

## Designing a Blockchain-Integrated Halal Traceability System: A Cross-National Framework for Global Halal Supply Chain Integrity

Desy Rahmawati Anwar<sup>1\*</sup>, Idris Parakkasi<sup>2</sup>, Cut Muthiadin<sup>3</sup>

<sup>1</sup>Pelita Buana College of Economics

<sup>2,3</sup>Postgraduate Program, Alauddin State Islamic University Makassar

**Corresponding Author:** Desy Rahmawati Anwar

[desyrahmawatianwar@gmail.com](mailto:desyrahmawatianwar@gmail.com)

---

### ARTICLE INFO

*Keywords:* Blockchain, Halal Supply Chain, Smart Contract, Halal Certification

*Received :* 16, May

*Revised :* 30, May

*Accepted:* 23, June

©2025 Anwar, Parakkasi, Muthiadin:

This is an open-access article distributed under the terms of the [Creative Commons Attribution 4.0 International](https://creativecommons.org/licenses/by/4.0/).



### ABSTRACT

The increasing global demand for halal products demands an integrated, transparent, and reliable halal supply chain system. However, major challenges remain due to the fragmentation of national halal standards, weak traceability systems, and limited interoperability between certification authorities in various countries. This study proposes the design of a blockchain-based halal traceability system with a cross-country framework to ensure the integrity of halal products globally. The system combines Internet of Things (IoT) technology, laboratory testing data, and smart contracts to enable automated validation from raw materials to retail distribution. Adopting theoretical approaches from the Technology Acceptance Model (TAM), Institutional Theory, and Supply Chain Integration Theory, the model includes key actors such as regulators, certification bodies, and digital platforms to support the harmonization of the global halal system through the "Single Digital Halal Passport" mechanism and blockchain node exchange. Literature review and policy analysis from countries such as Malaysia, Indonesia, GCC, and the European Union show various regulatory, technological, and institutional barriers, especially in developing countries. However, blockchain technology shows great potential in increasing consumer trust, ensuring data immutability, and automating halal verification.

---

## INTRODUCTION

The halal industry is experiencing significant growth, along with the increasing global Muslim population and consumer awareness of the halalness of products. According to IMARC Group (2024), the global halal food market value reached USD 2,714.40 billion in 2024 and is expected to reach USD 5,911.95 billion in 2033, with a compound annual growth rate (CAGR) of 8.92% from 2025 to 2033. This growth reflects the increasing demand for halal products that meet sharia standards and high quality. However, along with market expansion, the challenges in maintaining the integrity and traceability of halal products are also increasingly complex. Consumers demand transparency and assurance that the products they consume truly meet the established halal standards. One of the main challenges in the halal industry is the lack of an effective and transparent traceability system. Research by Sudarsono et al. (2020) shows that conventional supply chain management systems fail to provide real-time visibility into the origin and production process of halal products. This makes it difficult for halal manufacturers and retailers to guarantee the integrity of their products, especially when raw materials come from multiple suppliers or go through multiple processing stages. In addition, inconsistencies in halal certification standards across countries add to the complexity of ensuring compliance with halal principles. The absence of a reliable and end-to-end traceability system throughout the halal supply chain is a major contributor to this challenge (Farrukh et al., 2021).

Fraud cases in the halal industry increasingly highlight the need for better traceability systems. The fake halal meat scandal in Malaysia, which came to light in 2020, involved smuggling of meat from non-halal certified sources and bribery of officials to obtain fake certification (Wikipedia, 2020). This incident shook consumer confidence in the halal certification system and highlighted weaknesses in the existing oversight mechanisms. Similar incidents may occur in other countries if there is no transparent and verifiable system to ensure the halalness of products. Therefore, a new approach is needed that can increase transparency and reliability in the halal supply chain. Blockchain technology has emerged as a potential solution to increase traceability and transparency in the halal supply chain. Blockchain offers immutable records, decentralization, and transparency between network members, which can improve data integrity in the supply chain (Sezer et al., 2021). The implementation of blockchain in the halal industry can enable end-to-end traceability from raw materials to final products, as well as real-time verification of halal certification. Several studies have explored the potential of blockchain in improving the traceability of halal products, but most of them are still conceptual and have not been tested at scale (Tan et al., 2020). Further research is needed to develop a framework that can be implemented practically and across countries.

