Share
Jurnal Ekonomi dan Keuangan Islam
Journal of Islamic Economics and Finance

ISSN:
2089-6239 (Print)
2549-0648 (Online)

Digitalizing Halal Assurance: An Integrated Framework of Blockchain, IoT, and Laboratory Verification

ABSTRACT – The growing complexity of global halal supply chains has exposed structural weaknesses in conventional halal certification systems, particularly in ensuring traceability, transparency, and scientific verification. This study aims to propose an integrated conceptual framework for strengthening halal product assurance by combining blockchain technology, the Internet of Things (IoT), and laboratory testing within a unified governance model. Using a conceptual and theory-driven approach, the framework systematically maps each technology to specific stages of the halal value chain, from raw material sourcing and processing to logistics and certification, thereby forming a closed-loop compliance monitoring system. The findings show that blockchain enables immutable and transparent data recording, IoT supports real-time monitoring of environmental and logistical conditions, and laboratory testing provides empirical validation of product composition. The integration of smart contracts further automates compliance verification, reducing human error and increasing operational efficiency. The framework is theoretically grounded in traceability systems theory, socio-technical systems theory, and the objectives of Islamic law (*maqāṣid al-sharīʿah*), ensuring both technological reliability and Shariah alignment. The study's implications highlight the potential of ethically aligned digital innovation to enhance trust, accountability, and governance in halal assurance, offering strategic insights for certification bodies, industry actors, and regulators navigating halal governance in the digital era.

ABSTRAK - Digitalisasi Jaminan Halal: Kerangka Terintegrasi Blockchain, IoT, dan Verifikasi Laboratorium. *Meningkatnya kompleksitas rantai pasok halal global telah mengungkap berbagai keterbatasan sistem sertifikasi halal konvensional, khususnya dalam menjamin keterlacakan, transparansi, dan validitas ilmiah produk. Penelitian ini bertujuan merumuskan sebuah kerangka konseptual terintegrasi untuk memperkuat jaminan produk halal melalui pemanfaatan teknologi blockchain, Internet of Things (IoT), dan verifikasi laboratorium dalam satu sistem tata kelola yang komprehensif. Dengan pendekatan konseptual berbasis teori, setiap teknologi diposisikan secara strategis pada tahapan rantai nilai halal, mulai dari pengadaan bahan baku, proses produksi, distribusi, hingga penerbitan sertifikat, sehingga membentuk mekanisme pengawasan kepatuhan yang bersifat menyeluruh dan berkelanjutan. Blockchain berfungsi menjamin integritas dan ketertelusuran data, IoT memungkinkan pemantauan kondisi lingkungan dan logistik secara real time, sementara pengujian laboratorium memberikan pembuktian empiris atas kandungan produk. Penerapan smart contract mengotomatisasi proses verifikasi kepatuhan, meningkatkan efisiensi, serta meminimalkan kesalahan manusia. Kerangka ini berlandaskan teori sistem keterlacakan, teori sistem sosial-teknikal, dan maqāṣid al-sharīʿah, sehingga selaras secara teknis maupun normatif. Studi ini berimplikasi pada penguatan tata kelola halal berbasis teknologi yang etis, serta memberikan rujukan strategis bagi lembaga sertifikasi, pelaku industri, dan regulator di era digital.*

Idris Parakkasi[1*]
Faisal Akib[1]
[1]UIN Alauddin Makassar, Indonesia
**Corresponding email:*
idris.parakkasi@uin-alauddin.ac.id

Article History
Received: 16 August 2025
Last Revised: 09 October 2025
Accepted: 01 December 2025
Published: 20 December 2025

Keywords
Halal assurance, blockchain, Internet of Things, laboratory testing, Islamic economic system

JEL Classification
O33, L15, Z12, L86, G18

INTRODUCTION

Over the past two decades, the global halal economy has experienced substantial growth, driven by the expansion of Muslim populations and a growing preference for ethical and Shariah-compliant consumption. Importantly, halal consumption is no longer confined to religious adherence alone but has increasingly attracted a broader global consumer base that values safety, quality, sustainability, and ethical integrity. Recent industry estimates suggest that the halal market may exceed USD 3 trillion in value, reflecting strong and sustained demand for products aligned with Islamic law while meeting international standards of quality and consumer protection. This growth is further reinforced by the multi-sectoral nature of the halal economy, which extends beyond food and beverages to include pharmaceuticals, cosmetics, logistics, fashion, and tourism, demonstrating the pervasive influence of halal principles across diverse industries (Castro et al., 2021; Mahsun et al., 2023; Talib, 2020).

Despite this rapid expansion, the halal industry faces persistent challenges related to ensuring halal integrity throughout increasingly complex global supply chains. Many jurisdictions continue to rely on decentralized and fragmented halal certification systems that depend heavily on manual documentation and conventional auditing practices. Such approaches are often inefficient and vulnerable to risks including fraud, mislabeling, cross-contamination, and regulatory non-compliance (Ibrahim, 2023). These risks threaten not only economic performance but also the ethical foundations of the halal ecosystem, undermining trust, transparency, and collective responsibility—values that are central to the Islamic economic system (Hendayani & Fernando, 2022; Kamarulzaman et al., 2021; Munawar & Mugiono, 2024; Voak & Fairman, 2021).

Growing scholarly and practitioner awareness highlights the multifaceted consequences of these operational vulnerabilities, particularly their adverse effects on consumer confidence and the preservation of religious values underpinning halal assurance. Effective monitoring and governance of halal products across their entire lifecycle are therefore not merely operational requirements but moral obligations grounded in Islamic jurisprudence. As consumer sensitivity to misrepresentation increases, the role of halal certification bodies becomes more critical in ensuring transparency, accountability, and compliance with established halal standards (Mohamed et al., 2020; Munawar & Mugiono, 2024).

In this context, halal assurance must evolve beyond procedural compliance toward an integrated system that is scientifically verifiable, technologically advanced, and aligned with the objectives of Islamic law *(maqāṣid al-sharīʿah).* Advances in digital technologies offer transformative potential to address existing assurance gaps. Blockchain technology, for example, provides a decentralized and immutable mechanism for recording supply chain transactions, enabling transparent and tamper-resistant data management that strengthens trust across certification processes (Dilla & Fathurohman, 2021; Harsanto et al., 2024).

Complementing blockchain, the Internet of Things (IoT) enhances halal assurance through real-time monitoring of critical operational conditions throughout production, storage, and distribution. The deployment of sensors at key stages of the halal supply chain enables continuous data collection on parameters such as temperature, hygiene, and handling procedures,

thereby supporting consistent compliance with halal requirements. When integrated, IoT-generated data and blockchain-based validation form a synergistic technological convergence capable of sustaining rigorous halal compliance across complex and geographically dispersed supply chains (Anggraini et al., 2023; Castro et al., 2021; Ismail et al., 2022).

In addition to these digital technologies, laboratory testing plays a crucial role in providing empirical verification of product composition. Analytical techniques such as polymerase chain reaction (PCR) and enzyme-linked immunosorbent assays (ELISA) enable the detection of trace amounts of prohibited substances, thereby strengthening the reliability and credibility of halal certification decisions. Integrating laboratory test results into blockchain-based systems further enhances traceability, accountability, and evidence-based decision-making within halal assurance frameworks (Dashti et al., 2024; Munawar & Mugiono, 2024; Voak & Fairman, 2021).

However, despite increasing academic interest in blockchain, IoT, and laboratory testing within halal supply chains, existing research remains fragmented. Most studies examine these technologies in isolation—focusing on blockchain for traceability, IoT for environmental monitoring, or laboratory testing for post-production verification—without offering an integrated framework that systematically links all components across the halal value chain. Moreover, the incorporation of Islamic legal objectives *(maqāṣid al-sharīʿah)* into technological design remains limited, resulting in models that are operationally effective but normatively insufficient. This fragmentation reveals a critical research gap in developing a holistic, Shariah-aligned, multi-technology halal assurance framework.

