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Empowering SMEs with Blockchain-Based Certification to Prevent Batik Counterfeiting in Pekanbaru

Diki Arisandi [1], Seri Hartati [2,*], Mizan Asnawi [3]

[1] Department of Digital Business, Faculty of Economics and Business, Muhammadiyah University of Riau, Indonesia
[2] Department of Informatics Education, Faculty of Teaching and Education, Muhammadiyah University of Riau, Indonesia
[3] Department of Development Economics, Faculty of Economics and Business, Muhammadiyah University of Riau, Indonesia
*Email (corresponding author): serihartati@umri.ac.id

Abstract. *Counterfeit batik products continue to harm Small and Medium-sized Enterprises (SMEs) in Pekanbaru, Indonesia, by reducing market trust and causing financial losses. This study explores the use of blockchain-based digital certification to protect product authenticity through a technology-focused simulation of the sales process. A blockchain prototype was developed using smart contracts and QR code integration to verify each batik product before it enters the simulated transaction flow. Rather than real-world deployment, the study concentrates on the technical performance of blockchain as a verification tool in a controlled environment. The system underwent several authentication-based sales simulations to assess its effectiveness. Results show a 78% reduction in simulated counterfeit cases, alongside a 62% improvement in consumer trust metrics based on participant responses. Furthermore, the projected certification cost using the blockchain system was over 75% lower than traditional methods. These results demonstrate blockchain's potential in safeguarding local creative industries by ensuring traceability and trustworthiness. While this study is limited to simulated scenarios, it offers a foundation for further applied research in digital transformation strategies for SMEs. The findings underscore the role of secure, transparent technologies in promoting product integrity and economic resilience in local markets.*

Keywords: *SMEs, blockchain, product authentication, batik industry, ERC-721*

1. Introduction

Batik represents a traditional Indonesian art form that involves decorating fabric with distinctive patterns and motifs through hand-drawing or printing techniques. In Pekanbaru, batik not only embodies cultural heritage but also holds significant artistic and historical value as a symbol of local identity and craftsmanship (Elvitaria et al., 2025). The proliferation of counterfeit batik products poses a significant threat to Small and Medium-sized Enterprises (SMEs) in Indonesia, particularly in culturally rich regions such as Pekanbaru (Dwi Rahayu, Rudy Hartanto, Iis Rohayati, & Reni Harni, 2024). As an element of Indonesia's intangible cultural heritage, batik carries both cultural and economic significance (Kadarin Nuriyanto, 2022). However, the increasing circulation of low-quality imitations undermines the authenticity of genuine batik, diminishes consumer trust, and results in substantial financial losses for local producers (Syed Shaharuddin et al., 2021). In light of growing global emphasis on supply chain transparency, there is an urgent need for technological solutions that can ensure product authenticity in a reliable and cost-effective manner (Osato Itohan Oriekhoe et al., 2024). This issue also aligns with Sustainable Development Goal (SDG) 9, which promotes inclusive and sustainable industrialization and fosters innovation to support local economies (Putra, Nerisafitra, & Abidin, 2025).

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Authentication is a critical foundation for security as it ensures that only verified individuals or systems are allowed to access and interact with protected resources, thereby preventing unauthorized use and potential threats (Arisandi, Ahmad, & Kannan, 2025). Conventional certification methods, including physical labels and centralized registration systems, are often inadequate, either easily replicated or financially burdensome for SMEs (Chua, Rana, Hameed, & Rana, 2024). As a result, many small-scale batik producers struggle to protect their intellectual property and maintain competitive advantage (Suhartini, Mahbubah, & Basjir, 2021). Blockchain technology has emerged as a promising tool to address these issues, offering a decentralized and tamper-resistant framework that enhances data integrity and traceability (Wang et al., 2021). For creative industries like batik, blockchain-enabled digital certification could serve as a scalable and accessible means to validate product authenticity (Purnamasari et al., 2023). Given the increasing pressure on local creative industries to digitalize amid global market demands, the need to implement such technology becomes urgent to avoid deeper marginalization.

