional sostenible e inclusivo.

La investigación amplía la Visión Basada en Recursos (Resource-Based View, RBV) y la Teoría de la Gobernanza Cooperativa al ámbito digital, demostrando cómo las tecnologías descentralizadas pueden incorporar los principios éticos del cooperativismo en sistemas algorítmicos. Las implicaciones políticas y gerenciales destacan la necesidad de promover una transformación digital liderada por las propias cooperativas, establecer entornos de prueba regulatorios (*blockchain sandboxes*) con apoyo gubernamental e implementar iniciativas de capacitación que garanticen una adopción equitativa de estas tecnologías.

El estudio concluye que blockchain de consorcio ofrece un marco escalable, democrático y resiliente para la digitalización de las cooperativas, con capacidad para fortalecer la continuidad de las cadenas de suministro, la inclusión social y el empoderamiento económico local.

Palabras clave. Trazabilidad, transparencia, sostenibilidad, participación, tecnología digital, contratos inteligentes.
Claves Econlit. J54, O33, O14, Q56

ENG Consortium Blockchain architectures for ESG-Driven democratic governance and supply chain resilience in textile cooperatives

ENG **Abstract.** This study explores the application of consortium blockchain technology as a transformative mechanism for enhancing transparency, accountability, and democratic governance within textile cooperatives in Tamil Nadu, India. The research builds upon the principles of the Protection, Participation, and Profitability (3P) model of cooperative management, integrating digital innovation with traditional cooperative values. Through a pilot study involving selected textile cooperatives, the research examines blockchain's potential to improve financial feasibility, operational traceability, and member trust. Preliminary results indicate a 15% increase in average Net Present Value (NPV), a 40% reduction in

traceability errors, and over 75% member acceptance of smart-contract-based governance. These findings demonstrate that blockchain functions not merely as a technological tool but as a shared cooperative resource, reinforcing transparency and participatory decision-making.
This study further contributes to the governance (G) dimension of Environmental, Social, and Governance (ESG) frameworks by examining how blockchain-enabled cooperative networks foster transparency, accountability, and democratic participation. By embedding governance mechanisms into digital infrastructures, consortium blockchain architectures reinforce the cooperative principle of "one member, one vote," thereby aligning technological innovation with sustainable and inclusive institutional development.
The study extends Resource-Based View (RBV) and Cooperative Governance Theory into the digital domain, illustrating how decentralized technologies can embed cooperative ethics into algorithmic systems. Policy and managerial implications emphasize the need for cooperative-led digital transformation, government-supported blockchain sandboxes, and training initiatives to ensure equitable adoption. The research concludes that consortium blockchain offers a scalable, democratic, and resilient framework for cooperative digitization, capable of strengthening supply chain continuity, social inclusion, and local economic empowerment.
Keywords. Traceability, transparency, sustainability, participation, digital technology, smart contracts

Summary. 1. Introduction and background. 2. Research objectives / Questions. 3. Literature review / Theoretical framework. 4. Methodology and data. 5. Key findings / Results. 6. Discussion and implications. 7. Conclusion and recommendations. 8. References.

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1. Introduction and background

Because of its textile industry, Tamil Nadu is a major part of India's industrial economy. This setting needs textile cooperatives to help individuals make a living, distribute wealth fairly, and develop local production ecosystems. Cooperatives focused on democratic governance, communal welfare, and common ownership shield small-scale farmers and workers from global supply chain uncertainty (Lanzer, 2025). Despite their importance to society and the economy, many cooperatives struggle with disconnected operational systems, imprecise data flows, inadequate traceability, and a lack of digital integration. These problems reduce openness, accountability, and competitiveness as global markets demand verified sustainability, ethical sourcing, and digitally traceable industrial processes.

Blockchain technology offers a revolutionary solution to these systemic issues. Blockchain, first used for digital currency, is now a distributed ledger technology that ensures immutable records, independent verification, and secure data transfer. Transparent and real-time supply chains may now track material origins, transaction histories, and contractual obligations. Blockchain goes beyond technology to rethink cooperative leadership, openness, and trust, especially for emerging-market companies (Thanasi-Boçe & Hoxha, 2025). Decentralising record-keeping and decision-making makes blockchain technology compatible with cooperative ideals, including democratic participation, member control, and fair benefit sharing.

1.1. Context of Blockchain adoption in the textile cooperative sector

More corporations, consumers, and authorities are pressuring the textile and garment industry to manufacture ethically and sustainably. Transparent supply chains that track and verify all fibre production and distribution phases have become more important since the outbreak. After high-profile examples of worker exploitation, bogus goods, and environmental violations, several well-known firms and organisations have adopted blockchain-enabled traceability solutions. Lenzing AG, an Austrian fibre company, uses blockchain traceability through Textile Genesis to track every batch of fibre from its origin to the finished garment. Many international brands have tested blockchain technology to verify organic certifications and environmental impacts, including H&M and Patagonia. However, blockchain adoption is minimal in developing countries of South Asia, notably in Tamil Nadu's cooperative-dominated textile clusters. Despite their vital role in production and employment creation, cooperatives often operate in analogue environments with poor data infrastructure.

Due to handwritten production logs, payment records, and member contributions, most systems cannot provide real-time visibility and traceability (Boçe & Hoxha, 2024). Lack of digital transparency risks undermining members' and other parties' (auditors, certifying agencies, and buyers) trust in cooperatives. Spin, weave, dye, and garmenting cooperatives operate in Tamil Nadu's Coimbatore, Erode, Tiruppur, and Dindigul. After India's independence, many of these cooperatives grew during the industrialisation boom rather than being established primarily to maximise profits. These cooperatives have struggled to update their internal systems to keep up with the globalised and digital textile sector. Industry 4.0 supply chains conflict with cooperative governance, but blockchain technology integration may help. Multiple cooperatives can use consortium-based blockchain technologies to validate transactions, production data, and governance choices on a common ledger. This capability enables transparent decision-making, efficient auditing, and authentic sustainability claim verification for cooperatives competing in digital-first global

markets.

Blockchain's cooperative nature makes it suited for decentralised enterprises. Participant trust, openness, and shared ownership underpin both systems. A cooperative blockchain consortium can verify records, enforce democratic smart contracts, and prevent data manipulation. For instance, using the blockchain to record industrial output or raw material acquisition gives all cooperative network participants certified data, reducing disagreements and information asymmetry (Ahmed & MacCarthy, 2021). Blockchain technology can also automate smart contracts, which follow cooperation and operational standards. Digital tools ensure the cooperative's democratic culture and fair and transparent execution of decisions like profit-sharing, dividend distribution, and resource allocation. Blockchain-enabled technologies could improve transparency for Tamil Nadu textile cooperatives in several ways. First, greater traceability meets ethical and international buyers' expectations by making cotton, yarn, and fabric origins verifiable and unchangeable (Qiao et al., 2025). Second, audit-ready ledgers reduce fraud and internal mismanagement, making financial transactions more accountable. Third, it empowers members by allowing them to follow cooperative development, vote in governance decisions online, and be recognised for their work. Fourth, blockchain links small cooperatives into consortiums, giving them collective negotiating strength and improving market and funding access without intermediaries.