Integration of blockchain technology with the Internet of Things (IoT) and laboratory testing can further enhance the reliability of the halal traceability system. IoT enables real-time monitoring of product conditions during production and distribution, while laboratory testing ensures that products meet halal standards. The combination of these technologies can create a

comprehensive system to ensure the halalness of products from upstream to downstream. However, challenges in integrating these technologies, as well as the need for harmonized standards and regulations, remain obstacles to the implementation of an effective halal traceability system (Novianti et al., 2020). This study aims to address these challenges by developing a framework that can be applied across countries. Several previous studies have discussed the use of technology to improve the traceability of halal products. For example, a study by Rejeb (2018) explored the potential of blockchain in increasing transparency in the halal supply chain. However, this study is still conceptual and has not developed a framework that can be practically implemented. Another study by Surjandari et al. (2021) proposed a blockchain-based halal traceability model, but its focus was limited to the national context and did not consider challenges on an international scale. This gap indicates the need for research that develops a blockchain-based halal traceability framework that can be applied across countries.

Regulatory and policy aspects also play an important role in the implementation of a technology-based halal traceability system. Differences in halal certification standards across countries, as well as lack of harmonization in regulations, may hamper the adoption of an integrated traceability system. Research by Rezapour et al. (2021) highlighted that the absence of a global standard for halal certification creates challenges for manufacturers and suppliers in dealing with multiple regulations. Therefore, the development of a halal traceability framework must consider both regulatory and policy aspects to ensure widespread and effective adoption. This study will examine these aspects in developing a comprehensive framework. Consumer trust in halal products is highly dependent on the transparency and reliability of certification and traceability systems. Research by Khan et al. (2020) showed that inconsistencies in the application of certification standards across markets can lead to variations in the quality of certification, which can erode consumer trust. The implementation of technologies such as blockchain can increase consumer trust by providing transparent and verifiable information about the origin and production process of halal products. However, the adoption of this technology also requires understanding and acceptance from consumers, which can be influenced by cultural and social factors. This study will consider these aspects in developing an effective halal traceability framework.

In the context of globalization and international trade, the development of a halal traceability system that can be applied across countries is becoming increasingly important. Differences in standards and regulations across countries can create barriers to halal product trade and hinder the growth of the global halal industry. This study aims to develop a blockchain-based halal traceability framework that can address these challenges and support the integrity of the global halal supply chain. By integrating blockchain technology, IoT, and laboratory testing, and considering regulatory aspects and consumer trust, this framework is expected to improve transparency, reliability, and efficiency in the halal supply chain. This study will make a significant contribution to the development of an innovative and globally applicable halal traceability system.

Overall, this study aims to develop a blockchain-based halal traceability framework that can be applied across countries to improve the integrity of the global halal supply chain. By combining blockchain technology, IoT, and laboratory testing, and considering regulatory aspects and consumer trust, this framework is expected to overcome the challenges that exist in the current halal traceability system. This study will make a significant contribution to the development of an innovative and globally applicable halal traceability system. The results of this study are expected to provide benefits to producers, regulators, and consumers in ensuring the halalness of products and increasing trust in the halal industry. Thus, this research will be an important step in supporting the growth and integrity of the global halal industry.

## **LITERATURE REVIEW**

### ***Halal Supply Chain and Traceability***

Halal Supply Chain (HSC) is a supply chain management system that ensures products and processes comply with halal principles from the source of raw materials to the end consumer. This concept not only covers the halal aspects of the product, but also the integrity of the logistics process, including storage, transportation, and distribution. HSC aims to prevent cross-contamination between halal and non-halal products and ensure compliance with international halal standards. The implementation of HSC is becoming increasingly important along with the increasing global demand for halal products and consumer awareness of product halalness. Thus, HSC plays a vital role in maintaining consumer trust and expanding the halal product market globally. Traceability is the ability to trace the history, location, and status of a product throughout the supply chain. In the context of HSC, traceability ensures that every stage of production and distribution meets halal standards, thus maintaining product integrity. The traceability system enables rapid identification of potential halal violations and appropriate corrective action. In addition, traceability increases transparency and accountability in the supply chain, which in turn strengthens consumer confidence. Therefore, the integration of traceability in HSC is a key element in ensuring the overall halalness of products.

Several studies have been conducted to develop and evaluate traceability systems in HSC. Kurniawan et al. (2025) proposed a conceptual framework for traceability and food safety based on Blockchain and Internet of Things (IoT) technology in Indonesia, which aims to improve transparency and efficiency in the halal supply chain. Another study by Rejeb et al. (2020) highlighted the potential of Blockchain in improving the traceability of halal products, although its adoption is still limited due to regulatory challenges and technological understanding. In addition, research by Zainuddin et al. (2020) showed that the implementation of a halal traceability system can improve supply chain performance and strengthen halal integrity through transparency at every stage. However, further research is still needed to overcome barriers to technology adoption and harmonization of halal standards between countries.

