

Research Paper

Modelling Consumer Adoption of Blockchain-based Halal Traceability System: Integrated Behavioural-Innovation Framework

Ramadhan Razali^{a,1*}, Muh. Nashirudin^{b,2}, Zulfikar^{a,3}, Mahdi^{a,4}

^aFaculty of Islamic Economics and Business, Universitas Islam Negeri Sulthanah Nahrasiyah Lhokseumawe, Indonesia

^bFaculty of Sharia, Universitas Islam Negeri Raden Mas Said Surakarta, Indonesia

¹ ramadhan@uinsuna.ac.id, ² muh.nashirudin@staff.uinsaid.ac.id, ³ zulfikar82@uinsuna.ac.id

⁴ mahdi@uinsuna.ac.id

*Corresponding author

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ABSTRACT

The increasing complexity of halal supply chains has intensified transparency challenges, yet limited studies integrate behavioural and innovation theories to explain consumer adoption of blockchain-based halal traceability systems. This study aims to analyze consumer demand and identify key drivers influencing the adoption of blockchain-based halal traceability using an integrated theoretical framework. A mixed-method design was employed, involving a survey of 400 respondents across four Indonesian provinces (Aceh, North Sumatra, DKI Jakarta, and West Java), complemented by in-depth interviews with industry stakeholders and thematic analysis. Quantitative data were analyzed using descriptive and explanatory techniques, while qualitative data provided contextual insights into adoption barriers and opportunities. The findings reveal that perceived transparency, trust enhancement, and relative advantage significantly influence consumers' intention to adopt blockchain-based systems. However, adoption is constrained by low technological literacy, high implementation costs, and regulatory uncertainty. This study integrates TPB, DOI, and SCTT into a unified adoption model while proposing a validated blockchain-based halal traceability framework that emphasizes the need for regulatory harmonization, technological literacy, and financial support to accelerate digital transformation in the halal ecosystem.

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Introduction

The growing demand for transparency and trust in halal products has become a central issue in the rapidly expanding global halal industry. The rapid growth of this sector, driven by an increasing Muslim population and heightened awareness of halal consumption, has intensified the need for transparent and reliable halal supply chains (Abbas et al., 2025; Randeree, 2020; Suryawan et al., 2022; Utomo et al., 2021). However, the complexity of modern supply chains introduces significant challenges, particularly in ensuring traceability, authenticity, and compliance with halal standards (Aung & Chang, 2014). Consumers frequently face uncertainty regarding product origin, certification validity, and production processes, increasing the risk of halal fraud and undermining trust (Al-Ansi & Han, 2018; Andespa et al., 2024; Islam, 2025). As supply chains become more globalized and fragmented, ensuring consistent halal integrity across multiple actors and jurisdictions becomes increasingly difficult, highlighting the urgent need for more robust and transparent traceability systems.

Halal fraud represents one of the most critical challenges facing the global halal industry today (Amid, 2024a; Prayuda et al., 2023). It refers to deliberate actions that mislead consumers through false halal claims, often resulting from weaknesses in supply chain design, implementation, and monitoring (Mohammed et al., 2021). Several factors contribute to this issue, including limited transparency in complex supply chains (Dashti et al., 2024), inadequate separation of halal and non-halal products (Zin et al., 2021), economic pressures to reduce operational costs (Rahman et al., 2024), weak regulatory oversight, and low halal awareness among supply chain actors (Ahmad et al., 2023). Additionally, the involvement of multiple international stakeholders increases the risk of losing control over halal compliance (Khan et al., 2022a), while unverified suppliers and distributors further heighten fraud risks (DuHadway et al., 2022; Ghadge et al., 2021). These challenges are exacerbated by inconsistent certification standards and weak audit mechanisms (Amid, 2024b; Harwati et al., 2024), ultimately threatening consumer confidence and industry credibility (Ahmad et al., 2023; Ahmed Osman, 2023).

A growing body of literature has explored technological solutions to enhance transparency and traceability in halal supply chains, with particular attention to blockchain technology. Previous studies highlight that blockchain enables secure, decentralized, and tamper-proof data recording, which improves accountability and reduces fraud risks (Harsanto et al., 2024; Humaidi & Balakrishnan, 2018; Zhu et al., 2021). It facilitates end-to-end visibility by recording information on raw materials, production processes, distribution, and certification, allowing consumers to verify halal status through digital interfaces such as QR codes (Essien et al., 2024; Tan et al., 2022). Moreover, blockchain adoption has been associated with increased efficiency, trust, and collaboration among supply chain actors (Ali et al., 2021; Kamilaris et al., 2019; Vazquez Melendez et al., 2024). Despite these advancements, prior research has predominantly focused on technological capabilities and system design, with limited attention to consumer behaviour and the underlying drivers of technology adoption in halal contexts. This indicates a critical gap in integrating behavioural and innovation perspectives to better understand adoption dynamics.