1.2. Challenges faced by Tamil Nadu cooperatives

Despite their cultural and economic significance, textile cooperatives in Tamil Nadu face a multitude of structural and operational challenges that impede efficiency, innovation, and competitiveness. These challenges can be broadly categorized into **fragmented processes, data opacity, and governance inefficiencies**, each of which hinders the potential for modernization and sustainable development.

a) Fragmented processes and lack of integration

Most textile cooperatives have separate divisions for sourcing, production, distribution, and member services that use semi-digital or manual methods. Delays, discrepancies, and incomplete information are often shared between departments. Failure to update yarn procurement data can cause budget discrepancies, overstock, and misaligned production plans. Paper communication between spinning and weaving units promotes human error and duplication. Disjointed procedures reduce operational agility and make stakeholder coordination harder (Maggio, 2025). Incompatible systems prevent cooperatives from connecting to bigger supply chain networks or government surveillance platforms. Cooperatives are often excluded from traceability programs and online markets promoted by multinational textile buyers. This gap prevents small producers from receiving ethical or sustainable production price premiums and inhibits global value chain visibility.

b) Data opacity and limited traceability

A key challenge for Tamil Nadu's cooperative sector is a lack of reliable data throughout production. Transactions, member contributions, and productivity are usually recorded manually or on decentralised spreadsheets with basic authentication. Members lose trust, payments are delayed, and audit errors occur. Being unable to track the entire material movement, from sourcing raw cotton to delivering finished fabric, exposes one to scams and false sustainability claims. Recently, ethical sourcing has become more scrutinised worldwide, making traceability more important. Brands and customers increasingly demand proof of product freedom from environmental infractions, forced labour, and child labour. Cooperatives often lack the means to provide independently verifiable statistics due to their complicated supply chains. Blockchain technology solves this by immutably and time-stamping recording production and transactions. The current data opacity requires standardising, validating, and digitising data inputs, which hinders system development.

c) Governance inefficiencies and member participation gaps

Democratic governance is the hallmark of the cooperative concept, yet many Tamil Nadu textile cooperatives lack transparency in decision-making and member engagement. Board decisions often favour a few members or are mediated by outside parties, limiting diversity. The information gap between management and regular members is eroding trust.

When members can't see the full picture in financials, operations, or strategic decisions, they lose faith in cooperative leadership (Wahome, 2025). Traditional consensus-building approaches like voting are slow and procedurally flawed. Profit sharing and leadership elections are decided at yearly general meetings, which are often postponed or poorly attended. The cooperative principle of "one member, one vote" is eroded. Manual paperwork delays and increases human error and manipulation, impeding compliance reporting and auditing governance. Blockchain smart contracts offer a digital alternative by incorporating cooperative rules into automated governance systems. For instance, on-chain transparent voting makes each member's vote immutable and verifiable. Project approval and fund distribution can be automated at certain levels of agreement. This encourages openness and confidence while reducing cooperative management administrative burden. Such solutions require digital literacy, technological infrastructure, and institutional support, which Tamil Nadu cooperatives lack.

d) Financial constraints and technological readiness

Cooperatives also struggle with digital transformation due to resource and knowledge shortages. Poor

margins, government subsidies, and limited financial reserves make blockchain investment difficult. Many cooperatives lack IT staff and affordable digital technology, making adoption difficult and expensive. Members' digital literacy differences limit system usage and acceptability (Kanjere, 2021). Pilot projects and state-level initiatives have digitalised some industries, but widespread use of blockchain technology will require a deeper organisational and cultural change than just buying hardware. This transition requires reinventing trust, data processing, and governance.

e) External market and policy pressures

Global compliance frameworks are increasingly affecting the textile industry. The U.S. Uyghur Forced Labour Prevention Act (UFLPA) and EU Corporate Sustainability Due Diligence Directive (CSDDD) demand ethical sourcing. Without digital traceability, export markets and supply alliances may not accept cooperatives. Interoperable data systems for certification and reporting are needed for India's "India Chain" program and the Ministry of Textiles' e-labelling programs, two internal policies that are heading towards digital integration. Tamil Nadu cooperatives risk being excluded from national and worldwide textile networks unless they change soon.

1.3. The need for digital democratic governance

This convergence of issues emphasises the need for a supply chain-wide paradigm shift in cooperative data management, decision-making, and stakeholder involvement. Blockchain consortium architecture, where cooperatives and regulatory entities share a distributed ledger, is viable and extensible. This architecture embeds democratic decision-making in smart contracts and guarantees data ownership through transparent recordkeeping and tamper-resistant audits.

Moving from centralised, paper-based governance to distributed digital solutions will help Tamil Nadu textile cooperatives fight fraud and market volatility, meet international requirements, and promote member engagement (Aamir, 2023). The cooperative is aligning its core goals of justice, involvement, and trust with digital needs of accountability, traceability, and openness by using blockchain technology.

The integration of blockchain technology into Tamil Nadu textile cooperatives is a major step towards democratising digital change in a socially important and labour-intensive Indian industry. It may help link compartmentalised and untrustworthy systems into sturdy, interconnected webs that promote economic efficiency and cooperative honesty. This project will examine consortium blockchain designs to fulfil these goals and prepare the textile sector for cooperatively led, inclusive technology integration.

1.4. The role of Blockchain in ensuring transparency, traceability, and resilience

Blockchain technology could revolutionise decentralised information, commerce, and governance. Cryptographic security, distributed validation, and immutability tackle the challenges of centralised databases and inaccessible records in traditional supply chain management systems. In textile cooperatives, blockchain technology can improve transparency, traceability, and resilience across the value chain. The transfer of commodities and information involves cotton producers, spinners, dyers, weavers, and distributors.

a) Enhancing transparency through decentralized records

Transparency has long been a concern in textile production due to power asymmetries, subcontracting, and complex supplier networks. Traditional recordkeeping relies on government agencies, cooperative boards, or lead buyers to collect and verify production statistics. Centralization-induced delays, data manipulation, and selective disclosure can damage buyer and member confidence. All authorised parties can see the timestamps and records of all transactions, certificates, and operational activities using blockchain technology.

This eliminates middlemen and gives stakeholders and cooperative members real-time production volumes, payment transactions, and compliance documentation. Blockchain smart contracts can automatically validate contractual conditions like payment milestones and quality benchmarks, triggering applicable actions transparently (Selvaprabhu, 2023). Payment delays, quality grading, and profit-sharing commonly cause conflict in Tamil Nadu cooperative mills. Blockchain-enabled transparency can help handle these concerns and reduce misunderstandings.

Transparency goes beyond operations because it builds confidence. When cooperative members can independently verify facts without management's input, confidence is rebuilt. This is crucial in member-owned organisations because trust in each other's knowledge is important. Clear digital records can improve auditors', banks', and buyers' reputations, making it simpler for cooperatives to get loans or access export markets by proving compliance and ethics.

b) Strengthening traceability and authenticity

Global textile markets increasingly want traceability, or the ability to track a product from manufacturer to customer. Ethical and sustainable sourcing certifications like GOTS and Fair Trade require verifiable data at every manufacturing stage. Multi-tiered verification is too much for manual approaches. Blockchain technology assigns a cryptographic hash to each production action, preventing data changes.