Current literature also tends to underemphasize the ethical, religious, and socio-economic dimensions that fundamentally underpin the halal economy (Kamri et al., 2014). Consequently, there is a pressing need for a conceptual model that integrates blockchain, IoT, and laboratory testing within a unified halal assurance paradigm—one that transcends operational efficiency and embeds Islamic principles of justice, transparency, and mutual accountability into technological infrastructures (Kusnadi et al., 2024).

This study addresses the existing gap through an integrative halal certification framework that combines blockchain, IoT, and laboratory verification to ensure comprehensive product traceability across all stages of the halal supply chain. The framework reinforces halal assurance from raw material sourcing and production to laboratory validation and automated certification processes. In tackling systemic weaknesses in current assurance mechanisms, the proposed model advances technological innovation while upholding the spiritual and ethical principles of halal consumption in accordance with Islamic values (Adiningtyas & Yunus, 2024; Davids & Sabrain, 2022).

Beyond technological integration, this study seeks to bridge the gap between emerging digital innovations and Shariah-compliant economic governance through the development of scalable, efficient, and ethically grounded halal assurance paradigms (Ibrahim, 2022). The proposed framework prioritizes transparency, integrity, and end-to-end traceability, contributing to the ongoing discourse on the digital transformation of Islamic economics. In doing so, it offers practical guidance for certification authorities, industry stakeholders, and technology providers (Masudin et al., 2022).

The novelty of this research lies in the development of a unified, Shariah-embedded halal assurance framework that integrates blockchain, IoT, and laboratory testing into a single interoperable system. Unlike existing models (Dashti et al., 2024), the proposed framework explicitly aligns technological functionalities with Islamic ethical imperatives, enabling continuous verification, scientific validation, and automated compliance decisions guided by *maqāṣid al-sharīʿah.*

This study contributes to the intersection of digital technologies and Islamic economic principles by advocating for a synchronized approach wherein blockchain, IoT, and scientific validation mechanisms collectively establish a robust halal assurance paradigm capable of addressing the complexities of the contemporary global halal economy. It envisions a future where technology functions not merely as a tool for efficiency but as a medium for religious adherence and ethical governance, fostering enhanced trust and accountability across global halal markets (Dashti et al., 2024).

Consequently, the proposed framework holds significance for both theory and practice. Theoretically, it advances the literature by synthesizing socio-technical systems theory, traceability theory, and Islamic economics into a coherent conceptual foundation. Practically, it equips regulators, certification bodies, and industry stakeholders with a scalable digital blueprint to strengthen halal integrity, mitigate fraud risks, and enhance cross-border certification interoperability.

LITERATURE REVIEW

Technological Innovations in Halal Assurance

Technological innovation has become increasingly critical to halal assurance as the global market for halal-certified products continues to expand and grow in complexity. The integration of advanced technologies—particularly blockchain, the Internet of Things (IoT), and laboratory testing—has been widely examined for its potential to enhance traceability, verification, and compliance with Islamic principles throughout halal supply chains. Nevertheless, the extant literature reveals that these technologies are often studied independently, with limited attention given to their holistic integration within a unified halal assurance framework.

Blockchain Technology

Blockchain technology offers a decentralized and tamper-resistant ledger system that enhances traceability and transparency across distributed supply chain networks. Within the context of halal certification, blockchain enables the secure recording of transaction data, including slaughtering certifications, raw material origins, and processing histories. Its immutable structure significantly reduces the risk of counterfeit documentation and data manipulation. Empirical studies demonstrate that blockchain adoption can improve real-time verification of halal status, thereby addressing consumer concerns regarding product authenticity and regulatory compliance (Abidin & Perdana, 2020).

Despite these advantages, several barriers continue to hinder the widespread adoption of blockchain in halal certification systems. These challenges include technological incompatibilities, the absence of standardized protocols across certification bodies, and

institutional resistance from regulatory authorities within the halal ecosystem. Consequently, scholars emphasize the necessity of developing robust frameworks that combine technological advancement with regulatory innovation to overcome these structural impediments and facilitate effective blockchain implementation in halal assurance (Mehmood et al., 2024).

Internet of Things (IoT)

The integration of IoT technologies plays a pivotal role in strengthening halal assurance systems by enabling real-time monitoring and data collection across production, storage, and distribution processes. IoT devices such as RFID tags, temperature sensors, and GPS trackers facilitate automated compliance validation by ensuring proper handling, segregation from non-halal products, hygiene standards, and optimal transportation conditions. Although IoT has demonstrated substantial potential across various industries, its application within halal certification practices remains relatively underdeveloped, suggesting considerable opportunities for further innovation and empirical investigation (Yi et al., 2021).

Critically, the effective integration of IoT-generated data with complementary technologies—particularly blockchain—can form a robust assurance framework that satisfies both technical requirements and societal trust expectations in halal governance. However, existing studies frequently highlight unresolved challenges related to data interoperability and system convergence, particularly concerning how IoT data can be securely integrated into blockchain platforms while remaining aligned with Islamic ethical standards (Karyani et al., 2024)

Laboratory Testing

Laboratory testing constitutes a fundamental component of halal verification, particularly for processed or complex products where visual inspection or document-based assessments are insufficient. Analytical techniques such as polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA), and Fourier Transform Infrared Spectroscopy (FTIR) are widely employed to detect prohibited substances and potential contaminants. Despite their critical role, laboratory testing processes are frequently isolated from digital certification platforms, resulting in fragmented documentation practices, inefficiencies, and data silos within the halal assurance ecosystem (Abidin & Perdana, 2020). The central challenge lies in integrating empirical laboratory results into real-time monitoring and digital verification systems to enhance the credibility and reliability of halal certification outcomes.

Smart Contracts

Smart contracts—self-executing digital agreements encoded within blockchain systems—present an innovative mechanism for automating halal certification processes. Through smart contracts, halal certifications can be automatically issued, updated, or revoked based on real-time data inputs obtained from IoT devices or laboratory testing results. While this automation enhances efficiency and consistency, concerns persist regarding technical vulnerabilities, the need for human oversight, and the alignment of automated decision-making with Islamic legal principles, particularly the role of intention (*niyyah*) in certification processes (Munawar & Mugiono, 2024).

Global Perspectives on Halal Assurance Technologies

Comparative studies across regions demonstrate that digital transformation in halal governance is progressing unevenly yet consistently worldwide. Research from Southeast Asia, the Middle East, and Europe indicates increasing adoption of blockchain-enabled traceability systems in response to growing cross-border halal trade complexity. Meanwhile, laboratories in countries such as Japan and Turkey have advanced DNA-based detection techniques to enhance contamination control in processed food products. These international experiences reveal that challenges related to fragmented certification regimes, inconsistent monitoring capabilities, and uneven technological readiness are globally shared, reinforcing the need for integrated and interoperable halal assurance systems capable of accommodating diverse regulatory and cultural environments (Castro et al., 2021; Dashti et al., 2024).

Research Gaps and Integration Needs

While the existing literature affirms the effectiveness of blockchain, IoT, and laboratory testing as standalone tools for halal assurance, a clear absence of integrative models that embed these technologies within a comprehensive, ethical, and scalable framework remains evident. Moreover, the intersection between technological innovation and theological, institutional, and governance considerations is insufficiently explored, underscoring the need for interdisciplinary research that aligns technical advancement with Islamic values and regulatory realities (Siddiqi et al., 2024).

Unlike technology integration models in sectors such as pharmaceuticals or organic food traceability—where the emphasis is placed predominantly on product safety and operational efficiency—the proposed framework uniquely incorporates Islamic ethical imperatives by aligning technological components with the spiritual and social responsibilities inherent in halal assurance.