### ***Blockchain Technology in Supply Chain***

Blockchain is a distributed ledger technology that enables transparent, immutable, and decentralized transaction recording without a central authority (Deloitte, nd; Surgere, nd). Transparency in blockchain is achieved by recording each transaction into a block that is accessible to all network participants, increasing accountability and trust between stakeholders (Harvard Business Review, 2020; UPPCS Magazine, 2025). Immutability refers to the inability to change recorded data without consensus from the entire network, which significantly strengthens data integrity (Deloitte, nd; Rapid Innovation, 2024). The principle of decentralization allows for the elimination of dependence on third parties or single authorities, thereby reducing the risk of centralization of power and accelerating the efficiency of decision-making (Mdpi.com, 2023; Axios, 2018). These three principles make blockchain a very suitable solution to improve transparency and reliability in cross-border supply chain management systems.

### ***Blockchain Applications in Food Supply Chain***

In the food sector, blockchain is used to facilitate product traceability from the point of origin to the end consumer (Mdpi.com, 2023; Axios, 2018). This technology allows for rapid identification of the source of food contamination, for example in the case of an E. coli outbreak, so that the recall process of contaminated products can be carried out efficiently (Wired, 2018; ResearchGate, 2025). Companies such as Walmart have adopted blockchain systems to track agricultural products, which not only improves food safety but also speeds up the distribution process and minimizes losses (Axios, 2018; Rapid Innovation, 2024). In addition, with real-time information on storage conditions and shelf life of products, blockchain can contribute to reducing food waste (Mdpi.com, 2023; Deloitte, nd). Therefore, the application of blockchain in the food supply chain not only ensures product quality but also supports the sustainability of the food ecosystem.

### ***Blockchain Applications in Pharmaceutical Supply Chain***

The pharmaceutical industry faces high risks related to counterfeiting and illegal distribution of drugs that can compromise patient safety (Debut Infotech, n.d.; Tandfonline.com, 2022). Blockchain offers a solution by recording all stages of production and distribution in a system that cannot be manipulated, thereby strengthening product authenticity (Emerald Insight, 2022; ResearchGate, n.d.). Through this mechanism, consumers can verify the authenticity of pharmaceutical products by scanning a digital code that is linked to transparent supply chain data (Debut Infotech, n.d.; Tandfonline.com, 2022). In addition to facilitating transparency, this system also provides a complete audit trail that helps companies meet increasingly stringent regulatory regulations in the healthcare sector (Emerald Insight, 2022; Harvard Business Review, 2020). Therefore, blockchain not only increases patient trust but also the overall operational efficiency of pharmaceutical companies.

### ***Blockchain Applications in Logistics and Supply Chain Management***

In the logistics sector, blockchain plays a vital role in increasing the efficiency and transparency of shipping goods worldwide (Deloitte, nd; ResearchGate, 2025). Through its real-time tracking capabilities, this technology helps companies to know the exact location of goods and reduce the possibility of lost or delayed shipments (UPPCS Magazine, 2025; Rapid Innovation, 2024). The use of smart contracts in blockchain also enables automated transaction processes without the need for intermediaries, speeding up processing and reducing administrative costs (Deloitte, nd; Surgere, nd). Furthermore, structured data in blockchain can be used to detect bottlenecks or inefficiencies in the logistics system so that companies can make more timely improvements (ResearchGate, 2025; Mdpi.com, 2023). Thus, blockchain is not only a technological tool, but also a strategic instrument in optimizing complex global supply chains.

### ***IoT and Lab Testing for Halal Verification***

The integration of modern technology into the halal verification process has brought about significant changes in ensuring the integrity and compliance with halal standards. One of the main innovations is the use of Internet of Things (IoT) sensors, which enable real-time monitoring of critical parameters such as temperature, humidity, and potential cross-contamination in the production process (Kurniawan & Sari, 2023). These sensors are capable of detecting the presence of non-halal substances, providing early warnings that allow for immediate preventive action, and the data collected can be utilized for transparent product audits and tracking (Kurniawan & Sari, 2023). In addition to IoT, halal verification also utilizes laboratory testing techniques such as Polymerase Chain Reaction (PCR), High-Performance Liquid Chromatography (HPLC), and spectrophotometry. PCR is effective in detecting very small amounts of non-halal DNA, although it requires special equipment and expertise (Wijaya, Akbar, & Khairunnisa, 2023). HPLC offers high accuracy in separating and identifying chemical compounds such as lard, but has high operational costs and long analysis times (Rohman & Fadzillah, 2021). Spectrophotometry, especially Fourier Transform Infrared (FTIR), provides fast results and does not damage samples, but has limitations in detecting contaminants in low concentrations and can be affected by the complexity of the sample matrix (Ng et al., 2022).