The halal supply chain (HSC) plays a crucial role in ensuring that products comply with Sharia principles across all stages, from raw materials to end consumers (Mohammed et al., 2021; Khan et al., 2022b). An ideal HSC requires strict adherence to halal standards in

production, packaging, storage, transportation, and distribution processes. However, the absence of a universally accepted framework continues to hinder its effective implementation, as different countries and certification bodies adopt varying standards, often leading to inconsistencies and trade conflicts. Although existing studies have addressed supply chain transparency and halal traceability, significant research gaps remain. Specifically, there is limited empirical evidence on consumer demand for blockchain-based halal traceability, a lack of integrated models combining behavioural and technological theories, and insufficient efforts to develop validated and applicable frameworks. These gaps highlight the need for a more comprehensive approach that bridges theoretical perspectives and practical implementation challenges.

Accordingly, this study aims to analyze consumer demand and identify the key drivers influencing the adoption of blockchain-based halal traceability systems by integrating the Theory of Planned Behaviour (TPB), Diffusion of Innovation (DOI), and Supply Chain Transparency Theory (SCTT). The novelty of this study lies in its development of a unified adoption model that combines behavioural, innovation, and transparency perspectives within a single analytical framework, as well as in its proposal of a validated blockchain-based halal traceability blueprint grounded in both empirical and simulation-based evidence. By mapping consumer needs and addressing real-world implementation challenges, this study offers both theoretical advancement and practical insights. The findings are expected to inform policymakers, halal certification bodies, and industry stakeholders in designing more transparent, efficient, and trustworthy halal supply chain systems, thereby supporting the broader digital transformation of the halal ecosystem.

Method

Research Design and Participants

This study adopts a mixed-method research design integrating both quantitative and qualitative approaches to comprehensively examine consumer adoption of blockchain-based halal traceability systems. The use of a mixed-method design is appropriate as it enables a more holistic understanding of the research problem by combining numerical data on consumer demand with in-depth insights into stakeholder perspectives. Quantitative data provide measurable evidence of adoption patterns and influencing factors, while qualitative data offer contextual explanations of underlying motivations and challenges. In addition, document studies and technology simulations are incorporated to strengthen the analytical rigor and to support the development of a practical blockchain-based halal traceability model that aligns with real-world industry needs.

Data Source and Participants

The data were obtained from 400 respondents consisting of consumers/business actors, producers/retailers, and distributors, who served as the primary participants in the quantitative phase of this study. Respondents were selected using a cluster sampling technique across four Indonesian provinces, Aceh, North Sumatra, DKI Jakarta, and West Java, to ensure representation from diverse geographical and economic contexts within Indonesia's halal ecosystem. This sampling technique enables the capture of varied perspectives across regions with different levels of halal industry development and digital

readiness. In addition to the survey, qualitative data were collected through in-depth interviews with key stakeholders, including halal industry players, regulators, and blockchain experts (n = 8), selected using purposive sampling to ensure their relevance and expertise in halal supply chains and digital technology implementation. These interview participants provided contextual insights into the opportunities and challenges of adopting blockchain-based traceability systems. The combination of cluster sampling for the survey and purposive sampling for interviews strengthens the comprehensiveness of the data by integrating both broad quantitative representation and in-depth qualitative perspectives, thereby enabling a more holistic understanding of adoption dynamics from both demand-side and supply-side viewpoints.

Instrument and Data Collection

The research instruments consisted of a structured questionnaire and semi-structured interview protocols. The questionnaire was developed based on three theoretical frameworks: the Theory of Planned Behavior (TPB), Diffusion of Innovation (DOI), and Supply Chain Transparency Theory (SCTT), as presented in Table 1. The TPB indicators include Attitude Toward Use, Subjective Norms, Perceived Behavioral Control, Intention to Use, and Actual Use. The DOI indicators comprise Relative Advantage, Compatibility, Complexity, Trialability, and Observability. Meanwhile, SCTT indicators include Information Disclosure, Accountability, Traceability, Stakeholder Collaboration, and System Integrity. In addition, interview protocols were designed to explore stakeholders' perceptions, challenges, and expectations regarding blockchain implementation in halal traceability systems.

Data collection was conducted in several stages. First, quantitative data were gathered through surveys distributed to halal product consumers to assess their understanding, trust, and readiness to adopt blockchain systems. Second, in-depth interviews were conducted with halal industry players, regulators, and blockchain experts to explore opportunities and challenges in implementation. Third, document studies were carried out to review halal regulations, blockchain standards in the food industry, and global best practices. Finally, a technology simulation was performed by testing blockchain models within halal supply chain scenarios to evaluate system performance and feasibility.