Theoretical Foundations for an Integrated Framework

To establish a robust conceptual foundation for integrating blockchain, IoT, and laboratory testing into halal assurance systems, this study adopts a hybrid theoretical approach combining traceability systems theory, socio-technical systems theory (STS), and Islamic economic principles, particularly maqāṣid al-sharīʿah. Together, these perspectives address the technical, social, and ethical dimensions necessary for constructing a comprehensive and Shariah-aligned halal assurance framework.

Although prior models have incorporated digital traceability into halal assurance, few have explicitly embedded Islamic ethical imperatives into the core operational logic of technological systems. This study advances the literature by integrating technological tools, religious oversight mechanisms, and scientific validation into a unified framework, shifting from fragmented applications toward a harmonized, multi-technology architecture grounded in maqāṣid al-sharīʿah.

Traceability Systems Theory

Traceability systems theory emphasizes the systematic tracking of a product's origin, history, and movement across the supply chain. In halal assurance, traceability extends beyond logistics to encompass compliance with religious and ethical standards. The theory identifies three essential pillars: data generation, data integrity, and data accessibility, all of which are critical for developing a trustworthy and auditable halal assurance system.

Within the proposed framework, IoT technologies facilitate real-time data generation, enabling continuous monitoring of compliance conditions. Blockchain ensures data integrity through tamper-resistant storage of transaction records and certification data, while laboratory testing provides empirical validation of halal status by confirming the absence of prohibited substances. Collectively, these technologies form a cross-verification mechanism in which each component reinforces system reliability, resulting in a multidimensional assurance model that integrates technical, scientific, and ethical dimensions—a significant departure from traditional traceability approaches (Bux et al., 2022).

Socio-Technical Systems Theory (STS)

Socio-technical systems theory posits that system effectiveness depends on the alignment of technical infrastructures with social, organizational, and institutional contexts. In the halal industry, where multiple stakeholders—including religious authorities, certification bodies, producers, and consumers—possess diverse interests and expectations, this alignment is particularly critical.

Applying STS principles facilitates the development of halal assurance systems that are not only technologically advanced but also socially legitimate and institutionally viable. This includes designing user-friendly interfaces for auditors, transparent systems for regulators, and culturally sensitive mechanisms that respect Muslim values. Systems grounded in STS are more likely to gain stakeholder acceptance, thereby enhancing the effectiveness and credibility of halal certification processes (Fauzi et al., 2022).

Islamic Economic Principles and Maqāṣid al-sharīʿah

Islamic economic principles, particularly maqāṣid al-sharīʿah, constitute the ethical foundation of the proposed framework. These objectives include the preservation of faith (dīn), life (nafs), wealth (māl), intellect (ʻaql), and lineage (nasl). In the context of halal assurance, these principles translate into ensuring religious permissibility, food safety, fraud prevention, informed consumer decision-making, and moral integrity.

To uphold these objectives, halal assurance systems must prioritize transparency, verifiability, and integrity rather than focusing solely on operational efficiency. Embedding technological innovation within maqāṣid al-sharīʿah ensures that digital advancements support Shariah compliance while simultaneously addressing commercial and regulatory demands (Bux et al., 2022; Mahama et al., 2020).

This conceptual orientation represents a substantive advancement over prior traceability frameworks, which typically assess Shariah compliance only at the certification stage. In

contrast, the proposed model adopts a compliance-by-design approach, embedding Islamic ethical values directly into system architecture, data flows, and governance mechanisms. This alignment provides the framework with both normative depth and practical rigor (Mahsun et al., 2023).

Synthesis of Theoretical Perspectives

The integration of traceability systems theory, socio-technical systems theory, and Islamic economic principles establishes a comprehensive theoretical foundation for the proposed halal assurance framework. Traceability theory ensures functional completeness, STS promotes social and institutional alignment, and Islamic economics provides ethical legitimacy grounded in spiritual and cultural values.

This synthesis enables the development of a halal ecosystem that is resilient, scalable, and responsive to future challenges. Through the alignment of ethical principles and technical standards across stakeholders, this framework strengthens institutional trust and fosters sustainable development within international halal markets (Adiningtyas & Yunus, 2024).

Ultimately, this study advances the halal assurance discourse by offering an integrated, ethically embedded framework that harmonizes Islamic jurisprudence with technological innovation and institutional governance, addressing both contemporary challenges and future demands of the global halal economy.

METHODOLOGY

Research Design

This study adopts a conceptual research design to develop an integrated framework for halal product assurance through the combined use of blockchain technology, the Internet of Things (IoT), and laboratory testing. Conceptual research is appropriate given the fragmented treatment of these technologies in existing halal assurance literature, where they are typically examined as isolated interventions rather than as interdependent components of a Shariah-aligned system. The objective of this study is not empirical hypothesis testing but the construction of a coherent system architecture that enhances integrity, transparency, and compliance in halal certification processes (Mahsun et al., 2023).

Data Sources and Literature Selection

The framework was developed through a systematic review and synthesis of secondary sources, including peer-reviewed journal articles, conference proceedings, regulatory documents, industry reports, and Islamic jurisprudential texts related to halal certification, digital traceability, supply chain governance, and Shariah-compliant technology. Literature was retrieved from academic databases such as Scopus, Web of Science, IEEE Xplore, and Google Scholar, supplemented by grey literature from halal certification authorities and Islamic economic institutions. Selection criteria required sources to (1) address halal assurance or food integrity, (2) involve blockchain, IoT, or laboratory testing, and (3) reference ethical, institutional, or Islamic governance considerations.

Analytical Procedure and Framework Construction

The analytical process followed four stages. First, selected literature was mapped thematically to identify technological applications, verification mechanisms, system integration challenges, and Islamic legitimacy considerations. Second, a conceptual synthesis was conducted to define the core functional requirements of an effective halal assurance system, namely real-time data acquisition (IoT), immutable and auditable data storage (blockchain), scientific product validation (laboratory testing), automated compliance decisions (smart contracts), and alignment with maqāṣid al-sharīʿah principles. Third, the emerging framework was aligned with traceability systems theory, socio-technical systems theory, and Islamic economic theory to ensure operational feasibility, institutional compatibility, and ethical coherence. Fourth, the framework was structured into five sequential phases—raw material sourcing, production, distribution, validation, and certification—each linked to specific technologies and verification functions reflecting real-world halal supply chain processes.

Validation Logic and Scope

As a conceptual study, validation is achieved through internal logical consistency, theoretical grounding, and alignment with challenges documented in halal industry literature. The framework is designed to be scalable and adaptable to varying regulatory and technological contexts and is intended to serve as a foundation for future empirical testing, pilot implementations, and system prototyping. The conceptual methodology is justified by persistent gaps in Shariah-compliant technology integration (Mahsun et al., 2023), rapid digital transformation in halal markets (Castro et al., 2021; Talib, 2020), the need to safeguard ethical foundations of the halal economy (Kamarulzaman et al., 2021; Munawar & Mugiono, 2024), and the established role of conceptual research in halal and Islamic economic studies (Hendayani & Fernando, 2022; Voak & Fairman, 2021).

RESULTS AND DISCUSSION

Functional Architecture of the Proposed Framework

The functional architecture presented in this section operationalizes the methodological synthesis developed earlier by translating theoretical principles into an integrated system design. Through the coordinated deployment of blockchain technology for data integrity, the Internet of Things (IoT) for real-time monitoring, and laboratory testing for scientific validation, the proposed framework directly addresses the primary deficiencies identified in the literature, including fragmented verification mechanisms, vulnerability to fraud, inconsistent data reliability, and limited transparency across halal supply chains. Accordingly, the framework represents more than a conceptual proposition; it constitutes a structured methodological extension in which each technological component is deliberately aligned with a specific structural weakness in prevailing halal assurance practices (Mohamed et al., 2020).