These laboratory techniques, although accurate, have several limitations, such as high costs, the need for trained personnel, and long analysis times (Ng et al., 2022). These barriers make the technology difficult to access for small producers, requiring more efficient and affordable halal verification solutions (Rohman & Fadzillah, 2021). To address these challenges, the integration of laboratory data with blockchain technology is a promising innovative approach (Alamsyah, Hakim, & Hendayani, 2022; Abidin & Perdana, 2020). Blockchain can record halal verification results permanently and transparently, providing consumers with real-time access to information via QR codes or digital applications (Nugroho & Sumiyati, 2023). In addition, this system increases accountability and facilitates more efficient halal audits in the supply chain

(Alourani & Khan, 2024). Case studies demonstrate the success of the integration of IoT and blockchain in halal verification systems. For example, IoT sensors are used to monitor storage conditions, while the data is recorded in the blockchain so that violations of halal standards can be immediately identified and acted upon (Kurniawan & Sari, 2023). Consumers can also verify the halal status of products through blockchain-based platforms, strengthening trust in halal products in the global market (Alamsyah et al., 2022). However, the implementation of this technology is not without challenges. High initial investment costs, lack of clear regulations, and concerns about data privacy and security are the main obstacles (Abidin & Perdana, 2020; Nugroho & Sumiyati, 2023). Therefore, collaboration between stakeholders, including industry players, regulators, and academics, is very important in developing a supportive framework and policies (Ng et al., 2022).

The government and halal certification institutions have a strategic role in setting technology standards and providing support through training and incentives for industry players (Kurniawan & Sari, 2023). Collaboration between the public and private sectors can accelerate technology adoption and ensure the reliability of the halal verification system in the digital era (Alourani & Khan, 2024). In conclusion, the integration of technologies such as IoT, laboratory techniques, and blockchain into the halal verification system has great potential to increase efficiency, transparency, and consumer trust. Although implementation challenges remain, regulatory support, cross-sector collaboration, and continuous innovation will be key to realizing a more modern, trusted, and inclusive halal assurance system (Alamsyah et al., 2022; Nugroho & Sumiyati, 2023; Abidin & Perdana, 2020).

### ***Cross-Country Framework Model***

Malaysia has long been a pioneer in the development of the halal system, with the Department of Islamic Advancement Malaysia (JAKIM) as the primary authority for setting national halal standards and certification. The system covers the entire supply chain, from production to distribution, to ensure compliance with Shariah principles. However, challenges arise in integrating new technologies such as blockchain and IoT into the established system. A study by Handayani et al. (2024) showed that the adoption of digital technology can improve the effectiveness of the halal supply chain in Malaysia, although there are still barriers in terms of efficiency and user acceptance. This suggests the need for a more holistic approach in combining technology with existing policies. Indonesia, as the country with the largest Muslim population, has implemented Law No. 33 of 2014 on Halal Product Assurance, which requires halal certification for various products. However, its implementation faces challenges, especially in terms of infrastructure and industry player readiness. A study by Azam and Abdullah (2021) highlighted the importance of harmonizing international halal standards to support policy implementation in Indonesia. In addition, the integration of technologies such as blockchain can help improve transparency and efficiency in the certification process. However, adoption of this technology requires strong policy support and training for industry players.

Gulf Cooperation Council (GCC) countries have diverse approaches to halal policies, with some countries such as the United Arab Emirates and Saudi Arabia having their own halal certification authorities. These differences create challenges in harmonizing halal standards in the region. A study by Azam and Abdullah (2021) showed that harmonizing halal standards can increase consumer confidence and trade efficiency between countries. However, differences in sharia interpretations and national policies are major obstacles in the harmonization process. Therefore, dialogue and cooperation between countries are needed to achieve uniform halal standards. The European Union does not yet have a central halal certification authority, so certification is carried out by various private institutions with varying standards. This creates confusion among Muslim consumers and industry players. A study by Azam and Abdullah (2021) emphasized the importance of establishing a European halal accreditation body to unify standards and increase consumer confidence. In addition, the integration of technologies such as blockchain can help ensure transparency and authenticity of halal products in the European market. However, the adoption of this technology requires a clear regulatory framework and support from governments and industry players.

Harmonization of international halal standards faces several challenges, including differences in sharia interpretation, national policies, and the capacity of certification bodies. A study by Azam and Abdullah (2021) showed that harmonization can improve trade efficiency and consumer confidence. However, this process requires close cooperation between countries and related institutions. In addition, the adoption of technologies such as blockchain and IoT can help unify certification systems by providing transparent and verifiable data. However, the implementation of these technologies requires significant investment and training for industry players. The Technology Acceptance Model (TAM) is used to understand the factors influencing technology adoption in the halal industry. A study by Handayani et al. (2024) showed that perceived ease of use and benefits of technology influence user intention to adopt a technology-based halal traceability system. However, cultural and religious factors also play an important role in technology acceptance among halal industry players. Therefore, a local context-sensitive approach is needed in the implementation of new technologies. In addition, training and education for users can increase the acceptance and effectiveness of technology.