A Tamil Nadu cooperative might utilise the blockchain to keep each batch of yarn or fabric's unique digital ID. From dyeing to weaving to finishing, everything is tracked on-chain. Every inspection, shipment, and payment is recorded on the blockchain, creating a transparent and traceable transaction history (Huubse,

2025). This creates a digital copy of the real thing, ensuring its authenticity, quality, and provenance. Cooperations that offer ethically conscious markets can boost brand value by fighting counterfeit goods and providing consumers with certified product origin information.

Blockchain traceability can assist regulators and trade groups in monitoring environmental and labour norms. E-labelling systems or certifying organisations can integrate blockchain records to accelerate audits and minimise paperwork for cooperatives. Small enterprises often struggle with complex regulatory paperwork, making efficiency even more crucial. Blockchain data interoperability allows real-time environmental monitoring using IoT sensors or QR code solutions. This involves monitoring dyeing unit water use and processing plant emissions.

c) Building supply chain resilience through decentralization

Supply chain managers now view resilience, "the ability of a system to endure shocks and recover from disruptions," as a strategic need. The COVID-19 pandemic, global trade disruptions, and raw material shortages have weakened centralised textile networks. Since they have fewer middlemen and operate in more regional markets, cooperatives were more exposed to these shocks due to data transparency and coordination issues.

Blockchain's decentralised architecture enhances resilience by spreading control and verification across network participants (Dzreke, 2025). No data loss or operational collapse will occur if other cooperative or intermediary nodes fail to use the shared ledger. Smart contracts in blockchain technology can rapidly reroute production orders or switch suppliers during disruptions.

Since supply bottlenecks, transportation delays, and market volatility affect Tamil Nadu cooperatives, decentralised resilience solutions like these can help. Blockchain combined with digital finance systems and predictive analytics can decrease third-party brokers and financial risks for cooperatives. This facilitates real-time and informed decision-making. Blockchain ensures fair participation and equal recovery during crises, improving operational continuity and socio-economic resilience.

Blockchain is a socio-technical framework that advocates openness, verifiability, and robustness. It transforms cooperatives from top-down, paper-based organisations into bottom-up, digitally-connected ecosystems based on trust and verified responsibility, ensuring cooperative identity and sustainability

1.5. Justification for focusing on consortium architectures and democratic governance

A consortium blockchain architecture was selected for its combination of decentralization, efficiency, and governance control, which supports the cooperative model of shared ownership and democratic decision-making. Unlike public blockchains, which are inefficient for sensitive data, and private blockchains that enhance centralization, consortium blockchains allow collaborative governance where stakeholders share a ledger. This structure empowers smaller cooperatives, fosters procedural fairness through smart contracts requiring multi-signature consent, and addresses the challenges faced by underdeveloped economies.

By utilizing permissioned ledgers, consortium models enhance transaction speed and reduce costs, ensuring compliance with local data protection laws (Merlec & In, 2024). Blockchain smart contracts further streamline cooperative operations, allowing for automated voting and dividend distribution, thus enhancing accountability and preventing manipulation. Overall, consortium architectures provide scalable solutions that contribute to digital inclusion and sustainable development, positioning cooperatives as leaders in ethical and community-driven technology integration.

1.6. Conceptual clarification of consortium Blockchain, networks, and DAOs

A consortium blockchain is a permissioned distributed ledger governed collaboratively by multiple authorized entities, such as cooperatives, regulatory bodies, and supply chain stakeholders. Unlike public blockchains, which allow unrestricted participation, and private blockchains, which are controlled by a single organization, consortium blockchains offer a balanced model of decentralization, efficiency, and shared governance.

In cooperative ecosystems, consortium blockchains function as digital governance networks that enable secure data sharing, consensus-based decision-making, and transparent auditing. These networks align closely with cooperative principles of collective ownership and democratic participation.

Furthermore, the emergence of Decentralized Autonomous Organizations (DAOs) illustrates how blockchain-based governance can automate institutional processes through smart contracts, facilitating decentralized voting, resource allocation, and stakeholder coordination.

Although DAOs represent a fully decentralized governance paradigm, consortium blockchains provide a more practical and legally compliant framework for cooperatives by combining technological decentralization with institutional accountability. Consequently, consortium architectures serve as a transitional model bridging traditional cooperative governance with emerging decentralized digital ecosystems.

2. Research objectives / Questions

- **Primary aim:** To explore how consortium blockchain can enhance cooperative governance and supply chain resilience.
- **Specific objectives:**

1. Quantify the financial viability of shared-ledger implementations.
2. Identify governance mechanisms embedding cooperative principles.
3. Evaluate operational improvements in traceability and fraud reduction.
4. Develop a scalable democratic blockchain adoption framework.

- **Research questions:**
  1. How does blockchain enhance transparency and member trust in cooperatives?
  2. What governance structures best align with cooperative principles?
  3. What are the measurable financial and operational impacts?

3. Literature review / Theoretical framework

Blockchain technology has rapidly emerged as a transformative tool in global supply chain management, particularly in industries characterized by complex, multi-tiered supplier networks such as textiles and fashion. Its promise lies in addressing longstanding issues of opacity, inefficiency, and ethical non-compliance that have plagued traditional supply chain systems.

The literature on blockchain in supply chains, while still evolving, has grown substantially since 2017, focusing on how distributed ledger technologies (DLTs) enhance transparency, traceability, and sustainability. This review synthesizes current theoretical and empirical studies, highlighting the experiences of major textile companies such as **Lenzing AG** and the **Textile Genesis** platform, and examines how blockchain applications contribute to broader goals of sustainable and ethical production.

3.1. Blockchain and the transformation of supply chain transparency

Traditional, opaque, and linear supply chains lack insight beyond proximate suppliers. Lack of transparency between producers, middlemen, and customers hides immorality concerns such as child labour, environmental damage, and phoney goods. According to Saberi et al. (2019), blockchain technology allows real-time, immutable recording of all network transactions, creating a new sort of distributed transparency. Any member of a blockchain-enabled supply chain can independently verify data, improving trust and accountability. Food and pharmaceutical studies have shown that blockchain technology can reduce fraud and increase traceability (Taheri Hosseinkhani, 2025). Blockchain technology might securely record and exchange raw material, production, certification, and logistical data in the textile business. Customers want ethical production and less environmental impact; thus, this helps prove sustainability promises. Blockchain-based solutions can track organic cotton from its origins to the garment using verifiable digital signatures. Tracking ensures compliance with sustainability standards like GOTS or OEKO-TEX, reducing "greenwashing" risk. Blockchain is a technical breakthrough and a governance tool that empowers customers through transparency and regulation enforcement (Leal Filho et al., 2020).

3.2. Case study: Lenzing AG and the use of Blockchain for fibre traceability

Austrian company Lenzing AG develops sustainable cellulose fibres, including TENCELTM and LENZING ECOVEROTM and was one of the first textile firms to employ blockchain technology. Lenzing teamed with Textile Genesis, a blockchain-based digital platform, to enable end-to-end traceability for its fibres to meet market demand for sustainable and traceable textiles. This alliance has been cited in academic and business publications as a sustainable blockchain use. Lenzing's blockchain effort lets manufacturers and retailers verify fibre origin across the supply chain (Fattahi Bafghi, 2024). Every batch of fibre is issued a "Fibercoin" and tracked through the supply chain as it is processed into yarn, fabric, and clothing.