The proposed halal assurance framework is designed to enable end-to-end traceability, secure data governance, and automated compliance decisions through the integration of three core technologies: blockchain, IoT, and laboratory testing. These technologies are systematically embedded within a phased halal supply chain model consisting of five functional stages: raw

material acquisition, production, distribution, validation, and certification. Each stage performs a distinct role in preserving halal integrity while remaining interconnected through a unified digital infrastructure.

The architecture adopts a modular design that supports continuous data acquisition, immutable recordkeeping, and dynamic compliance evaluation. Operationally, the system begins with IoT-enabled devices capturing real-time data at each stage of the supply chain, including environmental conditions, handling procedures, and logistical movements. These data are continuously transmitted to a permissioned blockchain, where every recorded event—such as temperature logs, halal slaughter verification, or laboratory test outcomes—is stored in an immutable ledger, thereby establishing a transparent and verifiable audit trail.

Smart contracts function as the regulatory logic layer within the blockchain infrastructure. They automatically assess recorded data against predefined halal compliance thresholds and execute certification decisions accordingly. Laboratory testing operates as a critical validation gate within the framework, providing empirical confirmation of biological and chemical compliance prior to certification issuance. Only when laboratory results satisfy established halal criteria do smart contracts authorize the generation of halal certification records.

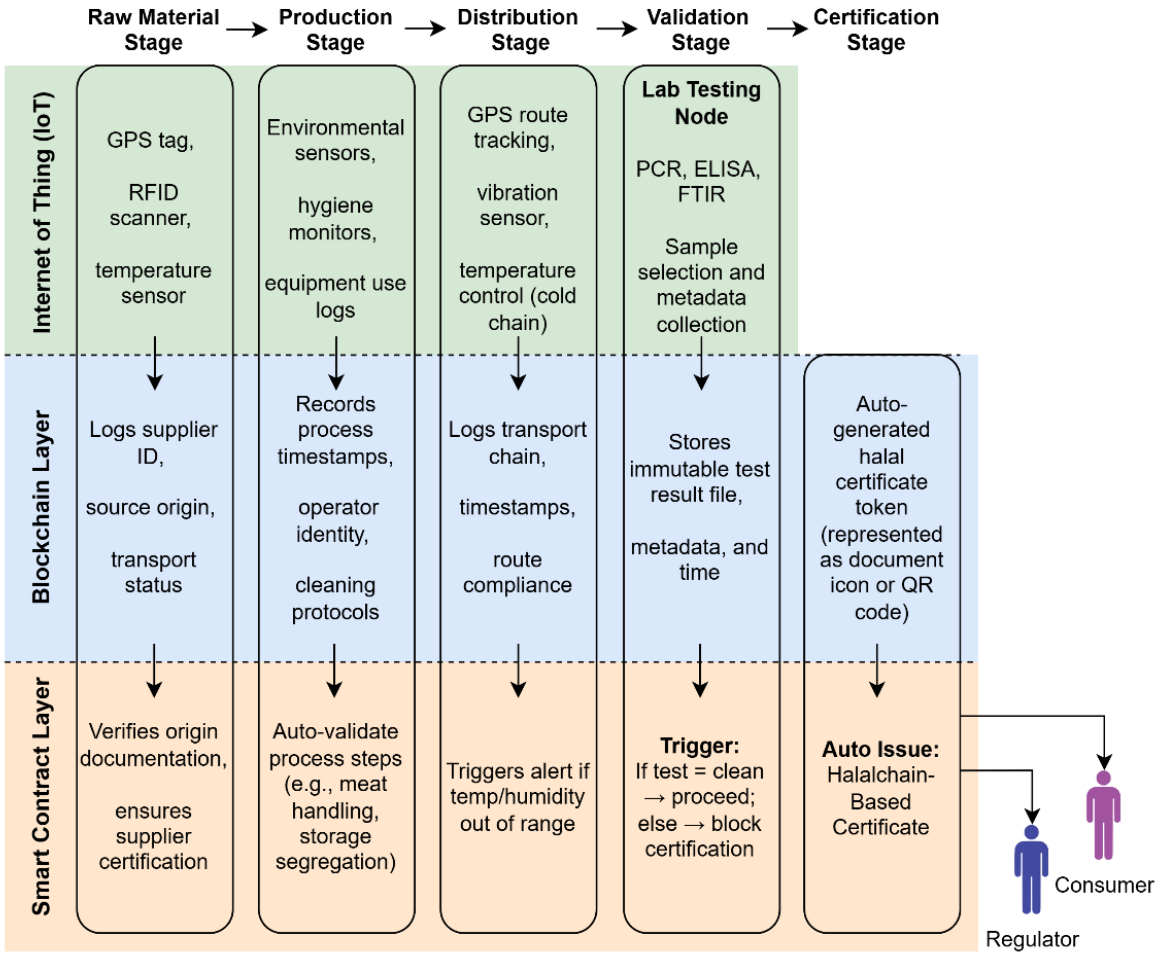

Figure 1. Integrated Architecture of the Halal Assurance Framework

Figure 1 illustrates the integrated architecture of the proposed halal assurance framework. The model depicts five sequential supply chain stages supported by IoT-based real-time data inputs, which are securely recorded on a blockchain layer. Smart contracts operate atop the blockchain to manage verification and decision logic, while laboratory testing results are incorporated at the validation stage. The final output is an automated halal certificate stored as a blockchain-based digital token, accessible via a QR code for verification by stakeholders.

Technological Component Integration

The effectiveness of the proposed halal assurance framework derives from the functional integration of its technological components and the clearly defined interdependencies among them. Rather than operating as standalone tools, blockchain, IoT, laboratory testing, and smart contracts are systematically assigned complementary roles across each stage of the halal supply chain. Table 1 summarizes the specific contributions of each technology to halal assurance throughout the supply chain lifecycle.

Table 1. Technology Integration Across Halal Supply Chain Stages

Supply Chain Stage	IoT Function	Blockchain Function	Laboratory Testing Function	Smart Contract Role
Raw Materials	Track source origin, GPS location, and storage conditions	Log supplier identity and halal source credentials	—	Ensure acceptance of certified halal sources only
Production	Monitor hygiene standards, temperature, and equipment usage	Record production activities with time-stamped entries	—	Validate process compliance and flag deviations
Distribution	Enable real-time tracking (GPS, vibration, container status)	Store transportation logs and maintain chain-of-custody records	—	Enforce cold-chain continuity and issue breach alerts
Validation	Support sample selection and metadata capture	Immutably register laboratory test results	Detect non-halal contamination using PCR, ELISA, and FTIR	Trigger pass/fail certification outcomes
Certification	—	Issue blockchain-based halal certificates with QR verification	—	Automatically issue certification upon fulfillment of Shariah criteria

(Source: Author's development based on integrative synthesis, 2024)

The integration of these technologies enables the formation of a closed-loop halal assurance system that is autonomous, tamper-resistant, and readily auditable. In contrast to conventional certification models that rely heavily on manual audits and retrospective documentation, the proposed framework facilitates continuous, data-driven, and objective evaluation of halal compliance across the entire supply chain.

A critical advancement of the model lies in the direct incorporation of laboratory testing results into the blockchain infrastructure. This integration enhances scientific rigor by ensuring that empirical validation data are securely stored and permanently linked to supply chain records, thereby eliminating data silos and minimizing the risk of manipulation. IoT devices function as trusted data oracles, supplying real-time operational inputs that are automatically evaluated by smart contracts. This configuration enables immediate system responses to compliance breaches,

such as halting product distribution, suspending certification processes, or issuing alerts to relevant stakeholders.