Data Analysis

Data analysis was conducted using both quantitative and qualitative techniques. Quantitative data were analyzed through descriptive and explanatory methods to identify patterns and relationships in consumer responses. Qualitative data were analyzed using thematic analysis to interpret interview findings and identify key themes related to blockchain adoption. Document analysis was employed to synthesize regulatory and industry insights, while technology simulation and validation were used to develop an ideal blockchain-based halal traceability blueprint. The thematic analysis approach, as suggested by Tan et al. (2020), is particularly useful for identifying patterns in complex qualitative data, and was applied to map opportunities and challenges in the halal blockchain context. To enhance analytical robustness, the study integrates TPB to explain behavioural intentions, DOI to assess innovation adoption factors, and SCTT to ensure transparency in system design, with findings from all approaches combined to validate the proposed model.

Table 1. The Indicators of the Questionnaire

Theory	Variable	Indicator	Description
Theory of Planned Behavior	Subjective Norms	Halal Values	Consumer demand for applications to display halal certificates, expiration dates, and raw material details.
		Capital Transparency	Clear display of cost and payment information.
		Traceability	Product journey details, complete and accountable proof of supply chain.
		Accountability	Accountability items in halal certification, financing, and production processes.
	Attitude Toward Use	Consumers' positive perceptions of the use of blockchain technology in halal tracking.	Greater assurance of halal expectations, increased consumer confidence.
	Perceived Behavioral Control	Ease or obstacles experienced in using the application.	Technological literacy, availability of user-friendly features.
Intention to Use	Actual Use	Consumers' readiness and intention to use blockchain-based halal traceability applications.	Interest in using the application due to supporting conditions such as the availability of a stable internet connection and auto-notification features that help users keep track of product halal status.
		Actual implementation of the application by consumers.	Users actually open the app at least once a day during their shopping trip, or according to their monthly shopping frequency
Diffusion of Innovation Theory	Relative Advantage	Perceived advantages over the old way.	Better transparency, immutable data, higher trust.
		The suitability of the system to the needs, values, and practices of users.	Synchronization with payment systems, Google Maps, business contacts.
	Complexity	The level of ease or difficulty in using the application.	Simple interface, user training.
	Trialability	The ability to try out the system before full adoption.	Demo/simulation features, pilot project.
	Observability	The extent to which the results of using the system can be seen and evaluated by others.	Easily verifiable halal audit evidence, QR code for consumers.

Theory	Variable	Indicator	Description
Supply Chain Transparency Theory	Information Disclosure	Availability of easily accessible data at every stage of the supply chain.	Halal certification, raw material origin, production process.
	Accountability	Determination of the responsible party at every stage of the supply chain.	Validation by halal certification agency.
	Traceability	Ability to track products from upstream to downstream in real time.	Transaction log on blockchain, QR code for consumers.
	Stakeholder Collaboration	Cooperation between supply chain actors to share consistent and reliable data.	Manufacturers, distributors, retailers, regulators.
	System Integrity	Security and integrity of data that cannot be manipulated.	Blockchain encryption, smart contracts.

Sources: Ajzen (1991); Centobelli et al. (2022); Galvez et al. (2018)

Results

Respondent Profile

Table 2 presents the demographic and socio-economic profile of respondents across four provinces, highlighting variations in education level and gender distribution. In terms of education, respondents with compulsory basic education dominate in Aceh (71%), while a more balanced distribution is observed in North Sumatra (53% basic vs. 47% higher education) and West Java (53% vs. 47%). DKI Jakarta also reflects a relatively even composition, with 56% of respondents having basic education and 44% holding higher education qualifications. These findings indicate that, although respondents with lower formal education remain predominant in some regions, a substantial proportion of participants across all provinces possess higher education backgrounds. Regarding gender, the distribution is relatively balanced overall, with female respondents slightly dominating in Aceh (53%), while male respondents are more represented in North Sumatra (53%), DKI Jakarta (55%), and West Java (58%). This balanced composition suggests that the data capture perspectives from both male and female participants across diverse regional contexts.

From a business perspective, the majority of respondents across all provinces are categorized as consumers or business operators, accounting for 50%–55% of the sample, followed by retailers/manufacturers and distributors in smaller proportions. This indicates that the study predominantly reflects demand-side perspectives while still incorporating supply chain actors. In terms of ownership structure, most respondents operate independently, with “own” businesses representing the largest share in all provinces, particularly in West Java (70%) and Aceh (67%). Partnership or rental arrangements also form a significant portion, especially in North Sumatra (40%) and DKI Jakarta (35%), whereas family-based ownership remains relatively limited across regions. Overall, this profile demonstrates a diverse yet representative sample in terms of educational background, gender, business roles, and ownership types, thereby strengthening the generalizability of the study’s findings within the Indonesian halal supply chain context.