These tokens are unchangeable digital authenticity certificates. Textile Genesis's blockchain records every transaction from fibre delivery to garment creation to build a digital supply chain. Three notable Lenzing case results are in the literature. Blockchain technology allowed supply chain parties to verify item provenance and processing without paperwork, improving confidence and data integrity. Second, it let brand partners share verified sustainability pledges with customers. Finally, blockchain's scalability was shown by Lenzing's methodology's applicability to many fibres and products. This program increased supply chain transparency, helping Lenzing achieve its circular economy goals, according to Brown (2024).

The Lenzing case study highlights how blockchain technology might help ESG reporting and other corporate sustainability standards. Textile Genesis automates sustainability parameter verification to create an immutable audit trail, improving ESG disclosure dependability. Because businesses can prove their ethical claims with data, blockchain improves operational transparency and institutional credibility.

3.3. The Textile Genesis platform: a digital infrastructure for sustainability

Textile Genesis, founded in 2018, is a premier blockchain-based textile traceability platform. This system, designed for fashion and garment value chains, tracks organic cotton, recycled polyester, and man-made cellulosic fibres. Blockchain technology and fiber-to-retail traceability allow the platform to track materials throughout manufacturing.

The hybrid blockchain architecture of Textile Genesis protects public and private data while retaining openness. This architecture keeps sensitive business data like supplier pricing and formulation confidential while preserving an immutable record of material provenance. Textile Genesis integrates sustainability standards and certification organisations to increase verification accuracy. The platform can automatically sync certification data with Lenzing E-Branding Service, OEKO-TEX, and Higg Index. Since its founding, Textile Genesis has been credited with overcoming the sustainability "last-mile verification problem" (Saurabh et al., 2023) in academia. It has been difficult to ensure downstream vendors met sustainability

standards once goods left licensed producers. The immutable ledger of blockchain technology eliminates this uncertainty and ensures digital continuity across the supply chain. This new idea lets shoppers scan a QR code to discover their items' full history, building trust between firms, suppliers, and consumers.

The research warns that scaling such systems across disconnected supply chains is difficult. Implementation costs, data standardisation issues, and suppliers' digital capabilities remain issues. Textile Genesis offers modular adoption to help suppliers digitise processes and join. Blockchain ecosystems may evolve steadily, not disruptively.

3.4. Blockchain and sustainability applications in the textile sector

In addition to traceability, textile blockchain applications are increasingly focused on environmental, social, and governance sustainability. According to stakeholder theory and institutional theory, which underpin these applications, sustainable practices arise when corporations align technical innovation with stakeholder expectations and regulatory frameworks. Blockchain technology gives customers, brands, regulators, and producers access to a verifiable record, enabling this alignment. Blockchain technology promotes environmental sustainability by providing verified recycling, emission, and resource use data. Circular IDTM and IBM's Textile Traceability Initiative track waste-reduction and closed-loop manufacturing systems using blockchain technology. Blockchain-based product passports record material composition information to aid garment recycling and reuse. This supports the circular economy model's waste reduction and material reuse goals. Blockchain technology supports ethical sourcing and fair work, which benefits society. (Martinez-Trejo, 2024) and others found that blockchain technology can reduce compelled or underpaid labour by generating transparent digital ledgers of labour audits, salary payments, and worker certifications. Blockchain technology can directly record member contributions and automate equitable pay-outs using smart contracts in cooperative or small-producer networks to ensure fair compensation and stakeholder trust. Blockchain reduces manual documentation and verification costs, improving economic efficiency. Smart contracts, automatic algorithms that execute pre-defined agreements when specific criteria are met, are a crucial new governance instrument. Smart contracts could enable democratic control and shared ownership in cooperative supply chains. Blockchain and cooperative governance promote decentralisation, openness, and communal decision-making. Scholars (Wu et al., 2022) recommend blockchain for community-based organisations aiming to digitise, since its consensus mechanisms imitate cooperative voting.

Among the three pillars of ESG, governance represents a critical dimension for cooperatives, as it embodies democratic participation, transparency, and accountability. Blockchain technology strengthens this governance dimension by embedding verifiable decision-making mechanisms within decentralized networks. In cooperative ecosystems, distributed ledger technologies facilitate transparent voting, equitable profit-sharing, and immutable record-keeping, thereby reinforcing institutional trust. As highlighted by Navarro Lérida (2023), blockchain, tokenization, and decentralized autonomous organizations (DAOs) have the potential to transform governance structures by promoting participatory and sustainable business models.

3.5. Theoretical underpinnings: Socio-Technical Systems and Trust Theory

The theoretical foundation of this study integrates Socio-Technical Systems Theory, Trust Theory, and four key organizational frameworks—Resource-Based View (RBV), Institutional Theory, Cooperative Governance Theory, and the Technology Acceptance Model (TAM)—to explain blockchain adoption in textile cooperatives. Socio-technical systems theory highlights that blockchain, as both a technological and social innovation, transforms trust, power, and governance relationships, while trust theory reframes traditional interpersonal or institutional trust into computational trust based on transparency and consensus. The RBV positions blockchain as a strategic, inimitable resource that enhances cooperative competitiveness through immutable data, cost efficiency, and resilience, especially via shared digital infrastructures. Institutional theory explains adoption pressures—normative (ethical governance), coercive (regulatory traceability demands), and mimetic (industry imitation)—that drive cooperatives to seek legitimacy through blockchain. Cooperative governance theory demonstrates how smart contracts can encode democratic principles, enabling transparent voting, equitable profit-sharing, and decentralized oversight, reinforcing accountability and member empowerment (Badi, 2025). Finally, TAM captures the human side of adoption, where perceived usefulness, ease of use, and participatory training determine members' willingness to engage with blockchain tools. Together, these perspectives position consortium blockchain as a socio-technical enabler of cooperative trust, digital democracy, and organizational resilience, while revealing a research gap: limited empirical evidence linking blockchain-based governance to cooperative sustainability and member empowerment in developing economies like Tamil Nadu's textile sector.

3.5.1. Integrative theoretical framework

To establish a cohesive conceptual foundation, this study integrates the Resource-Based View (RBV), Cooperative Governance Theory, Institutional Theory, the Technology Acceptance Model (TAM), Trust Theory, and Socio-Technical Systems Theory. While RBV conceptualizes blockchain as a strategic and inimitable digital resource, Cooperative Governance Theory explains its role in reinforcing democratic participation and transparency. Institutional Theory highlights the regulatory and normative pressures driving digital adoption, whereas TAM explains user acceptance based on perceived usefulness and ease of use.

In decentralized digital environments, blockchain mitigates information asymmetry by enabling immutable record-keeping, automated verification, and consensus-driven governance. This capability enhances trust among cooperative members and stakeholders while strengthening accountability and transparency. The convergence of these theoretical perspectives provides a robust analytical lens for examining blockchain-enabled governance and supply chain resilience in textile cooperatives.

3.6. Synthesis: Consortium Blockchain as a socio-technical enabler of collective trust

Consortium blockchain integrates several theoretical frameworks to understand strategic, institutional, and social collaborative resilience. Consortium blockchains, unlike public or private blockchains, are semi-decentralized and managed by many stakeholders. They are ideal for cooperative entities with shared ownership and decision-making.

RBV believes consortium blockchains can help firms create distinctive, shared data ecosystems.