The proposed framework introduces mechanisms for granular monitoring, automated enforcement, and real-time verification, effectively mitigating persistent shortcomings in existing halal certification systems such as lack of transparency, delays, human error, and susceptibility to fraud. In addition, its design reflects the principles of *maqāṣid al-sharīʿah* by promoting trust (*amānah*), transparency (*shafāfiyyah*), and safeguarding religious authenticity across the halal value chain.

Halal Compliance Mapping Across Supply Chain Stages

While the preceding subsection demonstrates how blockchain, IoT, laboratory testing, and smart contracts function as an integrated technological ecosystem, technological capability alone does not inherently guarantee halal compliance. The effectiveness of such a system ultimately depends on how these technological functions are systematically aligned with halal requirements at each stage of the supply chain. Accordingly, the following subsection extends the discussion by mapping halal compliance criteria onto the sequential stages of the halal value chain, illustrating how technological controls operationalize Shariah requirements from raw material sourcing to final certification. This compliance mapping clarifies the correspondence between technological enforcement mechanisms and halal governance principles, thereby demonstrating how the proposed framework ensures continuous, stage-specific adherence to halal standards throughout the supply chain.

Raw Materials Stage

Halal compliance is initiated at the raw material stage through rigorous verification of ingredient origins and supplier legitimacy. IoT devices are employed to capture essential data, including supplier identification and geolocation information, while blockchain technology securely stores halal certificates issued by recognized certification authorities. This decentralized and immutable recordkeeping enables immediate validation of suppliers' halal credentials, aligning with Islamic legal requirements that halal products must originate from verified and permissible sources (Handayani et al., 2021; Mohamed et al., 2020). Within this framework, smart contracts are configured to automatically reject raw materials lacking valid certification, thereby reinforcing traceability and preventing non-compliant inputs from entering the supply chain.

Production Stage

During the production stage, strict compliance with hygiene protocols and segregation from non-halal materials is critical across sectors such as food, pharmaceuticals, and cosmetics. IoT sensors installed within production facilities continuously monitor key environmental and operational parameters, including temperature, humidity, and equipment usage. These data are time-stamped and immutably recorded on the blockchain, generating a verifiable history of compliance (Ismail et al., 2022; Kusnadi et al., 2024). Smart contracts assess these inputs in real time and are capable of triggering alerts or suspending production activities in response to detected violations, such as cross-contamination from non-halal sources. This automated

enforcement enhances operational reliability while satisfying both Shariah principles and audit requirements (Amid, 2024).

Distribution Stage

Maintaining halal integrity during distribution is essential, particularly for products sensitive to environmental conditions. GPS tracking and thermal sensors are utilized to monitor transport routes, container integrity, and storage conditions throughout transit. Any deviations from predefined halal compliance thresholds, including exposure to prohibited substances or temperature breaches, are documented on the blockchain as immutable records. These data provide verifiable evidence for regulatory inspections and can activate predefined contractual responses, such as alerts or revocation of halal status, when compliance is compromised (Hendayani & Febrianta, 2020; Mohamed et al., 2020).

Validation Stage

The validation stage integrates scientific laboratory testing to provide empirical confirmation of halal compliance, especially for processed or complex products. Analytical techniques such as polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA) are employed to detect the presence of non-halal substances at a molecular level. Laboratory test results are securely uploaded to the blockchain, becoming an integral component of the product's certification record (Namasudra et al., 2022). This integration strengthens the scientific rigor of the halal assurance process and enhances confidence among consumers, certification authorities, and regulators.

Certification Stage

Following successful compliance verification across all preceding stages, smart contracts automatically initiate the issuance of a halal certificate in the form of a blockchain-based digital token. This certificate is accessible via a QR code, enabling consumers and regulators to verify halal status through transparent and user-friendly blockchain interfaces. The automation of certification issuance, combined with immutable recordkeeping, enhances transparency, accessibility, and trust, while ensuring the continuity and integrity of halal assurance throughout the entire supply chain (Rusydiana et al., 2023; Talib, 2020).

Comparative Analysis with Traditional Halal Assurance Systems

A comparative assessment of the proposed framework and conventional halal assurance models highlights the transformative potential of technology-enabled compliance systems. Traditional halal assurance practices are typically characterized by fragmented documentation, heavy reliance on manual auditing, and retrospective verification procedures. Such characteristics increase vulnerability to fraud, human error, delayed detection of non-compliance, and inconsistent application of halal standards across supply chains.

Overall, the proposed framework signifies a shift from conventional trust-dependent halal assurance practices toward a technology-mediated model of verification. Rather than relying primarily on institutional discretion and periodic human audits, halal compliance in this framework is embedded within the technical architecture of the system itself. Automated data

capture, immutable recordkeeping, and rule-based validation collectively institutionalize compliance as a continuous and verifiable process. As a result, halal assurance becomes more transparent, consistent, and resilient, enhancing regulatory effectiveness while strengthening confidence among consumers, certifiers, and industry stakeholders.

Table 2. Comparison Between Traditional Halal Assurance Systems and the Proposed Framework

Aspect	Traditional System	Proposed Framework
Traceability	Partial, manual, and document-based	Real-time, automated, and blockchain-enabled
Verification	Retrospective, based on periodic inspections	Continuous, driven by live IoT and laboratory data
Data Integrity	Susceptible to tampering or data loss	Immutable through blockchain architecture
Audit Frequency	Periodic and scheduled	On-demand and event-triggered via smart contracts
Transparency	Limited to certifiers and internal stakeholders	Accessible to multiple stakeholders (e.g., QR code verification for consumers)
Certificate Authenticity	Physical or PDF-based, vulnerable to duplication	Digitally signed and publicly verifiable on blockchain
Alignment with Shariah	Dependent on institutional interpretation	Codified through smart contracts and laboratory-integrated compliance logic

(Source: Author's development, 2024)

Strategic Benefits and Institutional Implications

Beyond operational efficiency gains, the proposed framework yields several strategic advantages that align with Islamic economic principles and the evolving landscape of digital governance within the halal ecosystem.

Strengthening Consumer Trust

The proposed framework enhances consumer trust by enabling independent and transparent verification of halal status through accessible digital mechanisms. This level of transparency is particularly critical amid growing consumer skepticism toward regulatory authorities, especially in cross-border halal markets. Through direct access to verifiable certification data, the framework institutionalizes accountability and openness in halal governance, reflecting the Islamic principles of *mas'uliyyah* (accountability) and *shafāfiyyah* (transparency). As a result, consumer confidence in the credibility and integrity of halal-certified products is significantly strengthened.

Enhancing Global Halal Trade

The standardization of halal certification data via blockchain infrastructure facilitates greater interoperability across jurisdictions. This capability is particularly valuable in international trade, where exporters and importers must navigate diverse regulatory and certification requirements. Through programmable smart contracts, the framework can encode compliance conditions from multiple halal authorities (e.g., JAKIM, MUIS, BPJPH), thereby streamlining approval processes, reducing administrative complexity, and lowering transaction costs in global halal trade.

Supporting Maqāṣid al-Sharīʿah

The proposed framework substantively advances the objectives of *maqāṣid al-sharīʿah* by embedding mechanisms of verification, transparency, and safety directly within its system architecture. It contributes to the protection of religion (*ḥifẓ al-dīn*) by ensuring consistent and verifiable compliance with halal principles throughout the supply chain. In addition, the integration of scientific validation and continuous monitoring supports the protection of life and intellect (*ḥifẓ al-nafs* and *ḥifẓ al-ʿaql*) by enhancing food safety and product integrity. Furthermore, by minimizing opportunities for fraud, misrepresentation, and unethical economic practices, the framework promotes the protection of wealth (*ḥifẓ al-māl*). Collectively, these contributions demonstrate how technological innovation can be harmonized with Shariah objectives to strengthen halal governance.