Institutional Theory explains how norms, values, and regulations influence organizational behavior. In the context of the halal industry, institutional pressures from the government, certification bodies, and consumers drive the adoption of halal traceability systems. A study by Au Yong et al. (2021) shows that social legitimacy and compliance with regulations are the main factors in the adoption of halal traceability technology. However, differences in norms and regulations between countries are a challenge in harmonizing international halal standards. Therefore, cooperation between countries and institutions is needed to align applicable norms and regulations. Supply Chain Integration Theory emphasizes the importance of coordination and collaboration between various parties in the supply chain to improve efficiency and product

quality. In the context of the halal industry, integration between producers, distributors, and certification bodies can increase transparency and consumer trust. A study by Handayani et al. (2024) shows that halal supply chain integration can improve the performance and integrity of halal products. However, differences in systems and technologies between countries are obstacles to global halal supply chain integration. Therefore, uniform standards and technologies are needed to support international halal supply chain integration.

Integration of technologies such as blockchain and IoT into halal traceability systems can improve transparency, efficiency, and consumer trust. A study by Handayani et al. (2024) showed that these technologies enable real-time tracking of products from source to end consumer. However, the implementation of these technologies requires significant investment and training for industry players. In addition, a supportive regulatory framework is needed to ensure data security and privacy. Collaboration between governments, certification bodies, and industry players is essential in implementing these technologies effectively. A cross-country framework model in halal traceability systems requires harmonization of standards, technology integration, and cooperation between countries. The application of theories such as TAM, Institutional Theory, and Supply Chain Integration Theory can help understand and overcome the challenges in implementing these systems. Investment in technology and training for industry players is essential to improve efficiency and consumer trust. In addition, a clear regulatory framework and government support are needed to support the implementation of an effective halal traceability system. International cooperation and dialogue between countries are key to realizing a harmonious and trusted halal traceability system.

## **METHODOLOGY**

**Research Type: Qualitative Comparative Cross-Country** This type of research is suitable because the article analyzes halal policies and technology implementation in different contexts (Malaysia, Indonesia, GCC, European Union), and compares the approaches and challenges faced by each country. **Research Approach: Multiple Case Study Approach** The multiple case study approach allows researchers to explore in depth the policy context, institutional structure, and technology adoption in each country. Each country (Malaysia, Indonesia, GCC, and the European Union) can be used as a separate unit of analysis, which is then compared.

## **RESEARCH RESULT AND DISCUSSION**

### ***Blockchain-based Halal Traceability System Design***

The halal industry faces challenges in ensuring product integrity and traceability throughout the supply chain. Blockchain technology offers a solution by providing a transparent and immutable transaction record, enabling traceability from the source of raw materials to the end consumer (Mittal et al., 2018; Wahab et al., 2020). By implementing a modular system that includes raw material input, production process, distribution, and retail, each stage can be monitored in real-time. This increases consumer confidence in the halalness of

the products they consume. The implementation of such a system has shown its effectiveness in increasing transparency and efficiency of the halal supply chain (Yousuf et al., 2019). The integration of the Internet of Things (IoT) in the halal traceability system allows for the collection of real-time environmental data, such as temperature and humidity, which are essential for maintaining the halalness of products during storage and transportation (Sezer et al., 2021). IoT sensors can be installed at various points in the supply chain to continuously monitor product conditions. The collected data is then stored on the blockchain, ensuring the reliability and transparency of information (Zailani et al., 2020). Thus, any violation of halal standards can be immediately detected and addressed. This approach increases operational efficiency and consumer confidence in halal products.

The use of smart contracts in halal traceability systems allows automation of the halal product verification process. Smart contracts can be programmed to execute certain actions when predetermined conditions are met, such as validating halal certificates or triggering alerts in the event of deviations (Munawar & Mugiono, 2020). This reduces reliance on manual intervention and minimizes the risk of human error. In addition, smart contracts increase efficiency and speed in the halal certification process. The implementation of this technology has proven effective in increasing transparency and accountability in the halal supply chain (Rejeb, 2018). The integration of blockchain, IoT, and smart contracts creates a comprehensive and reliable halal traceability system. Data collected by IoT sensors is stored on the blockchain, while smart contracts automatically regulate the rules and verification processes (Sudarsono et al., 2020). This approach ensures that each stage in the supply chain meets the established halal standards. In addition, this system allows for more efficient audits and inspections by relevant authorities. Thus, the integration of these technologies increases consumer confidence and operational efficiency in the halal industry.