Institutional Theory aligns cooperatives with normative and coercive openness and sustainability requirements.

Digital ecosystems become more democratic and egalitarian via Cooperative Governance Theory.

It captures TAM adoption behaviour to ensure technology integration matches user perception and member confidence.

These views agree that blockchain technology's cooperative governance requires social and computational trust. Blockchain transforms cooperative collaboration, decision-making, and resilience (Haughton, 2024). The socio-technical framework recognises this.

Blockchain promotes human collaboration through verifiable digital agreements, according to this assessment. Thus, consortium blockchain is a new cooperative architecture that integrates transparency, accountability, and participation into governance and operations.

From an architectural perspective, consortium blockchain systems operate across multiple governance layers, including the infrastructure layer (distributed ledger technology), the protocol layer (consensus mechanisms and smart contracts), and the application layer (cooperative governance and supply chain management). This multi-layered structure enhances clarity regarding the relationship between networks, consortium models, and DAO-inspired decentralized governance.

3.6.1. Hypotheses development

Based on the theoretical synthesis, the following hypotheses are proposed:

H1: Consortium blockchain adoption positively influences transparency in textile cooperatives.
H2: Blockchain-enabled transparency significantly enhances member trust.
H3: Blockchain adoption improves operational efficiency and supply chain traceability.
H4: Smart-contract-based governance strengthens democratic participation and accountability.
H5: Transparency mediates the relationship between blockchain adoption and cooperative resilience.
H6: Perceived usefulness and ease of use significantly influence blockchain adoption among cooperative members.

3.7. Identified research gap

Academics are interested in blockchain-enabled supply chains, but most of the research has focused on developed-world implementations driven by enterprises or brands. Lenzing AG, IBM Textile Initiative, and Textile Genesis show how blockchain technology may improve sustainability and traceability in structured contexts with considerable digital infrastructure.

Despite being common in emerging markets like India's textile sector, the cooperative-driven adoption strategy has garnered little attention. There is little empirical data tying blockchain-based governance tools to cooperative resilience outcomes, including democratic participation, member trust, and crisis adaptability. Current research often regards blockchain as a technical intervention rather than a social and organisational system, ignoring the human and governance dimensions required for cooperative success. Thus, this study meets two needs: Blockchain research has two gaps: (1) a lack of empirical data on blockchain's effects on cooperative network governance in the real world, and (2) a conceptual gap between cooperative governance theories and technology acceptability. This project designs and tests a consortium blockchain governance model for Tamil Nadu textile cooperatives to better understand how distributed ledger systems might increase cooperative resilience, democratic control, and monetary and social value generation. RBV and TAM theory are used to provide a blockchain-enabled cooperative transformation paradigm

4. Methodology and data

4.1. Research design

The research adopts a mixed-method design integrating both quantitative and qualitative approaches to capture the multidimensional aspects of blockchain adoption in textile cooperatives. This methodological triangulation ensures robustness in findings, balancing empirical data with rich contextual insights. The study specifically examines how blockchain technologies—particularly consortium-based architectures—enhance transparency, traceability, and governance resilience within Tamil Nadu's cooperative textile ecosystem. The research design is structured into three interlinked components: quantitative surveys, qualitative interviews, and a pilot case study involving a blockchain deployment.

Quantitative component
The quantitative phase focuses on a structured survey conducted among 100 members and managers across two cooperative societies located in Tamil Nadu—one in an urban industrial cluster (such as Coimbatore) and another in a rural textile production area (such as Erode). The survey aims to quantify members' perceptions regarding blockchain's impact on operational efficiency, transparency, and governance trust.

The instrument comprises both Likert-scale items and categorical variables, capturing data on technological readiness, perceived usefulness, and financial expectations. This phase helps identify measurable trends across different cooperative roles and demographic contexts, contributing to generalizability.

Qualitative component
The qualitative strand complements the numerical data by providing interpretative depth. Semi-structured interviews are conducted with key stakeholders—namely board members, technology solution providers, policymakers, and cooperative auditors. The interview design emphasizes open-ended questions to elicit nuanced understandings of blockchain implementation challenges, governance expectations, and the socio-technical dynamics shaping cooperative digital transformation. These conversations explore both enablers and barriers to adoption, such as digital literacy gaps, cultural resistance, and infrastructural constraints, offering insights beyond what quantitative surveys can reveal.

Case study component
To ground the research in real-world practice, a pilot blockchain deployment is carried out using a platform modelled on Textile Genesis, which is a well-known blockchain solution for sustainable textile traceability. This pilot involves mapping the cooperative's cotton-to-yarn supply chain—from farmer cooperatives to spinning units—on a permissioned blockchain ledger. The pilot aims to test key functionalities such as transaction recording, tokenized tracking of textile batches, and integration of cooperative member approvals via smart contracts. By embedding cooperative governance principles into the pilot's architecture, the study captures operational and social implications of blockchain adoption within a controlled, observable environment.

4.2. Data collection
Sampling and site selection
Data collection is conducted over a six-month period, strategically encompassing both rural and urban cooperative contexts to reflect the diversity of Tamil Nadu's textile ecosystem. The two cooperatives selected differ in scale, governance maturity, and digital exposure, offering a comparative basis for analysis. A purposive sampling method is used for interviews and case study participation to ensure inclusion of individuals with relevant expertise and decision-making authority.

Sampling justification
The sampling strategy combines stratified random sampling and purposive sampling to ensure representativeness and analytical depth. Stratified sampling enables proportional representation of cooperative members and managers across functional divisions, thereby enhancing the generalizability of findings. Purposive sampling is employed for interviews to select participants with domain expertise, including policymakers, auditors, and blockchain solution providers. This methodological approach ensures both statistical validity and contextual richness.

The survey sampling, by contrast, follows a stratified random approach—members and managers are selected proportionately based on cooperative size and department. This design ensures representativeness across different roles, including production, finance, and marketing divisions. Ethical considerations, such as informed consent and confidentiality, are strictly observed, consistent with qualitative research ethics and local cooperative norms.

Data collection tools
Data are gathered through three primary tools:

1. **Structured questionnaires** for the survey, distributed both digitally (via Google Forms) and physically where digital access is limited.
2. **Interview protocols** containing guiding themes but allowing flexibility for follow-up probing.
3. **Blockchain pilot documentation**, including system logs, transaction audit reports, and participant feedback during user training and simulation.

Each tool is pre-tested for clarity, reliability, and contextual fit. The questionnaire's Cronbach's alpha is targeted at above **0.75** to confirm internal consistency, while interview guides are validated through expert review by cooperative management scholars.

4.3. Data analysis
Thematic coding
Qualitative data from interviews and case observations are analyzed using thematic coding, employing either NVivo software or a manual coding protocol where software access is constrained. Transcripts are

first subjected to open coding, identifying key themes such as transparency, accountability, participation, and trust. These codes are then clustered into higher-order categories aligned with theoretical constructs from Institutional Theory, Cooperative Governance Theory, and Technology Acceptance Model (TAM). The aim is to trace how blockchain adoption reshapes institutional logics, member attitudes, and governance processes.

Quantitative analysis

Survey data are analyzed through descriptive and inferential statistics using software such as SPSS or R. Descriptive measures summarize participant demographics, technological exposure, and perceptions of blockchain benefits. Inferential tests—such as correlation analysis and multiple regressions—explore relationships between perceived usefulness, ease of use, and member satisfaction. A structural equation model (SEM) may be employed to test the mediating role of trust between blockchain transparency and cooperative participation.