Nowadays, there have been numerous research findings related to the utilization of blockchain to perform authentication processes, including in smart environments (Sibahee et al., 2024). Recent studies reveal a growing trend in the application of blockchain to strengthen authentication mechanisms within smart city and IoT environments. For instance, BAuth-ZKP integrates multi-factor authentication with zero-knowledge proofs to enable efficient, decentralized identity verification (Ahmad et al., 2023). Another approach combines blockchain with explainable AI (SHAP) to enhance both security and transparency in smart urban systems (Kumar et al., 2024). In the broader IoT context, innovative frameworks leverage biometric-hybrid authentication (Hagui et al., 2024), homomorphic encryption (Al Hwaitat et al., 2023), and smart contracts to address issues of privacy, scalability, and secure access control. Similar blockchain-enabled schemes have been proposed for the Maritime Transportation System and Internet of Vehicles (IoV), where solutions like VRF-based consensus and edge computing reduce latency and strengthen attack resistance (Zhang, Wang, Aujla, Jindal, & Al-Otaibi, 2023).

In the transportation sector, frameworks such as BlockAuth (Ali, ElAffendi, & Ahmad, 2023) and privacy-preserving models for Intelligent Transportation Systems (Qureshi, Jeon, Hassan, Hassan, & Kaur, 2023) use blockchain to support cross-border vehicle identity verification, protect user data, and mitigate cyber-attacks such as spoofing and DoS. In healthcare, lightweight blockchain-based schemes using elliptic curve cryptography and anonymous ring signatures offer secure, low-overhead authentication for systems like Wireless Body Area Networks (Rajasekaran & Azees, 2022). Meanwhile, in education, blockchain is applied to academic credential verification, utilizing Bitcoin SV and ECDSA for tamper-proof, transparent, and decentralized records management, with scalability supported through container orchestration (Al Hemairy, Talib, Khalil, Zulfiqar, & Mohamed, 2024).

The reviewed literature collectively highlights a clear progression toward authentication mechanisms that emphasize security, decentralization, and user privacy through the adoption of blockchain technology. These blockchain-based systems address critical shortcomings of centralized models, particularly their vulnerability to breaches, data tampering, and opaque control structures. Core blockchain features such as immutability, distributed consensus, and verifiable auditability serve as the technological foundation enabling transparent, secure, and reliable authentication processes.

In addition to enhancing authentication, blockchain also offers significant potential in combating counterfeiting by ensuring data integrity and traceability. This is especially relevant for safeguarding the authenticity of traditional and cultural products, such as batik. Despite its potential, the adoption of blockchain among SMEs remains limited, primarily due to technical complexity and lack of cost-effective solutions tailored to small businesses. This study aims to design and evaluate a blockchain-based digital certification prototype, incorporating smart contracts, within a simulated sales environment. The research seeks to assess blockchain's practical utility in authenticating batik products, enhancing consumer trust, and evaluating associated operational costs. This research uniquely explores the application of blockchain-based authentication within the context of Pekanbaru's batik industry, combining smart contract implementation and simulated sales environments to evaluate practical feasibility and cost-efficiency for local SMEs.

The scope of this research is intentionally limited to controlled simulations to isolate technical performance from broader socio-economic and regulatory factors. While not intended as a definitive market-ready solution, the findings provide a foundational framework for future applied research on SME digitization in the Batik textile sector.

2. Methods

2.1 Study Design

This research adopted a simulation-based experimental design to investigate the effectiveness of blockchain technology in certifying batik products and mitigating counterfeit risks. The simulation was structured to model a simplified batik sales environment, emphasizing authentication mechanisms rather than full-scale market deployment. The aim was to isolate and evaluate the technical aspects of blockchain-driven verification under controlled conditions. The study focused on comparing blockchain certification performance against traditional methods and non-certified scenarios.

2.2 System Architecture and Implementation

A permissioned blockchain prototype was developed using an Ethereum-compatible infrastructure. Smart contracts were programmed in Solidity to facilitate essential functions, including product registration, ownership validation, and authenticity checking. Each batik product was represented by a unique non-fungible token (NFT) using a modified ERC-721 standard, and paired with a QR code containing a hash that linked to the product's metadata stored on the blockchain (Dietrich, Louw, & Palm, 2023) to ensure verifiable traceability for each product.