Table 2. Respondent Profile

Category	Aceh	North Sumatra	DKI Jakarta	West Java
<i>Education</i>				
Compulsory basic education	71%	53%	56%	53%
Higher education	29%	47%	44%	47%
<i>Gender</i>				
Male	47%	53%	55%	58%
Female	53%	47%	45%	42%
<i>Business Type</i>				
Consumers / business operators	53%	53%	50%	55%
Retailers / manufacturers	33%	33%	40%	30%
Distributors	13%	13%	10%	15%
<i>Ownership Type</i>				
Family	6%	0%	10%	5%
Own	67%	60%	55%	70%
Partnership / rental	27%	40%	35%	25%

Source: data analysis (Authors, 2025)

Consumer Demand for Blockchain-based Halal Traceability

The findings indicate a strong consumer demand for blockchain-based halal traceability systems across the surveyed regions. This demand reflects increasing consumer concern regarding the credibility of halal claims, particularly within complex and fragmented supply chains. As illustrated in [Figure 1](#), respondents expressed clear preferences for key application features, emphasizing the importance of systems that enhance traceability, security, and halal assurance. The results highlight the need for reliable digital solutions that enable consumers to independently verify product authenticity and compliance with halal standards. These findings suggest that consumers are no longer satisfied with conventional certification labels alone, but increasingly expect real-time access to detailed, transparent, and trustworthy product information.

More specifically, the survey results reveal that consumers prioritize several key features in blockchain-based halal traceability applications. These include access to official halal certification, detailed information on the origin of raw materials, transparency in certified production processes, traceability of logistics and distribution, and records of payment transactions. Among these features, the ability to trace product movement from upstream to downstream and verify certification authenticity emerges as the most critical requirement. Such preferences indicate that consumer demand extends beyond basic information disclosure toward a comprehensive, end-to-end transparency system. Overall, these findings highlight the growing expectation for technologically enabled solutions that enhance trust, reduce uncertainty, and strengthen consumer confidence in halal products within an increasingly digitalized marketplace.

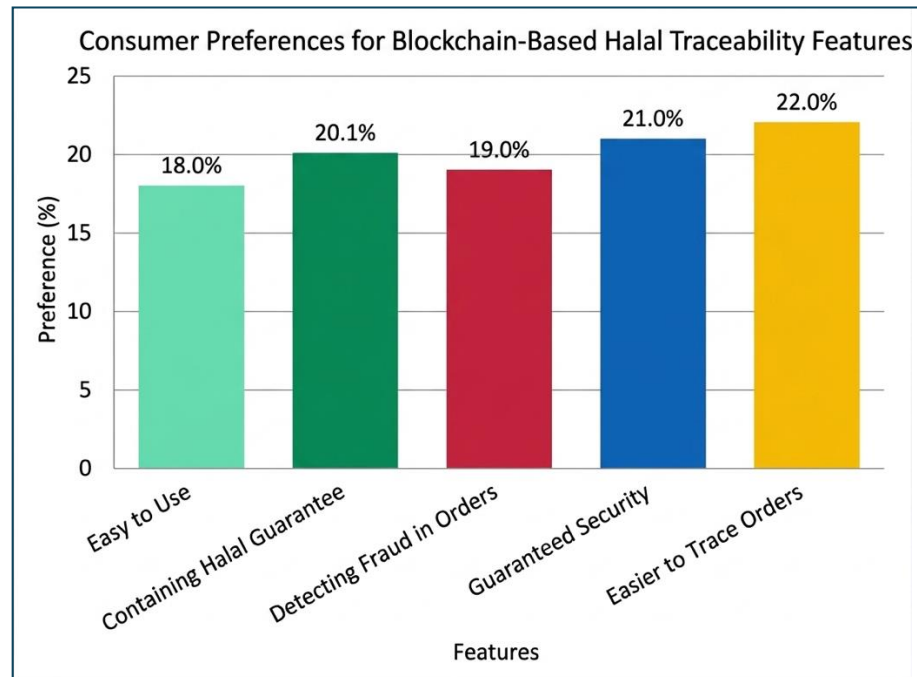


Figure 1. Consumer Preferences for Features in Blockchain-Based Halal Traceability Systems

Determinants of Adoption Intention

The quantitative findings reveal that consumers' intention to adopt blockchain-based halal traceability systems is largely driven by perceived transparency, trust enhancement, and relative advantage. As summarized in Table 3, perceived transparency plays a central role, as respondents value the ability to access clear, verifiable, and tamper-proof information regarding halal certification, product origin, and supply chain processes. This transparency strengthens trust, which emerges as another key determinant of adoption intention. Consumers are more inclined to adopt blockchain systems when they believe such technologies can reduce uncertainty and prevent halal fraud. In addition, relative advantage, as conceptualized in the Diffusion of Innovation (DOI) framework, significantly contributes to adoption intention, as respondents perceive blockchain-based systems to be more reliable, efficient, and informative compared to conventional traceability mechanisms.