Economic modeling

To evaluate financial feasibility, economic modeling techniques are applied, specifically Net Present Value (NPV) and Payback Period calculations across a five-year horizon. Cost and benefit estimates are derived from pilot data and cooperative financial statements. The analysis captures both capital expenditures (CapEx), including infrastructure and software investment, and operational expenditures (OpEx), such as maintenance and training costs. Expected benefits include audit savings, fraud reduction, and efficiency gains in traceability. A positive NPV and acceptable payback period (typically under three years) would signify blockchain's economic viability for cooperatives.

Economic and statistical models

To evaluate financial feasibility, the Net Present Value (NPV) method is applied using the following formula:

$$NPV = \Sigma [Ct / (1 + r)^t] - C_0$$

where **Ct** represents net cash inflows, r denotes the discount rate, **t** indicates time in years, and $\mathbf{C_0}$ represents the initial investment.

Quantitative data are analyzed using descriptive statistics, correlation analysis, multiple regression, and Structural Equation Modeling (SEM). These techniques examine relationships among blockchain adoption, transparency, trust, and governance efficiency. Statistical significance is evaluated at a 95% confidence level.

4.4. Key variables

To systematically assess blockchain's impact, the study identifies a set of financial, operational, and governance variables that together reflect cooperative resilience and sustainability.

Financial metrics

- **Capital Expenditure (CapEx):** Initial investment in blockchain infrastructure, training, and integration.
- **Operational Expenditure (OpEx):** Recurring costs for maintenance, digital certification, and node management.
- **Audit Savings:** Reduction in manual auditing costs due to immutable ledger verification.

Operational metrics

- **Traceability Accuracy:** The precision and reliability with which raw materials and finished goods can be tracked through blockchain tokens.
- **Fraud Incidents:** Frequency and magnitude of misreporting, inventory manipulation, or misappropriation before and after blockchain adoption.

Governance metrics

- **Member Participation:** Extent of involvement in decision-making processes facilitated by blockchain-enabled voting or consensus mechanisms.
- **Trust and Satisfaction:** Members' perceived confidence in cooperative transparency and fairness post-implementation.
- **Governance Efficiency:** Speed and quality of decision execution, as smart contracts automate approval workflows.

These variables are cross-validated across data sources—survey responses, interview insights, and blockchain system analytics—to ensure measurement accuracy and interpretative validity.

4.5. Validity and reliability

To ensure methodological rigor, multiple strategies are adopted for validity and reliability.

Triangulation

The study employs data triangulation by cross-verifying evidence from three distinct sources: survey results,

interview narratives, and pilot performance data. This approach mitigates bias from any single method and strengthens construct validity.

Internal validity
Instrument design and pilot testing help enhance internal validity by confirming that measurements accurately represent the intended constructs (e.g., trust, transparency, participation). Statistical tests for reliability, such as Cronbach's alpha for scales and test–retest validation for survey items, further establish measurement stability.

External validity
Although the study focuses on Tamil Nadu cooperatives, findings are positioned to hold **analytical generalizability** for similar cooperative ecosystems in developing economies, particularly those characterized by semi-formal governance structures and digital readiness gaps.

Reliability and replicability
Detailed documentation of data collection protocols and coding schemes allows replication by future researchers. All interviews are recorded (with consent), transcribed, and anonymized. Quantitative datasets are preserved in standardized formats to facilitate secondary analysis.

Bias mitigation strategies
To enhance methodological rigor, several bias mitigation strategies are employed. Inter-coder reliability is ensured in qualitative analysis through independent coding and cross-validation. Multicollinearity in regression models is assessed using the Variance Inflation Factor (VIF). Cronbach's alpha values exceeding 0.75 confirm internal consistency of survey instruments. These measures strengthen the reliability, validity, and reproducibility of the research findings.

4.6. Ethical considerations
Given the community-based nature of cooperatives, ethical sensitivity is paramount. Participants are informed of their rights to confidentiality, voluntary participation, and data withdrawal. Blockchain pilot data are pseudonymized to avoid linking identities with digital transactions. Institutional clearance from cooperative federations and ethical review boards is obtained prior to fieldwork commencement.

5. Key Findings / Results

5.1. Overview
Using a consortium blockchain framework can increase financial performance, operational transparency, and governance resilience for Tamil Nadu textile cooperatives, according to a survey-interview triangulation and prototype blockchain implementation. Despite being preliminary, the results reveal significant improvements in all impact and practicality categories.

Statistical validation of findings
To validate the empirical findings, inferential statistical analyzes were conducted. The results indicate statistically significant improvements in transparency, operational efficiency, and governance participation following blockchain implementation ($p < 0.05$). Correlation analysis demonstrates a strong positive relationship between blockchain adoption and member trust, while regression analysis confirms its significant impact on cooperative resilience.

Through replicating cooperative operations on a permissioned blockchain like Textile Genesis, smart-contract-enabled decision-making improved governance involvement, fraud incidence, and traceability accuracy. Blockchain technology increased net present value (NPV) by 15% over five years and halved the payback period to three years. These findings suggest blockchain may be economically and institutionally transformative for cooperative governance systems.

5.2. Financial feasibility
One of the primary objectives of the pilot was to assess whether blockchain adoption is financially sustainable for resource-constrained cooperatives. Using cost-benefit modeling based on collected data, the study estimated investment costs (CapEx), ongoing operational costs (OpEx), and quantifiable benefits from audit efficiency, fraud reduction, and enhanced market credibility.

The results, summarized in Table 1, demonstrate a positive NPV increase of approximately 15% compared to baseline financial performance. The payback period of three years suggests a moderate but acceptable recovery timeline for capital investment, consistent with industry norms for digital transformation projects in developing contexts.

Table 1. Financial feasibility results

Metric	Pre-Blockchain (Baseline)	Post-Blockchain (Pilot/Projection)	Change (%)	Interpretation
Net Present Value (NPV, ₹ Lakhs)**	520	598	+15%	Improved profitability due to reduced audit costs and transaction efficiency
Payback Period (Years)**	5.2	3.0	-42%	Faster investment recovery indicates economic viability
Annual Audit Cost (₹ Lakhs)**	45	30	-33%	Automated verification reduces external auditing expenses
Fraud-Related Financial Losses (%)	12	8.4	-30%	Enhanced ledger transparency minimizes financial leakages
Member Dividend Growth (%)	4.5	6.0	+33%	Higher profitability passed on to cooperative members

Source: Authors' own calculations based on financial data and cost-benefit estimates from the blockchain pilot study.

These results confirm that blockchain can enhance financial sustainability through automation and trust-based efficiencies. While initial setup costs remain a challenge, long-term savings from audit automation and fraud prevention contribute to positive financial returns.

Sensitivity analysis

A sensitivity analysis was conducted to evaluate the robustness of financial projections under varying discount rates. The analysis confirms that blockchain implementation remains economically viable across multiple scenarios, thereby reinforcing its financial sustainability for textile cooperatives.

5.3. Operational efficiency

Operational performance metrics were measured through both pilot data logs and member feedback regarding production traceability, inventory accuracy, and process integration. The blockchain platform demonstrated significant potential in reducing redundancies and ensuring end-to-end visibility across the cooperative supply chain.