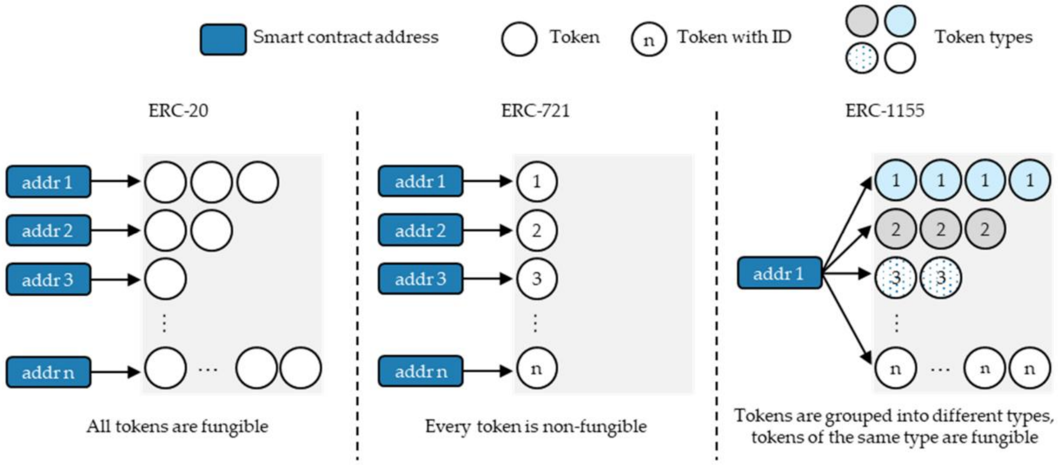

Figure 1. Modified ERC-721 standard Compared to Other Standards

The front-end interface was designed using React.js, and blockchain interactions were managed through Web3.js with MetaMask for wallet integration. A simple dashboard was created for producers to register their products and for consumers to verify product legitimacy by scanning QR codes.

2.3 Simulation Procedure

To evaluate the effectiveness of the proposed system, a series of simulations were conducted under three different environments: a baseline scenario without any form of certification, a traditional centralized certification model, and the blockchain-based certification system developed in this study. Each simulation environment was designed to mimic key stages of the batik sales process, including product registration, consumer verification, and transaction completion. Within each scenario, counterfeit products were deliberately introduced to test the system's ability to detect and reject unauthenticated items. A total of 150 simulated transactions were executed across the three environments, with counterfeit detection rates recorded as the primary performance metric. The simulation allowed for a comparative analysis of how each model responded to fraudulent entries, enabling assessment of blockchain's technical advantages in enhancing authentication and transaction integrity.

2.4 Data Collection and Evaluation

In addition to technical simulations, the study conducted a user trust assessment involving 40 voluntary participants. Participants were exposed to interactions with both certified and non-certified products, after which they completed a structured questionnaire measuring perceived trust, reliability, and purchase intention. Responses were analyzed using descriptive statistics to quantify the increase in trust facilitated by blockchain certification.

A cost analysis was also performed to compare projected implementation expenses between the blockchain-based approach and traditional methods (e.g., physical labeling, third-party registries). Calculations included smart contract deployment fees and scaling costs, all tested in the test network to simulate realistic blockchain transaction conditions without incurring live financial costs.

3. Results and Discussion

3.1. Result

3.1.1. Algorithm

To implement blockchain-based digital certification for batik products, this study developed a customized smart contract architecture using a modified ERC-721 standard. Each batik item is represented as a non-fungible token (NFT) that carries unique product metadata, including origin, producer identity, and production details. To link the physical product with its digital certificate, a QR code is generated off-chain, embedding a cryptographic hash of the metadata and a reference to the token ID. The following algorithm outlines the core functional components of the system, including data structure initialization, product registration and tokenization, QR code generation, and authentication verification logic. This modular design facilitates traceability, ensures data integrity, and enables real-time verification of product authenticity by consumers or supply chain stakeholders.