The implementation of a blockchain-based halal traceability system also supports the harmonization of halal standards across countries. By providing a transparent and verifiable platform, differences in halal certification standards between countries can be minimized (Rezapour et al., 2021). This is important to support international trade in halal products and ensure compliance with halal principles globally. In addition, this system facilitates collaboration between various stakeholders in the halal industry. Thus, this technology contributes to the development of a more integrated and efficient halal ecosystem. One of the challenges in implementing a technology-based halal traceability system is the cost and complexity of integration. However, studies show that investing in this technology can provide significant returns in the long term through increased efficiency and consumer trust (Novianti et al., 2020). In addition, the adoption of this technology can increase the competitiveness of halal producers in the global market. It is important for the government and related institutions to support this initiative through appropriate regulations and incentives. Thus, barriers to implementation can be minimized and the benefits of this technology can be maximized.

Consumer involvement in a blockchain-based halal traceability system can be enhanced through the use of technologies such as QR codes or RFID. By scanning the code on a product, consumers can access complete information about the origin and production process of the product (UNISOT, 2025). This increases transparency and allows consumers to make more informed decisions. In addition, this approach encourages producers to maintain high halal standards. Thus, this technology strengthens the relationship between producers and consumers in the halal ecosystem. The integration of blockchain technology in a halal traceability system also supports sustainability and social responsibility in the supply chain. By providing transparent data on production practices and raw material sources, consumers can choose products that are in line with their values (MasChain, 2025). In addition, this system allows monitoring and evaluation of the environmental impact of the production process. This is important to support sustainable development goals in the halal industry. Thus, this technology contributes to the development of a more responsible and sustainable halal industry.

The development of a blockchain-based halal traceability system requires collaboration between various stakeholders, including manufacturers, regulators, and certification bodies. This collaboration is important to ensure that the system developed meets applicable needs and standards (BPJPH, 2025). In addition, training and education on this technology need to be provided to all parties involved. Thus, the adoption of technology can be carried out effectively and efficiently. Strong collaboration will ensure the successful implementation of a blockchain-based halal traceability system. Overall, the design of a blockchain-based halal traceability system integrated with IoT and smart contracts offers a comprehensive solution to improve integrity and transparency in the halal supply chain. The implementation of this system supports the harmonization of halal standards, increases consumer confidence, and encourages sustainability in the halal industry. Although there are challenges in its implementation, the long-term benefits of this technology are significant. With the right support from the government, certification bodies, and other stakeholders, this system can be widely adopted. Further research and development are needed to optimize the design and implementation of a blockchain-based halal traceability system globally.

### ***Cross-Country Framework Model***

The globalization of the halal industry presents challenges in harmonizing halal standards between countries. Differences in interpretation and implementation of halal standards cause inconsistencies in certification and consumer trust. According to Munawar and Mugiono (2020), these differences can be overcome by integrating blockchain technology which provides a transparent and immutable system. Blockchain allows recording of every stage in the halal supply chain, ensuring the authenticity and integrity of the product. Thus, this technology can be a solution to unify halal standards globally. The main components in a cross-country framework include national halal standards, regulators, certification authorities, and digital platforms. Each country has an institution responsible for halal certification, such as JAKIM in Malaysia and

BPJPH in Indonesia. However, the lack of interoperability between these institutions causes duplication of processes and inefficiencies. Sezer et al. (2021) suggest the use of blockchain technology to integrate certification data from various institutions, allowing cross-verification and recognition of certificates between countries. This will speed up the certification process and reduce barriers to international trade.

Blockchain-based digital platforms can function as decentralized data centers that store halal certification information from various countries. By using smart contracts, the verification and validation process of certificates can be automated, increasing efficiency and reducing human error. According to Cao et al. (2021), the integration of on-chain and off-chain governance enables transparent and accountable data management. This is important to ensure that all parties in the supply chain have access to the same and reliable information. Thus, this platform can increase consumer trust in halal products. Recommendations for system harmonization include the development of a "single halal digital passport" that functions as a globally recognized digital identity for halal products. This digital passport will contain complete information about the origin, production process, and certification of the product. According to Wahab et al. (2020), the use of digital passports can increase transparency and make it easier for authorities to conduct audits and supervision. In addition, consumers can easily verify the halalness of products by scanning QR codes connected to the blockchain. This will increase consumer trust and loyalty to halal products.