Specifically, the pilot achieved a **40% reduction in traceability errors**, as each batch of cotton and yarn was assigned a tamper-proof digital token, eliminating manual discrepancies in movement records. Similarly, **fraud incidents decreased by approximately 30%**, primarily due to immutable ledger recording and multi-signature verification of transactions.

Table 2. Operational efficiency metrics

Parameter	Before Blockchain	After Blockchain	Improvement (%)	Operational Implication
Traceability Error Rate (%)	18.5	11.0	-40.5	Enhanced data integrity and process accountability
Fraud / Misreporting Cases (per annum)	20	14	-30.0	Greater deterrence due to immutable records
Average Transaction Verification Time (mins)	25	12	-52.0	Faster approvals and reduced administrative burden
Stock Discrepancy Rate (%)	10.2	6.1	-40.2	Improved real-time tracking reduces material mismatch
Digital Data Availability (%)	56	91	+62.5	Integration of all supply records in a unified ledger

Source: Authors' own calculations based on operational performance indicators and blockchain pilot records.

The operational outcomes demonstrate blockchain's ability to bridge information asymmetry within cooperative operations, providing near-real-time visibility across nodes—farmers, ginners, spinners, and cooperative management. By standardizing records through distributed ledgers, the system reduced dependency on manual reporting and increased process accountability.

5.4. Governance impact

Governance transformation emerged as one of the most notable findings of the study. Cooperative members, often facing hierarchical opacity in decision-making, experienced a new sense of empowerment through smart-contract-driven governance mechanisms.

Survey data indicated that 85% of members reported improved transparency in financial and administrative processes post-implementation. Additionally, 75% of respondents expressed willingness to adopt smart-contract governance systems for voting, audit approvals, and decision validation. This signifies a cultural shift towards digital democratic participation—a critical success factor for blockchain-enabled

cooperatives.

Table 3. Governance and member perception outcomes

Governance Indicator	Pre-Adoption (Baseline)	Post-Adoption (Pilot)	Change / Acceptance (%)	Interpretation
Perceived Transparency (Member Survey)**	62% satisfied	85% satisfied	+23 points	Blockchain ledger enhances visibility of cooperative records
Smart Contract Governance Acceptance**	40% positive	75% positive	+35 points	Growing trust in automated decision protocols
Member Meeting Attendance (%)	58	74	+28%	Easier digital participation via online platforms
Voting Turnout in Governance Decisions (%)	51	78	+53%	Blockchain voting improves inclusivity
Perceived Fairness in Decision-Making (%)	64	86	+22%	Immutable rules reduce bias and manipulation

Source: Authors' own analysis of survey responses collected from textile cooperative members.

These findings align with Cooperative Governance Theory, which emphasizes transparency, participation, and shared accountability as key determinants of institutional strength. The introduction of blockchain helped institutionalize these principles by embedding cooperative norms into the technological architecture itself, transforming governance from rule-based to code-based democracy.

5.5. Resilience outcomes

Beyond immediate financial and operational gains, blockchain's broader contribution lies in enhancing institutional and supply chain resilience. During pilot testing, blockchain-supported cooperatives showed improved continuity and adaptability in handling disruptions such as delayed raw material shipments and audit scheduling conflicts.

The immutable ledger's capacity to preserve transactional history facilitated quick verification and dispute resolution, reducing downtime. Moreover, digital tokens provided verifiable provenance information that strengthened trust among external buyers, particularly in sustainability-conscious export markets.

Table 4. Resilience and Continuity Indicators

Resilience Dimension	Observed Improvement	Key Mechanism Enabled by Blockchain
Auditability and Record Consistency	+45% increase in audit accuracy	Immutable transaction history; automated validation
Supply Chain Continuity	+30% fewer disruptions	Real-time visibility of shipments and inventory
Member Trust Index (Survey)	+28% improvement	Transparent financial reporting
External Buyer Confidence	+22% increase in engagement	Verified sustainability claims via blockchain traceability
Crisis Response Coordination	Improved by 35%	Instant access to decentralized information across nodes

Source: Authors' own analysis based on blockchain pilot observations and supply chain performance indicators.

These outcomes highlight that blockchain not only strengthens routine governance but also enhances the cooperative's ability to withstand external shocks, whether economic or logistical. This adaptive capacity underscores blockchain's potential as a resilience enabler—particularly crucial in volatile global textile markets.

5.6. Integrated interpretation

Blockchain technology unifies financial, operational, and governance outcomes, enabling cooperative modernisation. The results support Resource-Based View (RBV) predictions of blockchain as a strategic capacity that provides lasting advantage. The results further corroborate Institutional Theory and the Technology Acceptance Model (TAM), indicating how internal and external influences affect adoption.

The cooperative's digital transparency has transformed the textile supply chain and member confidence. Distributed blockchain works well with cooperative ideals of shared ownership and participatory governance because it combines technical efficiency with democratic spirit.

6. Discussion and implications

The findings from the consortium blockchain pilot provide significant insights that extend existing theoretical frameworks while offering actionable guidance for cooperative leaders, policymakers, and community stakeholders. This section discusses the broader implications of blockchain integration for cooperatives, emphasizing how decentralized systems can reconcile technological advancement with the cooperative movement's long-standing principles of democracy, equity, and shared ownership.

Multi-Level implications framework

The implications of this study are structured across three levels—micro, meso, and macro—to enhance analytical clarity and practical relevance. At the micro level, blockchain empowers cooperative members through transparent governance and equitable profit distribution. At the meso level, it facilitates collaboration among cooperative federations and industry stakeholders. At the macro level, it supports policymakers in designing regulatory frameworks that promote digital transformation and sustainable development.

6.1. Theoretical implications

This research affects how digital ecosystems use the Resource-Based View (RBV) and cooperative governance philosophy. The RBV has long held that strategic advantage comes from precious, rare, inimitable, and non-substitutable resources. This study found that blockchain is a shared strategic resource in a cooperative coalition. A distributed ledger can be co-owned and co-governed by multiple cooperatives, making the blockchain network a shared digital capability. This boosts competition and fosters mutual gain. Blockchain becomes a socio-technical tool for democratic accountability, transparency, and trust. Trust among members, authentic data that can be confirmed, and the ability to learn from each other strengthen cooperative advantages. These findings expand the RBV's application by considering cooperatives' social and institutional value creation. The research also advances cooperative governance by demonstrating how democratic control mechanisms can improve blockchain smart contracts. Traditional governance models often use manual monitoring and procedural voting, which can delay, prejudice, and undermine transparency. Smart contracts institutionalise cooperative ideas like "one member, one vote" in programmable logic for fairness, immutability, and procedural integrity. Blockchain makes governance a mathematical depiction of cooperative democracy, not an administrative process. The theoretical synthesis matches Institutional Theory because economic incentives, normative pressures (like transparency expectations), and coercive effects (like sustainability compliance in global supply chains) drive blockchain adoption. The Technology Acceptance Model (TAM) states that cooperative success depends on members' opinions of technology use and adoption ease. These models show that new digital governance methods can't work without following best practices and considering user psychology. This study fills a significant theoretical need by linking blockchain-enabled governance and collective resource advantage, establishing blockchain as a tool for cooperative resource management and an institutional mechanism that creates economic, social, and ethical value.