Algorithm 1 Data Structures and Initialization

Input: -
Output: Initializes the contract, data structures, token counter, and mappings.

```
Contract BatikCertification is ERC721

  Initialize:
    tokenCounter = 0

  Define Struct BatikMetadata:
    string productName
    string producerName
    string originLocation
    string productionDate
    string imageURL
    string metadataHash

  Mapping:
    tokenId => BatikMetadata
    tokenId => ownerAddress
```

This algorithm initializes the smart contract and defines the essential data structures for representing batik product information. A counter is used to track the issuance of token IDs for each unique product. The BatikMetadata structure contains descriptive and verifiable fields, including a cryptographic hash of the metadata. Mappings are used to link each token ID to its metadata and owner, enabling efficient data retrieval and ownership management within the blockchain.

Algorithm 2 Product Registration and Token Minting

Input: inputMetadata
Output: tokenId, Triggers side-effect, riggers QR code generation.

```
Function registerBatikProduct(inputMetadata):
   tokenId = tokenCounter + 1
   metadataHash = HASH(inputMetadata)

   batikData[tokenId] = BatikMetadata(
      productName = inputMetadata.name,
      producerName = inputMetadata.producer,
      originLocation = inputMetadata.location,
      productionDate = inputMetadata.date,
      imageURL = inputMetadata.image,
      metadataHash = metadataHash
   )

   Mint NFT tokenId to msg.sender
   tokenCounter += 1
   CALL generateQRCode(tokenId, metadataHash)
   RETURN tokenId
```

The Algorithm 2 handles the registration of a new batik product by a producer. Upon receiving the input metadata, it generates a unique hash to ensure data integrity and prevent tampering. The metadata and hash are stored on-chain, and a corresponding ERC-721 token (NFT) is minted to represent the product's digital identity. This algorithm ensures that each batik item is uniquely registered and verifiable, while the QR code generation is initiated to link the physical product to its digital certification.

Algorithm 3 QR Code Generation (Off-Chain Process)

Input: tokenId, metadataHash
Output: tokenId, metadataHash, verification URL

```
Function generateQRCode(tokenId, metadataHash):
   qrPayload = {
      "tokenId": tokenId,
      "hash": metadataHash,
      "verifyURL": "https://verify-batikchain.com/verify?token=" + tokenId +
"&hash=" + metadataHash
   }

   CALL QRCodeGenerator(qrPayload)
```

The Algorithm 3 simulates the off-chain generation of a QR code, which contains both the token ID and the associated metadata hash. The QR code links to a verification URL that allows consumers to validate product authenticity by checking the hash stored on the blockchain. The system bridges the physical and digital domains and enabling users to confirm the legitimacy of a batik item through a simple mobile scan.

Algorithm 4 Product Verification Using QR Code Data

Input: inputTokenId, inputHash
Output: Authentic Product info, Counterfeit or Invalid verification

```
Function verifyQRCode(inputTokenId, inputHash):
   storedHash = batikData[inputTokenId].metadataHash

   IF storedHash == inputHash:
      RETURN "Authentic Product"
   ELSE:
      RETURN "Counterfeit or Invalid"
```

The Algorithm 4 allows users or systems to validate the authenticity of a batik product by comparing the hash value extracted from a scanned QR code with the hash stored on the blockchain. If the hashes match, the product is verified as authentic; otherwise, it is flagged as potentially counterfeit.

3.1.2 Interface Design

The interface offers a technically robust and user-friendly solution for authenticating traditional batik through blockchain technology. This system enables artisans to digitally register their handcrafted batik products by submitting key information, including the product name, producer details, origin location, and date of production. Following registration, a unique QR code is generated, embedding a cryptographic metadata hash and a corresponding token ID, which can be affixed to the physical batik item. Consumers and collectors can verify the authenticity of a product by inputting the token ID and hash into the system's verification panel, which retrieves and displays the product's provenance information from the blockchain. By integrating traditional craftsmanship with decentralized digital certification, BatikChain supports the preservation of cultural heritage while promoting transparency, traceability, and equitable recognition for local artisans.