Institutional Readiness and Digital Transformation

Although the adoption of advanced digital technologies may encounter resistance from established institutional actors, the proposed framework offers a pragmatic foundation for incremental implementation. It is well suited to deployment within regulatory sandboxes or pilot initiatives led by halal certification authorities, governmental agencies, or multilateral Islamic economic institutions. As such, the framework provides a structured roadmap for the gradual yet systematic digital transformation of halal governance, balancing innovation with institutional legitimacy and regulatory oversight.

Halal Compliance Logic Grounded in *Maqāṣid al-Sharīʿah*

To ensure that the proposed halal assurance framework achieves not only technological efficiency but also religious legitimacy, its system architecture is explicitly grounded in the objectives of Islamic law (*maqāṣid al-sharīʿah*). This section explicates how the five foundational objectives—*ḥifẓ al-dīn* (protection of faith), *ḥifẓ al-nafs* (protection of life), *ḥifẓ al-māl* (protection of wealth), *ḥifẓ al-ʿaql* (protection of intellect), and *ḥifẓ al-nasl* (protection of lineage)—are systematically embedded within the operational logic of the integrated halal assurance system. Rather than remaining abstract ethical ideals, these principles function as design imperatives that shape system functionalities, data governance, and technological integration across the halal supply chain.

Ḥifẓ al-dīn (Protection of Faith)

The principle of *ḥifẓ al-dīn* necessitates the safeguarding of religious compliance throughout all stages of halal production. Within the proposed framework, Shariah adherence is embedded upstream through programmable controls rather than assessed solely at the certification stage. Smart contracts are configured to enforce mandatory halal conditions—such as verified slaughtering procedures, certified raw materials, and approved facilities—thereby preventing unverified actors or processes from entering the supply chain (Hendayani & Fernando, 2022; Mahsun et al., 2023). Operating autonomously and immutably, these contracts structurally preclude violations of Islamic law at the levels of data entry, authorization, and process execution. Consequently, Shariah principles are operationalized as enforceable governance logic within the digital infrastructure.

Ḥifẓ al-nafs (Protection of Life)

In alignment with *ḥifẓ al-nafs*, which prioritizes the preservation of human well-being, the framework embeds food safety and hygiene as non-negotiable system requirements. IoT sensors continuously monitor critical environmental parameters, including temperature, humidity, and contamination risks, across the supply chain. In parallel, laboratory testing results—such as the detection of porcine DNA or prohibited additives—are immutably recorded on the blockchain to ensure data integrity and verifiability (Mahama et al., 2020; Masudin et al., 2022). Unlike conventional approaches where laboratory analysis is conducted sporadically or retrospectively, this framework institutionalizes scientific testing as a prerequisite for blockchain registration. This architectural configuration directly aligns technological functionality with the *maqāṣid* objective of harm prevention.

Ḥifẓ al-māl (Protection of Wealth)

The objective of *ḥifẓ al-māl* emphasizes fairness in economic transactions and the prevention of fraud. To this end, the framework is designed to democratize access to halal traceability and certification mechanisms, particularly for small and medium-sized enterprises (SMEs), through modular and interoperable system components that reduce dependence on costly proprietary platforms (Bux et al., 2022). Blockchain's immutability safeguards certified halal products against counterfeiting, data manipulation, and misrepresentation, thereby preserving economic value across the market. Moreover, decentralized verification mechanisms mitigate the risk of monopolistic control by select authorities, fostering transparency and equity within halal commerce. These design choices reflect a *maqāṣid*-aligned commitment to economic justice and market integrity.

Ḥifẓ al-ʿaql (Protection of Intellect)

The protection of intellect (*ḥifẓ al-ʿaql*) is realized by enabling consumers to make rational and informed halal consumption decisions. The framework supports this objective through consumer-facing interfaces, including QR-code-based verification tools, mobile applications, and transparent audit logs that present certification and traceability data in accessible formats (Anggraini et al., 2023; Dilla & Fathurohman, 2021). Beyond procedural transparency, the system promotes *ʿilm* (knowledge) by structuring information in ways that can be independently verified, referenced, and understood by non-specialist users. In doing so, the architecture repositions consumers as informed participants rather than passive recipients within the halal value chain.

Ḥifẓ al-nasl (Protection of Lineage)

The final maqāṣid principle, *ḥifẓ al-nasl*, underscores the importance of preserving ethical integrity across generations. In the proposed framework, all halal-relevant data—including production methods, ingredient provenance, and certification records—are permanently stored on the blockchain, enabling long-term and intergenerational traceability (Mahsun et al., 2023). This feature is particularly critical for institutions such as schools, hospitals, and family-oriented enterprises that require sustained assurance of halal inputs. To meet these needs, the system is designed to serve both present and future stakeholders, embedding *maqāṣid al-sharīʿah* as a

lasting safeguard rather than a short-term compliance checkpoint. This approach reinforces continuity and resilience in halal governance.

Table 3 summarizes the alignment between halal supply chain stages, enabling technologies, compliance objectives, and *maqāṣid al-sharīʿah* principles. This mapping illustrates how technological functions are systematically coupled with religious and ethical objectives, reinforcing the framework's compliance-by-design approach.

Table 3. Mapping Halal Supply Chain Stages to Enabling Technologies and Compliance Logic

Supply Chain Stage	**Enabling Technologies**	**Compliance Objectives**	***Maqāṣid al-Sharīʿah* Alignment**
Raw Material Sourcing	IoT (source tracking), Blockchain	Verifies halal origin, ensures certified supplier input, prevents contamination	*Ḥifẓ al-dīn*, *Ḥifẓ al-nasl*
Slaughtering & Processing	IoT, Smart Contracts	Ensures *dhabḥ* compliance, authenticates facilities, logs timestamped proof	*Ḥifẓ al-dīn*, *Ḥifẓ al-nafs*
Packaging	Blockchain, QR-linked tags	Prevents substitution and relabeling, ensures product identity	*Ḥifẓ al-māl*, *Ḥifẓ al-ʿaql*
Transportation & Storage	IoT, Blockchain	Maintains cold chain integrity, detects cross-contamination	*Ḥifẓ al-nafs*, *Ḥifẓ al-nasl*
Laboratory Verification	Lab Testing, Blockchain	Confirms absence of haram substances, stores results immutably	*Ḥifẓ al-dīn*, *Ḥifẓ al-nafs*
Distribution & Retail	Smart Contracts, QR interfaces	Enables consumer verification, automates halal status	*Ḥifẓ al-ʿaql*, *Ḥifẓ al-māl*
Consumer Engagement	Web portals, Blockchain	Provides full product history and transparency	*Ḥifẓ al-ʿaql*, *Ḥifẓ al-dīn*
Regulatory Oversight	Blockchain audits, Dashboards	Facilitates real-time monitoring and cross-border traceability	*Ḥifẓ al-dīn*, *Ḥifẓ al-māl*, *Ḥifẓ al-ʿaql*

(Sources: Dilla & Fathurohman, 2021; Handayani et al., 2021; Mahsun et al., 2023)

Implementation Challenges and Mitigation Strategies

Despite the conceptual robustness and normative appeal of an integrated halal assurance framework incorporating blockchain technology, the Internet of Things (IoT), and laboratory verification, its practical implementation is accompanied by a range of challenges that must be critically acknowledged. These challenges encompass technical, economic, institutional, regulatory, and socio-cultural dimensions, particularly within halal value chains in the Global South where production systems are highly fragmented and resource-constrained. Addressing these constraints is essential to ensuring the feasibility, scalability, and long-term sustainability of the proposed framework.

A primary challenge relates to the financial and infrastructural burden associated with deploying advanced digital technologies. Micro, small, and medium enterprises (MSMEs), which constitute the majority of halal producers in countries such as Indonesia, Malaysia, and Pakistan, often lack the capital required to invest in IoT devices, blockchain infrastructure, and digital auditing systems. Unlike large firms with established information technology capabilities, MSMEs typically operate with limited margins and minimal digital readiness. Without targeted interventions—such as shared digital platforms, public subsidies, or cooperative infrastructure

models—the implementation of advanced halal assurance technologies risks exacerbating existing inequalities within the halal supply chain rather than alleviating them.