From a behavioural perspective, the findings are consistent with the Theory of Planned Behaviour (TPB), where attitude toward use and subjective norms positively influence adoption intention. A favourable evaluation of blockchain technology encourages consumers to engage with such systems, while social influences, such as recommendations from peers, regulators, and industry stakeholders, further reinforce this intention. However, the analysis also identifies important inhibiting factors. Perceived behavioural control and complexity exert negative effects on adoption intention, indicating that limited technological literacy and the perceived difficulty of using blockchain applications may discourage users. These findings suggest that, although the perceived benefits of blockchain are substantial, adoption is simultaneously shaped by users' capabilities and ease-of-use considerations. Overall, while the analysis is based on descriptive and explanatory patterns rather than formal regression modelling, the relationships presented in Table 3 provide

consistent and theoretically grounded insights into the key drivers and barriers influencing consumer adoption.

To further strengthen the interpretation, the patterns presented in [Table 3](#) highlight the complementary roles of technological, behavioural, and contextual factors in shaping adoption intention. The positive effects of perceived transparency and trust, grounded in Supply Chain Transparency Theory (SCTT), indicate that blockchain functions not only as a technological tool but also as a trust-enabling mechanism within the halal ecosystem. At the same time, the influence of relative advantage, complexity, and compatibility-related perceptions reflects the relevance of Diffusion of Innovation (DOI) in explaining how consumers evaluate new technologies. Meanwhile, the contribution of attitude, subjective norms, and perceived behavioural control confirms the explanatory power of the Theory of Planned Behaviour (TPB) in capturing individual readiness and social influence. The coexistence of enabling and constraining factors suggests that adoption is a multidimensional process, where perceived benefits must outweigh usability challenges. Therefore, these findings highlight the importance of not only improving system transparency and reliability but also enhancing user experience and digital literacy to ensure broader acceptance of blockchain-based halal traceability systems.

Table 3. Determinants of Adoption Intention (Analytical Summary)

Variable	Theoretical Basis	Effect on Adoption Intention	Direction	Interpretation
Perceived Transparency	Supply Chain Transparency Theory	Significant influence	Positive	Enhances visibility and credibility of halal information
Trust Enhancement	Supply Chain Transparency Theory	Significant influence	Positive	Strengthens confidence in halal certification and product authenticity
Relative Advantage	Diffusion of Innovation Theory	Significant influence	Positive	Perceived superiority over conventional traceability systems
Attitude Toward Use	Theory of Planned Behavior	Significant influence	Positive	Positive evaluation increases intention to adopt
Subjective Norms	Theory of Planned Behavior	Moderate influence	Positive	Social pressure encourages adoption behaviour
Perceived Behavioural Control	Theory of Planned Behavior	Constraining influence	Negative	Limited digital skills reduce adoption readiness
Complexity	Diffusion of Innovation Theory	Constraining influence	Negative	Perceived difficulty discourages system usage

Source: Data processed by Authors (2025)

Barriers to Blockchain Adoption

The qualitative analysis identifies low technological literacy as a fundamental barrier to the adoption of blockchain-based halal traceability systems. Many stakeholders, particularly MSMEs, lack sufficient understanding of how blockchain operates, including its core features such as decentralization, encryption, and smart contracts. This limited knowledge reduces their confidence in using the system and creates resistance to adoption. The findings suggest that blockchain is still perceived as a complex and abstract technology rather than a practical tool that can be easily integrated into daily business operations. Several respondents emphasized that without adequate training and continuous assistance, the system would be difficult to adopt at scale. This indicates that successful implementation requires not only technological infrastructure but also systematic efforts to improve digital literacy through education, training programs, and user-friendly system design.

- (1) *"We need training first; otherwise, it's difficult to understand. Blockchain is still unfamiliar."*
(Halal Industry Actor, West Java)
- (2) *"Most small businesses don't really understand how blockchain works, so they are hesitant to use it."* (MSME Actor, DKI Jakarta)

Another major barrier is the high cost of implementation, which disproportionately affects small and medium-sized enterprises. The adoption of blockchain technology requires substantial initial investment in infrastructure, system development, integration processes, and ongoing maintenance. For many MSMEs operating with limited financial capacity, these costs are perceived as a significant burden, making blockchain adoption economically unfeasible. Respondents highlighted that financial constraints not only limit adoption but also create inequality between large enterprises and smaller actors in the supply chain. This suggests that without financial support mechanisms, such as subsidies or shared digital platforms, widespread implementation will remain challenging.

- (3) *"If it's expensive, which MSMEs can afford it? Because perhaps only large companies can."*
(Distributor, North Sumatra)
- (4) *"The cost of implementing this system is still too high for small businesses like us."* (Retailer, Aceh)

Regulatory uncertainty further constrains the adoption of blockchain-based halal traceability systems. The absence of clear and harmonized standards regarding blockchain implementation in halal certification creates ambiguity among stakeholders, particularly concerning data validation, authority, and accountability. Without a well-defined regulatory framework, stakeholders are unsure about who should act as the central validator, how compliance will be monitored, and whether blockchain-based certification will be formally recognized. This uncertainty reduces institutional trust and delays adoption decisions, as businesses are reluctant to invest in systems that are not yet formally regulated or standardized. The findings highlight the critical role of government and halal certification bodies in providing clear guidelines and ensuring interoperability across systems.