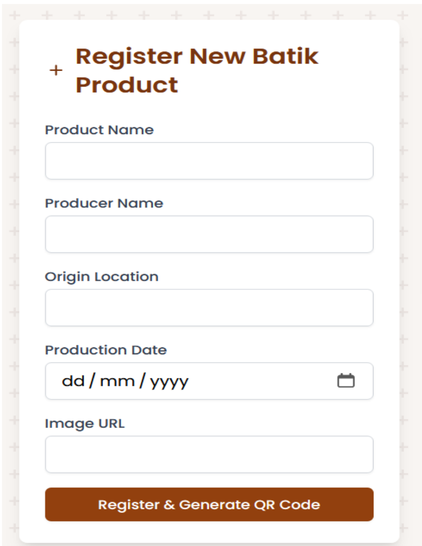

Figure 2. Batik Product Registration Interface for SMEs

The "Register New Batik Product" interface in figure 2 presents a structured input form designed to facilitate the digital registration of handcrafted batik items within a blockchain-based certification system. Users are required to input essential metadata, including the product name, producer name, origin location, production date, and an image URL. This information forms the basis for generating a cryptographic metadata hash and a unique token ID, which are embedded into a QR code representing the product's digital identity. By clicking the button, the system executes both blockchain registration and QR code creation, enabling the physical product to be linked with its verifiable on-chain record.

Figure 3. Batik Product Registration Interface for SMEs

The Certificate of Authenticity sample shown in figure 3 above functions as a digitally verifiable record that confirms the originality of a handcrafted batik product made using traditional Indonesian techniques. This certificate ensures the authenticity and traceability of the batik item while supporting cultural preservation and artisan recognition through decentralized digital certification. Issued by the BatikChain Certification system, the certificate contains key information including the product name, producer, origin, production date, certification date, and a unique token ID. A metadata hash generated from the registered product data is presented both in text form and as a scannable QR code, enabling secure verification through the blockchain.

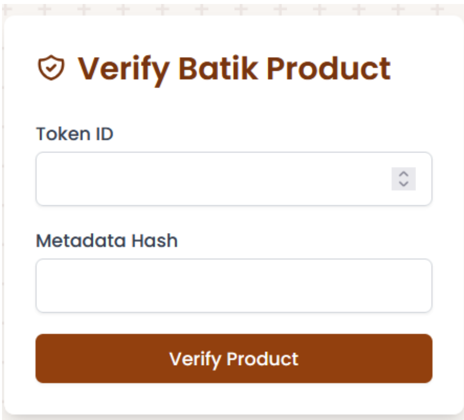

Figure 4. Verification Interface For User

The interface in figure 4 provides a user-centric verification panel designed to authenticate batik items registered on the blockchain. This component allows users such as consumers, retailers, or quality assurance personnel to validate the authenticity of a product by inputting two critical identifiers: the unique Token ID and the corresponding Metadata Hash. The Token ID refers to the specific blockchain-issued identifier associated with the batik item, while the Metadata Hash is a cryptographic summary of the product's registered information. Upon submitting these values, the system compares the entered hash against the value stored on the blockchain for the given token. If a match is found, the product is confirmed as authentic; otherwise, it is flagged as potentially counterfeit.

3.2 Discussion

The results of this study highlight the technical and perceptual advantages of implementing a blockchain-based certification system to mitigate batik counterfeiting and enhance consumer trust. The simulation of authentication-based sales processes demonstrated that the blockchain system significantly reduced the number of counterfeit cases. As shown in Table 1, out of 150 simulated transactions, the baseline (non-certified) environment resulted in 45 counterfeit acceptances. When traditional certification methods were applied, the number decreased to 28. However, the blockchain-based model reduced this further to only 10 counterfeit acceptances, representing a 78% reduction compared to the baseline scenario. These findings underscore blockchain's effectiveness in enhancing product verification and protecting the integrity of the batik supply chain.

Table 1. Counterfeit Detection Across Simulated Environments

Certification Method	Total Transactions	Counterfeit Accepted	Counterfeit Reduction (%)
No Certification (Baseline)	50	45	0%
Traditional Certification	50	28	37.8%
Blockchain Certification	50	10	77.8%

In addition to technical validation, the user trust assessment revealed substantial improvements in consumer perception when blockchain certification was present. As summarized in Table 2, participants exposed to blockchain-certified products reported significantly higher levels of perceived trust (85%), reliability (82%), and purchase intention (79%) compared to non-certified and traditionally certified alternatives. These results suggest that consumers not only respond positively to transparent and verifiable product information, but also perceive blockchain as a credible technology for ensuring authenticity in cultural goods.