This study significantly contributes to the “G” dimension of ESG by demonstrating how consortium blockchain architectures enhance democratic governance in cooperative networks. By encoding cooperative principles into smart contracts, blockchain reinforces transparency, accountability, and member participation, thereby aligning digital transformation with sustainable governance models.

6.2. Managerial implications

The paper gives cooperative managers and executives a realistic digital transformation plan without compromising cooperative principles (Lanzer, 2025). The experiment showed that many cooperatives can save costs and maximise benefits by incrementally introducing consortium blockchain systems.

Blockchain technology lets management automate transaction records, streamline audits, and increase supply chain coordination while keeping transparency. The system's distributed architecture supports cooperative cooperation by giving cooperatives autonomy over their data while contributing to a common network.

The emergence of smart-contract governance frameworks also affects managers. Programmable contracts can include voting, profit sharing, and compliance checks for procedural fairness and administrative efficiency (Thanasi-Boçe & Hoxha, 2025). Automating operations using confirmed blockchain data improves system efficiency and confidence. Periodic pay-outs or quality certifications are examples.

The trial outcomes also inspire managers to adopt participatory digital leadership. Blockchain deployment requires cultural adaptation as well as technological preparation. Training, interactive seminars, and awareness campaigns are needed to build member confidence in digital systems. Cooperative leaders must simplify members' social and economic goals by weaving attractive tales based on shared values around innovative technology ideas to drive change.

Blockchain technology allows managers to reinvent roles and responsibilities, creating a more open, inviting, and responsive culture to employee feedback and ideas.

6.3. Policy implications

These results demonstrate the policy need for a well-defined framework to encourage cooperative digitalisation in India and the Asia-Pacific. The experiment shows that consortium blockchain designs can work for decentralised public infrastructure with the correct institutional support.

Governments and cooperative federations can facilitate pilot tests in defined regulatory contexts by constructing policy sandboxes. Blockchain applications like traceability certification and transparent procurement might be tested by cooperatives without financial or legal constraints.

Equal adoption by medium and small cooperatives requires government incentives, capacity-building programs, and digital literacy campaigns. Many rural cooperatives cannot independently use blockchain technology (Boçe & Hoxha, 2024). State or regional cooperative federations can run shared service platforms to alleviate digital inclusion barriers.

Tokenised data, digital ledgers, and smart contracts can support cooperative governance, but legal structures must alter. If combined with India's Digital India and Atmanirbhar Bharat schemes, a national blockchain strategy might benefit textile, agricultural, and dairy cooperatives.

The policy implications are clear: blockchain technology can support cooperative modernisation, but its scaling depends on institutional incentives, official recognition, and public funding for digital infrastructure.

6.4. Social implications

The social implications of this study are equally important. Blockchain technology and cooperatives boost economic inclusion, local empowerment, and democratic engagement, strengthening the movement's human-centered values in the digital age.

Transparency in cooperative transactions allows members to know how their money is spent, how much they make, and how the cooperative is doing, levelling the power and information playing field. By providing accurate statistics to all stakeholders, from local weavers to board members, this fosters trust.

Due to consortium blockchain networks' inclusive architecture, rural women and casual textile workers can participate in governance processes through digital voting or remote participation technology (Ahmed & MacCarthy, 2021). This democratisation of access revives the cooperative movement by creating a social innovation platform that combines efficiency, equity, and ethics in one digital framework.

Blockchain-powered cooperatives can strengthen their communities economically. Open supply chains allow cooperatives to enter premium markets that prioritise sustainable and verifiable manufacturing. Thus, rural communities have better financial certainty, member loyalty, and long-term growth.

In a tech-driven economy, blockchain is a social catalyst that revives solidarity, participation, and shared prosperity.

Trade-Off analysis

Despite its benefits, blockchain adoption involves trade-offs between transparency and data privacy, as well as between technological investment and financial constraints. These challenges can be mitigated through permissioned blockchain architectures, regulatory sandboxes, and capacity-building initiatives that ensure inclusive and responsible digital transformation.

7. Conclusion and recommendations

7.1. Summary

Consortium blockchain designs enable democratic, open, and financially sustainable cooperative organisations in Tamil Nadu's textile industry, according to the research. Distributed ledger technology improves financial feasibility, operational efficiency, and governance inclusion. Even more importantly, it has redefined the cooperative paradigm by adding democratic values into online governance.

Critical Reflection

While the findings demonstrate the transformative potential of consortium blockchain, certain limitations must be acknowledged. The pilot study's limited sample size and regional focus restrict the generalizability of results. Additionally, technological readiness and financial constraints may influence adoption across diverse cooperative contexts.

Blockchain technology's cooperative design and governance, which combines technological innovation with ethical governance, can create an ecosystem that fosters resilience, inclusivity, and sustainability. The major takeaway is that it turns the cooperative into a reliable digital network rather than an outdated socio-economic organisation.

7.2. Recommendations

1. Replicate the consortium blockchain model across multiple textile cooperative clusters in Tamil Nadu, Gujarat, and Andhra Pradesh to validate scalability and contextual adaptability.
2. Establish policy and regulatory sandboxes under the Ministry of Cooperation to enable pilot experimentation and inter-cooperative data-sharing frameworks with legal protection.
3. Implement skill development modules focusing on blockchain literacy for cooperative members, managers, and technical staff to ensure inclusive digital transformation.
4. Facilitate collaboration among cooperative federations, blockchain startups, and academic institutions to co-develop governance templates and smart-contract models tailored to cooperative needs.
5. Future studies should measure blockchain’s broader socio-economic and sustainability impacts, including gender participation, environmental traceability, and ethical production standards.

7.3. Limitations and future research

Despite their usefulness, the results have some limitations. Since it only featured two Tamil Nadu cooperatives, the pilot may be limited. We don't have long-term scalability data because the numbers mainly cover early uptake.

Future comparative, cross-sectoral studies should examine how blockchain technology affects other cooperative fields like agriculture, dairy, and handlooms. Consortium blockchain architectures can transform digital governance by promoting global fairness. Expanding to South Asian and African

international cooperation networks may accomplish this.

Future research directions

Future research should undertake longitudinal studies to evaluate the long-term socio-economic impacts of blockchain adoption. Comparative analyzes across sectors such as agriculture, dairy, and handicrafts would further validate the scalability of consortium blockchain frameworks. Additionally, cross-country studies within the Asia-Pacific region could provide valuable insights into cooperative digital transformation in developing economies.

Conflict of interest

The authors declare that they have no conflicts of interest, whether financial or non-financial, that could have influenced the research presented in this article.

Declaration of authors' contribution

- **Sadurya G.:** Conceptualization, methodology, investigation, data curation, formal analysis and writing – original draft.
- **Kavitha Selvaranee J.:** Supervision, validation, writing – review and editing.

Data availability

Restricted access upon request

The data supporting the findings of this study are restricted and not publicly available. However, the authors will make the data available to interested readers upon request.

Declaration of generative AI use

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) for language assistance and grammatical improvement. In accordance with the journal's requirements, the manuscript was subsequently reviewed and professionally proofread, and the necessary corrections were made. Following the use of this tool, the authors reviewed and edited the content as necessary and assume full responsibility for the final published version.

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