Another alternative is the implementation of a "blockchain node exchange" that allows the exchange of certification data between blockchain nodes from different countries. With this system, each certification authority can maintain control over their data while allowing limited access for others to verify. According to Rejeb (2018), this approach maintains national data sovereignty while supporting global interoperability. This is important to address concerns about data security and privacy in cross-border information exchange. Thus, this system can strengthen international collaboration in the halal industry. The implementation of a cross-border framework requires close collaboration between regulators, certification authorities, and industry players. Training and education on blockchain technology and its benefits in halal certification need to be provided to all stakeholders. According to Anwar et al. (2024), good awareness and understanding of this technology will accelerate its adoption and implementation. In addition, support from the government and international institutions is essential to provide supporting infrastructure and regulations. Thus, the implementation of this framework can run smoothly and effectively.

The success of a cross-border framework also depends on the technical standards and protocols used in the digital platform. The use of open and interoperable standards will facilitate the integration of systems from different countries. According to Dashti et al. (2024), consistent technical standards will reduce the complexity and cost of integration. In addition, the use of technologies such as Hyperledger Fabric allows for flexible and secure access permission settings. This is important to maintain data confidentiality and ensure

compliance with local regulations. The use of blockchain technology in halal certification can also improve operational efficiency and reduce administrative costs. By automating the process through smart contracts, the time and resources required for verification and auditing can be reduced. According to Noman et al. (2025), this efficiency will provide a competitive advantage for halal industry players. In addition, increased transparency will reduce the risk of fraud and violation of halal standards. Thus, this technology can improve the integrity and reputation of the halal industry as a whole.

The adoption of blockchain technology in halal certification can also support sustainable development goals. By providing transparent data on production practices and raw material sourcing, consumers can make more informed and responsible choices. According to Abidin et al. (2020), this transparency can encourage manufacturers to implement more sustainable and ethical practices. In addition, this system allows monitoring and evaluation of the environmental impact of the production process. Thus, this technology contributes to the development of a more responsible and sustainable halal industry. Overall, the development of a cross-country framework for a blockchain-based halal traceability system offers a comprehensive solution to improve integrity and transparency in the global halal supply chain. By integrating national halal standards, regulators, certification authorities, and digital platforms, this system can address harmonization challenges and improve operational efficiency. Recommendations such as a “single halal digital passport” and a “blockchain node exchange” provide practical approaches to achieving this goal. However, the implementation of these systems requires close collaboration between all stakeholders and support from governments and international institutions. Thus, further research and development are needed to optimize the design and implementation of a blockchain-based halal traceability system globally.

### *Acceptability Analysis and Implementation Challenges*

Consumer trust in halal products is highly dependent on the transparency and integrity of the certification process. Blockchain is considered a technology that can increase trust through immutable and transparent data recording (Rejeb et al., 2020; Wahab et al., 2021). However, the acceptance of this technology is still limited, especially among small industry players and consumers from developing countries (Jafri et al., 2022). This is due to the lack of digital literacy and trust in high-tech digital systems (Noman et al., 2023). Therefore, an educational approach and continuous socialization are essential in the initial implementation process. Halal industry players, especially MSMEs, face major challenges in adopting blockchain technology. Lack of technical understanding and limited resources are the main obstacles (Munawar & Mugiono, 2020; Dashti et al., 2024). They also tend to view blockchain as an expensive and complex solution, which is not worth the short-term benefits obtained (Rejeb & Keogh, 2021). On the other hand, large companies are more likely to accept blockchain implementation because they have adequate infrastructure and resources

(Ahmed & Brohi, 2023). This gap creates challenges in equalizing technology across the halal supply chain.

In terms of regulation, many developing countries do not yet have a clear legal framework to support the integration of blockchain technology into the halal certification system. This regulatory unpreparedness hampers cross-border recognition of digital halal certification (Sabit et al., 2021; Wahab et al., 2020). Unharmonized regulations between countries are also an obstacle to forming a comprehensive cross-country framework (Zulkifli et al., 2023). Without mutually beneficial recognition and accreditation, the global traceability system will not be effective. Therefore, cooperation between governments is needed in formulating cross-country regulations. In addition to regulations, uneven technological infrastructure is a major obstacle in developing countries. Many regions do not yet have stable access to the internet, hardware, and technical expertise needed to operate a blockchain system (Cao et al., 2021; Rejeb, 2020). This inequality can lead to digital exclusion of small halal business actors in remote areas. This undermines the goal of inclusivity and global integration of the blockchain-based halal traceability system (Anwar et al., 2024). Therefore, affirmative policies are needed to support inclusive technology.