- (5) *"If blockchain is used, who will be the validator? There must be standardization from the Indonesian Ulema Council (MUI) or other halal institutions."* (Regulator, DKI Jakarta)

(6) "We need clear rules first, otherwise companies will hesitate to adopt the system." (Industry Stakeholder, West Java)

To sum up, these findings demonstrate that barriers to blockchain adoption are multidimensional, encompassing technological, economic, and institutional challenges. While the potential benefits of blockchain in enhancing transparency and trust are widely acknowledged, its implementation requires a supportive ecosystem that includes capacity building, financial accessibility, and regulatory clarity.

Proposed Blockchain-based Halal Traceability

Figure 2 illustrates the proposed blockchain-based halal traceability model, which integrates technological infrastructure with halal governance to ensure end-to-end transparency, accountability, and responsibility across the supply chain. The model is designed as a multi-layered system connecting key actors, suppliers, producers, distributors, retailers, regulators (MUI/BPJPH), logistics providers, investors, and consumers, within a unified blockchain network. At its core, the model ensures that all transactions and halal-related information are recorded in a decentralized and immutable ledger, enabling real-time verification and reducing the risk of data manipulation. This integrated architecture not only facilitates seamless information flow among stakeholders but also strengthens trust by ensuring that every stage of the supply chain is traceable and verifiable.

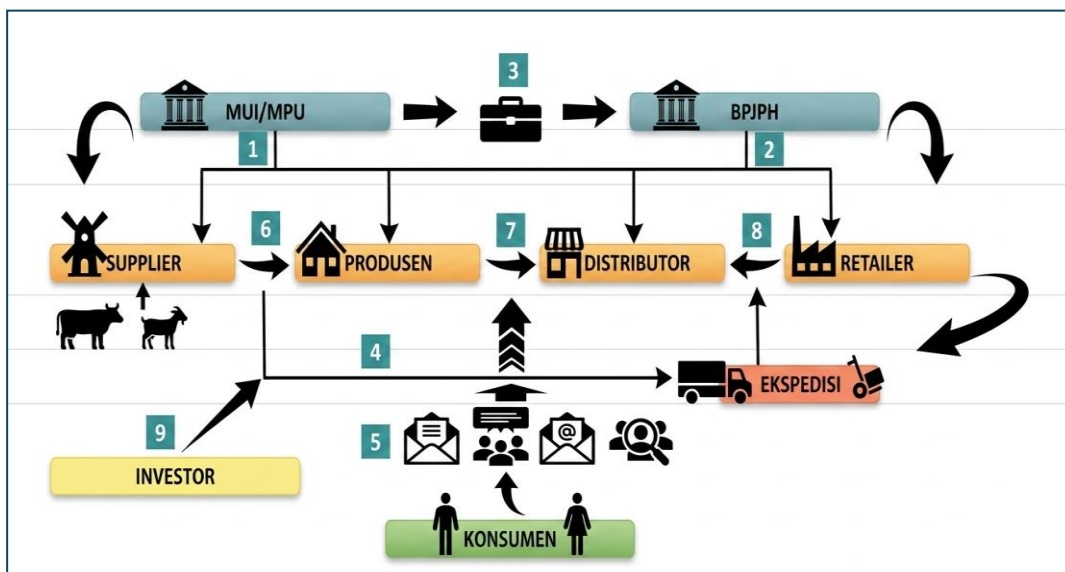


Figure 2. Proposed Model of Blockchain-based Halal Traceability

Note:

- (1) Halal certification process
- (2) Periodic monitoring and scheduled audits
- (3) Collaboration between MUI and BPJPH
- (4) Consumer-based traceability of product delivery (expedition tracking)
- (5) Availability of appeal mechanisms and accountability records
- (6) Product flow from supplier to producer
- (7) Product flow from producer to distributor
- (8) Product flow from distributor to retailer
- (9) Investor access to supply chain data and performance reports

The model is grounded in three fundamental principles: transparency, accountability, and responsibility. Transparency is achieved through the continuous recording of all supply chain data, including raw material sources, production processes, logistics activities, and retail transactions, which are made accessible to relevant stakeholders. Accountability is ensured by assigning identifiable roles to each actor in the supply chain, where every transaction is linked to a specific entity and permanently stored in the blockchain system. Responsibility, in turn, requires each actor to comply with halal standards and regulatory requirements, with their actions subject to verification by authorized institutions. These three principles function as the ethical and operational foundation of the system, ensuring that halal integrity is maintained throughout the entire product lifecycle.