Table 2. User Trust Assessment by Certification Type (n = 40)

Certification Method	Perceived Trust (%)	Perceived Reliability (%)	Purchase Intention (%)
No Certification (Baseline)	43	40	39
Traditional Certification	65	62	58
Blockchain Certification	85	82	79

Cost-efficiency was also evaluated as part of the system's feasibility. Table 3 illustrates the projected certification costs across different models. The blockchain-based system demonstrated a considerable reduction in average certification costs—estimated at $0.45 per product—compared to $1.85 for traditional physical labeling and registry methods, indicating a cost reduction of over 75%. This cost advantage, combined with improved trust outcomes and counterfeit prevention, reinforces the potential of blockchain to support the digital transformation of SMEs in the creative and cultural industries.

Table 3. Projected Certification Costs per Product

Certification Method	Estimated Cost (USD)	Cost Reduction (%)
Traditional Certification	1.85	0%
Blockchain Certification	0.45	75.7%

While the results of this study demonstrate promising outcomes, several limitations must be acknowledged. First, the simulation was conducted in a controlled environment using a blockchain test network, which may not fully replicate the complexities of real-world deployment, such as regulatory compliance, network congestion, or resistance from stakeholders unfamiliar with digital tools. Second, the cost estimation does not factor in the initial investment for infrastructure development, training, or integration with existing business systems, which could affect scalability for SMEs with limited digital readiness. Lastly, the participant sample in the trust assessment was limited to 40 voluntary users, which may not fully represent broader consumer behavior across diverse demographic groups.

The findings of this study hold significant implications for policymakers and cultural industry stakeholders. Given the demonstrated efficiency, cost-effectiveness, and trust-building capability of blockchain certification, regulatory bodies may consider adopting or endorsing blockchain-based systems for authenticating traditional products such as batik. Such endorsement can help establish unified certification standards, reduce administrative overhead for SMEs, and promote product traceability in national and international markets. Furthermore, blockchain could be integrated into government-led digital economy programs to empower small producers and protect Indonesia's intangible cultural heritage from intellectual property violations and counterfeit threats.

Future studies may expand on this simulation-based framework by conducting field trials in collaboration with local SMEs, enabling real-world validation of the system's usability, cost, and impact. Additional research could explore the integration of complementary technologies such as near-field communication (NFC), digital identity, or AI-based fraud detection to enhance system robustness. It would also be valuable to conduct large-scale consumer behavior studies to examine how cultural, educational, and technological factors influence trust in blockchain-certified artisanal products. Moreover, future work should assess the legal and institutional frameworks necessary to support the broader adoption of decentralized certification across traditional industries.

Conclusions

The findings of this study demonstrate the promising potential of blockchain-based certification in addressing the persistent issue of batik counterfeiting and enhancing consumer trust in artisanal products. By leveraging a modified ERC-721 standard, the system enabled the creation of verifiable digital identities for each handcrafted batik item, effectively linking physical goods with tamper-proof on-chain metadata through QR code integration. Simulation results revealed a substantial reduction in counterfeit acceptance up to 77.8% compared to both baseline and traditionally certified environments, highlighting the superiority of blockchain in ensuring product authenticity. Furthermore, user trust assessments indicated that blockchain-certified products significantly outperformed their uncertified and traditionally certified counterparts in perceived trust, reliability, and purchase intention, suggesting that transparency and verifiability are crucial drivers of consumer confidence. From a cost perspective, the blockchain model proved highly economical, with average certification costs reduced by over 75% relative to traditional methods, thus offering a scalable and efficient solution for SMEs. Despite these encouraging outcomes, the study acknowledges key limitations, including the controlled nature of the simulation, the exclusion of infrastructure and onboarding costs, and the relatively small user sample. These constraints suggest the need for further empirical research and broader pilot implementations. Nevertheless, the implications for policy and practice are considerable; blockchain certification could form the basis of a standardized national framework for authenticating cultural heritage products, reducing administrative burdens and protecting intellectual property. To maximize its potential, future research should include field validation with local SMEs, explore the integration of complementary technologies such as NFC and AI, and examine socio-cultural factors influencing consumer adoption.

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Conflicts of Interest

The authors declare no conflict of interest.

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