Data authenticity and input reliability present a second critical concern. While blockchain ensures data immutability, it does not inherently guarantee the accuracy or integrity of information entered at the source. Laboratory test results, sensor readings, and uploaded halal certificates remain dependent on the credibility of the institutions and personnel responsible for data generation. This limitation underscores the need for complementary validation mechanisms, including third-party accreditation, digital watermarking, cross-verification protocols, and randomized audits, to strengthen trust in system inputs and mitigate the risk of misinformation.

Regulatory fragmentation further complicates the adoption of a unified digital halal assurance system. Halal governance structures vary substantially across jurisdictions—and often within national boundaries—due to differences in religious authorities, certification bodies, and legal frameworks. In the absence of harmonized standards or mutual recognition agreements, the interoperability of blockchain-based systems may be constrained. Additionally, institutional inertia and resistance from stakeholders invested in traditional certification models may impede adoption. Consequently, policy coordination and inclusive, multi-stakeholder governance arrangements must be embedded into the framework's design to facilitate institutional alignment and regulatory acceptance.

Technological readiness also constitutes a structural barrier, particularly in rural and semi-urban production areas where internet connectivity, sensor infrastructure, and reliable energy supply remain limited. Heavy reliance on real-time IoT monitoring may therefore be impractical in such contexts. To address this challenge, the framework should incorporate adaptive features such as offline data capture, asynchronous synchronization, and mobile-compatible interfaces, thereby enhancing inclusivity and operational scalability across heterogeneous production environments.

Human capital constraints represent another often-overlooked challenge. Even where technological infrastructure is available, the absence of digitally skilled personnel and halal auditors proficient in data-driven systems can undermine effective implementation. The transition toward digital halal assurance necessitates systematic capacity-building initiatives, including targeted training programs, digital literacy development, and the emergence of interdisciplinary professionals capable of bridging Islamic jurisprudence and technological governance.

Finally, ethical and data privacy considerations require careful attention. While blockchain-based transparency enhances traceability and accountability, it may conflict with legitimate concerns regarding commercial confidentiality and personal data protection. Unrestricted disclosure of supply chain information, product formulations, or laboratory results could expose sensitive business data or contravene national data protection regulations. To mitigate these risks, the framework should adopt permissioned blockchain architectures with tiered access controls and Shariah-compliant privacy safeguards that balance transparency with confidentiality.

Taken together, these challenges indicate that the implementation of an integrated halal assurance framework cannot proceed through a uniform or prescriptive approach. Rather, a modular, adaptive, and context-sensitive strategy is required—one that accommodates diverse

production realities, regulatory environments, and socio-economic conditions. Effective mitigation must therefore combine technological innovation with institutional support, ethical governance, and community engagement to ensure that the digital transformation of halal assurance promotes not only efficiency and transparency but also equity, legitimacy, and inclusiveness within the global halal economy.

Practical and Normative Implications

The findings yield significant implications for both practical implementation and normative development in contemporary halal governance. From a practical perspective, the proposed framework offers regulators, halal certification bodies, and industry stakeholders a scalable digital infrastructure capable of enhancing transparency, reducing opportunities for fraud, and automating compliance monitoring through real-time, verifiable, and scientifically validated data streams. These functionalities are particularly pertinent in the context of cross-border halal trade, where fragmented documentation practices and divergent certification standards frequently constrain market access and erode consumer confidence. Through the systematic integration of IoT-enabled monitoring with blockchain-based data management and laboratory verification, the framework provides actionable pathways for strengthening supply chain integrity and improving the efficiency and reliability of halal assurance processes, consistent with evidence from comparable digital applications in global supply chains (Ismail et al., 2022; Rusydiana et al., 2023).

From a normative standpoint, the framework illustrates how digital innovation can be systematically aligned with *maqāṣid al-sharīʿah* by embedding ethical principles—such as transparency, accountability, and consumer protection—directly into the governance logic of halal certification systems. This alignment enhances the religious legitimacy of certification practices by ensuring that Shariah compliance is continuously enforced through system design rather than assessed solely through periodic audits. Moreover, by grounding technological governance in Shariah-oriented values, the model contributes to the broader discourse within Islamic economics on the role of digital transformation in advancing justice, trust, and collective welfare within halal markets. In this way, the framework extends beyond technical optimization to offer a normatively grounded approach to the future evolution of halal assurance (Mahsun et al., 2023).

CONCLUSIONS

This study develops a conceptual framework for halal product assurance that integrates blockchain technology, the Internet of Things (IoT), and laboratory testing to address structural limitations inherent in conventional halal certification systems. Grounded in traceability systems theory, socio-technical systems theory, and *maqāṣid al-sharīʿah*, the framework illustrates how coordinated technological integration can systematically mitigate challenges related to fragmented verification processes, data integrity, and limited transparency across halal supply chains. Distinct yet interdependent roles are assigned to IoT-enabled real-time monitoring, blockchain-based immutable recordkeeping, laboratory-driven scientific validation, and smart contract–based compliance automation, resulting in a coherent and value-oriented approach to end-to-end halal assurance. This integrative synthesis advances the academic literature by

clarifying the conceptual relationship between digital traceability mechanisms and Islamic ethical objectives, thereby strengthening the theoretical foundations of technology-enabled halal governance.

The proposed framework offers regulators, halal certification bodies, and industry stakeholders a scalable and adaptable blueprint for modernizing halal assurance practices. It enhances transparency, reduces opportunities for fraud, and enables continuous compliance monitoring through the integration of real-time data capture and automated verification mechanisms. These capabilities are particularly valuable in increasingly complex and cross-border halal markets, where inconsistencies in certification and documentation frequently undermine trust. The framework also demonstrates how scientific validation and digital traceability can be systematically incorporated into certification workflows to improve consistency and credibility. Moreover, the explicit integration of Shariah objectives into the system architecture illustrates how digital transformation in halal governance can advance operational efficiency while simultaneously reinforcing ethical accountability and institutional legitimacy within the Islamic economic ecosystem.

Despite its contributions, this study is subject to several limitations. As a conceptual investigation, the framework has not yet been empirically tested through field implementation, system prototyping, or stakeholder evaluation. Practical challenges—including regulatory heterogeneity, uneven technological infrastructure, and potential resistance to automation—may also affect adoption, particularly among small-scale producers and traditionally governed halal markets. Future research should therefore focus on pilot implementations in specific sectors, such as halal logistics, food processing, or pharmaceutical supply chains, to assess feasibility, cost-effectiveness, and user acceptance. Empirical studies examining governance outcomes, interoperability across jurisdictions, and the role of Shariah oversight in digital systems are also needed. Through such efforts, the proposed framework can be further refined and validated as a robust foundation for building transparent, trustworthy, and ethically grounded halal assurance systems in the digital era.