The operational workflow of the model consists of several key stages. The first stage involves data recording at the supplier level, where information related to raw materials, including origin, certification status, and handling processes, is entered into the system. This is followed by the production stage, where producers record detailed information on processing activities, ingredients, and compliance with halal procedures. The next stage involves distribution and logistics, where transportation conditions, storage processes, and delivery records are documented to prevent contamination and ensure traceability. At the retail level, product information, including certification details and transaction records, is updated and made accessible. These sequential stages form a continuous data chain that enables full traceability from upstream to downstream.

A critical component of the model is the third-party validation mechanism, represented by regulatory and certification bodies such as MUI and BPJPH. These institutions function as trusted validators within the blockchain network, responsible for verifying the accuracy and compliance of the data entered at each stage. Validation processes include halal certification, periodic audits, and monitoring of supply chain practices. By embedding these regulatory functions within the blockchain system, the model ensures that all recorded information is credible, standardized, and aligned with national halal regulations. This not only enhances institutional trust but also reduces the risk of fraudulent certification and inconsistent standards.

The final stage of the model focuses on consumer access, which represents the ultimate objective of the system. Consumers are provided with user-friendly interfaces, such as mobile applications or QR code scanning features, that allow them to retrieve complete product histories in real time. Through this mechanism, consumers can verify the origin of raw materials, production processes, certification status, and distribution pathways before making purchasing decisions. In addition, the model accommodates broader stakeholder engagement, including investors who can monitor supply chain performance and transparency. Overall, the proposed blockchain-based halal traceability model offers a comprehensive and practical framework that not only enhances supply chain transparency and trust but also supports the digital transformation of the halal industry through an integrated, accountable, and consumer-oriented system.

Discussion

The findings of this study demonstrate that blockchain technology holds substantial potential as a transparent and accountable solution for halal traceability within increasingly complex supply chains. The diversity of respondents implies the heterogeneous nature of

supply chain actors, which necessitates an interoperable and flexible tracking system capable of accommodating varying operational needs (Al-Rakhami & Al-Mashari, 2022; Viriyasitavat, & Hoonsopon, 2022). This reinforces the argument that blockchain-based systems must be designed not only as technological infrastructures but also as adaptive platforms that respond to contextual differences across stakeholders (Irresberger & Yang, 2023). The study further confirms that blockchain traceability aligns with the fundamental principles of transparency, accountability, and responsibility in the global food system (Aung & Chang, 2014; Galvez et al., 2018). By enabling immutable audit trails, blockchain enhances efficiency and collaboration while reducing information asymmetry. In doing so, it strengthens consumer trust and satisfaction through improved access to reliable product information (Centobelli et al., 2022; Cui et al., 2024; Chen et al., 2021; Galvez et al., 2018; Kamilaris et al., 2019).

The findings also reveal that consumers increasingly expect an end-to-end traceability system capable of tracking products from upstream to downstream. This expectation reflects the growing relevance of the farm-to-fork transparency paradigm, which emphasizes full visibility across the supply chain (Ajzen, 1991). Consumers who are more aware of halal fraud risks tend to demonstrate stronger support for blockchain-based systems, indicating that perceived risk plays a critical role in shaping adoption behavior (Karyani et al., 2024; Purusottama et al., 2023). From a theoretical standpoint, this aligns with the Diffusion of Innovation (DOI) theory, where perceived relative advantage significantly drives innovation adoption (Abdul-Rahman et al., 2021; Galvez et al., 2018). At the same time, the findings are consistent with the Theory of Planned Behavior (Peters et al., 1985), highlighting the importance of subjective norms and perceived behavioral control in influencing behavioral intention. These results suggest that blockchain adoption is not solely driven by technological attributes but is also shaped by social influence and individual readiness, positioning blockchain as both a technological and behavioral innovation in the halal industry.

Furthermore, the findings support the growing recognition of blockchain as a strategic tool for combating fraud and enhancing governance in food supply chains. This aligns with FAO (2021) recommendations advocating the use of digital technologies to improve transparency and traceability. The ability of blockchain to provide a permanent and tamper-proof audit trail enables clear identification of responsible parties at each stage of the supply chain, thereby reducing fraud risks and strengthening accountability (Hashim & Shariff, 2016). This is consistent with Supply Chain Transparency Theory, which emphasizes the importance of information disclosure and coordination among stakeholders (Matenga & Mpofu, 2023; Yele & Litoriya, 2024). By facilitating access to credible information, blockchain empowers consumers to make informed decisions and enhances trust in halal certification processes (Duan & Zhu, 2025). Moreover, improved transparency contributes to better coordination, reduced operational errors, and stronger compliance with established standards (Aswad, 2022; Tumiwa et al., 2023).

Despite these promising advantages, the study also identifies significant barriers that limit the widespread adoption of blockchain in halal supply chains. Limited technological literacy remains a critical challenge, particularly among MSMEs, as many stakeholders lack the necessary knowledge and skills to understand and utilize blockchain effectively. In addition, high implementation costs create financial constraints that disproportionately affect smaller businesses, reinforcing existing inequalities within the supply chain. This

finding is consistent with prior research highlighting cost as a major barrier to blockchain adoption in developing countries. Regulatory uncertainty further complicates adoption, as the absence of harmonized standards and clear institutional frameworks leads to fragmentation and reduces stakeholder confidence. These multidimensional challenges indicate that blockchain adoption must be approached as a systemic transformation requiring coordinated interventions across technological, economic, and regulatory domains (Harsanto et al., 2024).

Building on these challenges, the findings emphasize that blockchain adoption requires a supportive ecosystem rather than a purely technological solution. Effective implementation depends on the integration of capacity building, financial support, and institutional alignment. Technological literacy must be enhanced through targeted training programs to ensure that industry actors, particularly MSMEs, can effectively utilize blockchain systems (Ahmed, 2025; Khan et al., 2023). At the same time, economic incentives, such as subsidies and financial support mechanisms, are necessary to reduce the burden of initial investment costs. Evidence from prior studies suggests that such policy interventions can significantly accelerate technology adoption in developing economies (Pandey et al., 2022). In addition, the establishment of clear and harmonized national regulations is essential to ensure standardization and interoperability, particularly in the context of halal certification (Sharma & Kaur, 2023). These findings highlight the importance of multi-stakeholder collaboration involving government, certification bodies, and technology providers in building a robust and inclusive blockchain ecosystem.

From both theoretical and practical perspectives, this study demonstrates that blockchain adoption in halal supply chains represents not merely a technological advancement but a broader transformation in governance and trust mechanisms. By integrating the Theory of Planned Behavior (TPB), Diffusion of Innovation (DOI), and Supply Chain Transparency Theory (SCTT), the study offers a comprehensive framework that explains how behavioral readiness, innovation perception, and transparency-driven trust collectively shape adoption. This integration positions blockchain as a trust-enabling infrastructure that shifts traditional halal certification from centralized control toward decentralized and transparent systems, thereby advancing the discourse on digital governance in halal ecosystems. Practically, the findings highlight the need for coordinated actions among policymakers, industry stakeholders, and certification bodies. Governments should establish clear and harmonized regulatory frameworks while providing financial incentives to support adoption, particularly for MSMEs. Halal certification bodies are encouraged to adopt digital validation mechanisms to ensure real-time verification and enhance institutional credibility, while industry actors should invest in capacity building and collaborative platforms. Collectively, these efforts are essential to foster an inclusive, transparent, and technologically advanced halal supply chain.

Conclusion

This study provides robust empirical evidence that blockchain technology has substantial potential to enhance transparency, trust, and operational efficiency within halal supply chains, particularly in the Indonesian context. The findings indicate strong consumer demand for blockchain-based halal traceability systems, reflecting increasing expectations for transparent and verifiable halal information. The results confirm that transparency,

traceability, and accountability are not merely technological attributes but critical determinants of consumer trust and adoption intention. By integrating the Theory of Planned Behaviour (TPB), Diffusion of Innovation (DOI), and Supply Chain Transparency Theory (SCTT), this study develops a comprehensive and empirically grounded framework that explains how behavioural intentions, perceived innovation benefits, and transparency mechanisms jointly influence consumer adoption of blockchain technology. Theoretically, this study contributes by bridging behavioural and technological adoption perspectives within halal supply chains, an area that remains underexplored in prior research. Practically, the findings highlight the need for regulatory harmonization, digital validation mechanisms by certification bodies, and targeted support, such as financial incentives and capacity-building programs, to facilitate inclusive adoption, particularly among MSMEs.

Despite these contributions, this study has several limitations that should be acknowledged. First, the analysis relies primarily on descriptive and explanatory approaches without employing advanced statistical modelling, which may limit the generalizability and predictive strength of the findings. Second, the proposed blockchain-based model has been validated at a conceptual and simulation level but has not yet been tested in real-world implementation settings. Future research should therefore focus on pilot studies and field-based experiments to evaluate the practical effectiveness, scalability, and economic feasibility of blockchain systems in actual halal supply chains. In addition, further studies may incorporate more advanced analytical techniques, such as structural equation modelling, to provide deeper insights into causal relationships among variables. Overall, this study establishes blockchain not only as a technological innovation but as a transformative governance mechanism with the potential to strengthen the integrity, transparency, and global competitiveness of the halal industry.

Authors' Declaration


The authors made substantial contributions to the conception and design of this study. The authors take responsibility for the data analysis, interpretation, and discussion of the results. The authors have read and approved the final manuscript.

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ORCID

Ramadhan Razali  <https://orcid.org/0009-0007-1060-7016>

Muh. Nashirudin  <https://orcid.org/0000-0002-7902-5491>

Zulfikar  <https://orcid.org/0009-0008-4602-3773>

Mahdi  <https://orcid.org/0009-0005-8526-2003>

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