REFERENCES

Abidin, N. Z., & Perdana, F. F. P. (2020). A proposed conceptual framework for blockchain technology in halal food product verification. *Journal of Halal Industry & Services, 3*, Article a0000079. https://doi.org/10.36877/jhis.a0000079

Adiningtyas, Y., & Yunus, E. N. (2024). The influence of consumer knowledge of halal supply chain practices on purchase intention in halal personal care and beauty products. *Jurnal Aplikasi Bisnis dan Manajemen, 10*(3), 823–835. https://doi.org/10.17358/jabm.10.3.823

Amid, A. (2024). Halal detection technologies. In A. Amid, A. A. M. Elgharbawy, & W. A. Abualsunun (Eds.), *Solving halal industry issues through research in halal sciences* (pp. xx–xx). Springer. https://doi.org/10.1007/978-981-97-3843-4_3

Anggraini, W., Ciptono, W. S., Lusiantoro, L., & Tjahjono, H. K. (2023). Halal food integrity: A systematic literature review and research agenda. *ASEAN Network for Halal Science and Technology Proceedings*. https://doi.org/10.46254/an13.20230406

Bux, C., Varese, E., Amicarelli, V., & Lombardi, M. (2022). Halal food sustainability between certification and blockchain: A review. *Sustainability, 14*(4), 2152. https://doi.org/10.3390/su14042152

Castro, M. M. de, Mariano, R. A., Nuñez, C. L., & Legaspi, A. P. (2021). Philippine halal food export industry: Life cycle, trends, and global outlook. *E3S Web of Conferences, 316*, 02044. https://doi.org/10.1051/e3sconf/202131602044

Dashti, L. A. H. F., Jackson, T., West, A., & Jackson, L. (2024). Enhancing halal food traceability: A model for rebuilding trust and integrity in Muslim countries. *Journal of Islamic Marketing, 15*(12), 3382–3408. https://doi.org/10.1108/JIMA-06-2023-0167

Davids, Z., & Sabrain, D. (2022). The digital halal era: A look into the new normal. *Ekonomski Izazovi, 11*(22), 10–17. https://doi.org/10.5937/ekoizazov2222010d

Dilla, Z. U., & Fathurohman, M. S. (2021). Implementation of halal traceability supply chain using the SCOR model in the halal food industry. *Jurnal Ekonomi Syariah Teori dan Terapan, 8*(5), 617–629. https://doi.org/10.20473/vol8iss20215pp617-629

Fauzi, N. M., Hashim, N. I., Rahman, M. F. A., Hassin, W. S. W., & Shahar, W. S. S. (2022). Halal economy: Challenges and emerging opportunities in Malaysia. *Journal of Islamic Philanthropy and Social Finance, 1*(1), 29–37. https://doi.org/10.24191/jipsf/v1n12020_29-37

Handayani, D. I., Masudin, I., Haris, A., & Restuputri, D. P. (2021). Ensuring the halal integrity of the food supply chain through halal suppliers: A bibliometric review. *Journal of Islamic Marketing, 13*(7), 1457–1478. https://doi.org/10.1108/JIMA-10-2020-0329

Harsanto, B., Farras, J. I., Firmansyah, E. A., Pradana, M., & Apriliadi, A. (2024). Digital technology 4.0 in halal supply chains: A systematic review. *Logistics, 8*(1), 21. https://doi.org/10.3390/logistics8010021

Hendayani, R., & Febrianta, M. Y. (2020). Technology as a driver to achieve supply chain performance in family businesses. *Journal of Family Business Management, 10*(4), 361–371. https://doi.org/10.1108/JFBM-10-2019-0070

Hendayani, R., & Fernando, Y. (2022). Adoption of blockchain technology to improve halal supply chain performance and competitiveness. *Journal of Islamic Marketing, 14*(9), 2343–2360. https://doi.org/10.1108/JIMA-02-2022-0050

Ibrahim, A. (2022). The Notion of Work Ethic from an Islamic View. *Academia Letters*, *2*.

Ibrahim, A. (2023). Islamic economic and financial practices in Indonesia: From local to a potential global framework. *Share: Jurnal Ekonomi dan Keuangan Islam*, *12*(1).

Ismail, S., Nazarudin, N., & Muhamad, M. Z. (2022). Governance of halal logistics compliance. *Journal of Contemporary Islamic Studies, 8*(3). https://doi.org/10.24191/jcis.v8i3.6

Kamarulzaman, N. H., Muhamad, N. A., & Nawi, N. M. (2021). Adoption intention of halal traceability systems among food SMEs. *Journal of Islamic Marketing, 13*(9), 1872–1900. https://doi.org/10.1108/JIMA-11-2020-0349

Kamri, N. A., Ramlan, S., & Ibrahim, A. (2014). Qur'anic work ethics. *Journal of Usuluddin*, *40*, 135-172.

Karyani, E., Geraldina, I., Haque, M. G., & Zahir, A. (2024). Intention to adopt blockchain-based halal certification: Consumer and regulatory perspectives in Indonesia. *Journal of Islamic Marketing, 15*(7), 1766–1782. https://doi.org/10.1108/JIMA-03-2023-0069

Kusnadi, A., Arkeman, Y., Syamsu, K., & Wijaya, S. H. (2024). Assurance of halal beef products using ERP-based traceability systems. *IOP Conference Series: Earth and Environmental Science, 1358*(1), 012020. https://doi.org/10.1088/1755-1315/1358/1/012020

Mahama, S., Waloh, N., Chayutsatid, C., Sirikwanpong, S., Ayukhen, A., Marnpae, M., … Dahlan, W. (2020). Postmarket laboratory surveillance for forbidden substances in halal-certified foods in Thailand. *Journal of Food Protection, 83*(1), 147–154. https://doi.org/10.4315/0362-028X.JFP-19-051

Mahsun, M., Putra, Y. H. S., Asnawi, N., Djalaluddin, A., & Hasib, N. (2023). Blockchain as a reinforcement for traceability of Indonesian halal food information through the value chain analysis framework. *Al-Muqayyad, 6*(1), 49–66. https://doi.org/10.46963/jam.v6i1.1031

Masudin, I., Rahmatullah, B. B., Agung, M. A., Dewanti, I. A., & Restuputri, D. P. (2022). Traceability systems in halal procurement: A bibliometric review. *Logistics, 6*(4), 67. https://doi.org/10.3390/logistics6040067

Mehmood, N., Shah, M., & Faisal, H. (2024). Blockchain technology and halal certification: Issues and developments. In *Emerging technology and crisis management in the halal industry: Issues and recent developments* (pp. 3–14). Springer Nature Singapore.

Mohamed, Y. H., Rahim, A., & Ma'aram, A. (2020). Effects of halal supply chain management on halal integrity assurance. *Journal of Islamic Marketing, 12*(9), 1734–1750. https://doi.org/10.1108/JIMA-12-2018-0240

Munawar, M., & Mugiono, A. (2024). Framework for smart contract blockchain in halal traceability, integrity, and transparency. *International Journal of Electrical and Computer Engineering, 14*(3), 2875–2884. https://doi.org/10.11591/ijece.v14i3.pp2875-2884

Namasudra, S., Sharma, P., Crespo, R. G., & Shanmuganathan, V. (2023). Blockchain-based medical certificate generation and verification for IoT-based healthcare systems. *IEEE Consumer Electronics Magazine, 12*(2), 83–93.

Rusydiana, A. S., Irfany, M. I., As-Salafiyah, A., & Tieman, M. (2023). Halal supply chain research: A bibliometric analysis. *Journal of Islamic Marketing, 14*(12), 3009–3032. https://doi.org/10.1108/JIMA-01-2022-0009

Siddiqi, A. H., & Dallal, A. (2024). Technological advancements and Islamic ethical frameworks. *International Journal of the Universe and Humanity in Islamic Vision and Perspective, 1*(2), 87–94.

Talib, M. S. A. (2020). Identifying halal logistics constraints in Brunei Darussalam. *Journal of Islamic Marketing, 12*(6), 1145–1158. https://doi.org/10.1108/JIMA-09-2019-0189

Voak, A., & Fairman, B. (2021). Building human capability to ensure halal supply chain compliance. In *Halal development: Trends, opportunities and challenges* (1st ed., p. 6). Routledge. https://doi.org/10.1201/9781003189282-11

Yi, Y., Bremer, P., Mather, D., & Mirosa, M. (2021). Factors affecting diffusion of traceability practices in imported fresh produce supply chains. *British Food Journal, 124*(4), 1350–1364. https://doi.org/10.1108/BFJ-03-2021-0227