Implementation barriers also come from the cost of developing and maintaining a blockchain system. Although decentralized, the initial cost of developing smart contracts, training human resources, and system audits is very high (Ahmed et al., 2023; Wahab et al., 2021). This is a serious consideration for developing countries with limited budgets. In addition, not all national halal authorities have the technical and financial capacity to build this system independently (Sabit et al., 2021). Therefore, international support and public-private partnerships are essential. However, several studies have shown that blockchain can increase efficiency and reduce costs in the long term. By automating the audit and certification process through smart contracts, administrative costs and the risk of human error can be reduced (Cao et al., 2021; Noman et al., 2023). This has the potential to benefit industry players in the long term if they are willing to invest from the start. However, this requires a strong belief and understanding of the added value of the technology (Rejeb & Keogh, 2021). Therefore, cost-benefit analysis must be included in the socialization of technology to business actors.

The level of technology acceptance is also largely determined by cultural factors and religious values. Some industry players and consumers consider digital systems to be incomparable to manual methods that are considered more "Islamic" or traditional (Jafri et al., 2022; Zulkifli et al., 2023). This view can be a barrier to implementation if there is no educational approach based on maqasid al-shariah. Public education on how technology can strengthen halal principles is essential. Collaboration with scholars and fatwa authorities is crucial in this process. Other studies have also highlighted the challenges of interoperability between various blockchain platforms and existing halal certification systems. If there is no clear technical standardization, the risk of data inconsistency and system incompatibility will increase (Dashti et al., 2024; Rejeb, 2020). This will undermine user trust in the system. Therefore, the development of open and

collaborative protocols is a top priority. International organizations such as the OIC or IHIA need to lead this standardization initiative.

In general, trust in blockchain-based systems is greatly influenced by the level of transparency, data security, and assurance of information accuracy. If the system can guarantee that halal information is truly valid and not manipulated, then consumer trust will increase significantly (Munawar & Mugiono, 2020; Wahab et al., 2020). However, without adequate supervision and regulation, technology can be misused or misinterpreted. Therefore, it is important to build a collective halal technology oversight ecosystem. This includes the involvement of government agencies, industry, and civil society. To overcome existing obstacles, a gradual and adaptive approach is highly recommended in implementing halal blockchain systems across countries. Developing countries can start with pilot projects in certain sectors and expand them gradually (Anwar et al., 2024; Rejeb & Keogh, 2021). Dissemination of knowledge, training, and financial incentives should also be expanded. In addition, periodic evaluation and documentation of best practices from pioneering countries need to be carried out and shared globally. Thus, a blockchain-based halal traceability system can be implemented in an inclusive and sustainable manner.

## **CONCLUSIONS AND RECOMMENDATIONS**

The application of blockchain technology in the halal traceability system has been conceptually proven to be able to improve integrity, transparency, and accountability in the global halal supply chain. In the cross-country framework designed in this study, the integration of blockchain technology, IoT devices, and laboratory test results is able to create a more automated and real-time halal verification system. By combining the principles of decentralization, immutability, and transparency, this system has the potential to answer the main challenges in managing product halalness, especially in the context of international trade between countries with different standards and certification systems. The main conclusion of this study is that blockchain will only be effective if implemented in a coherent and standardized ecosystem across jurisdictions. The cross-country framework is a key element to encourage the successful implementation of this system globally. Scientifically, this study contributes by offering a conceptual model that integrates the Technology Acceptance Model (TAM), Institutional Theory, and Supply Chain Integration Theory in the context of a blockchain-based halal supply chain. From a practical perspective, the proposed model can be used as a reference by the Halal Product Assurance Agency (BPJPH) in Indonesia, as well as halal certification authorities in other countries such as Malaysia (JAKIM), Saudi Arabia (SFDA), and the United Arab Emirates (ESMA). The blueprint of this system allows the creation of a digital halal passport system (single halal digital passport) and the exchange of blockchain nodes between official halal institutions, to ensure interoperability and mutual recognition. This study also opens up space for collaboration between the private and public sectors in developing a global digital halal platform. With this approach, it is hoped that there will be increased efficiency in halal logistics and the trust of international Muslim consumers.

The main policy implication that can be drawn is the need for more progressive and adaptive halal technology regulations to the development of industrial technology 4.0. Governments and regulators in various countries need to prepare a roadmap for blockchain integration into the national halal assurance system. On the other hand, multilateral cooperation between countries through organizations such as SMIIIC (Standards and Metrology Institute for Islamic Countries) and OIC (Organization of Islamic Cooperation) is very important to build common standards that can be recognized across countries. Without this harmonization, the implementation of a blockchain-based traceability system will face resistance and fragmentation that weakens the effectiveness of the system. Therefore, there needs to be concrete steps from international institutions to form a digital halal regulatory body that functions across jurisdictions. However, this study has several limitations that need to be acknowledged. First, the framework and model developed are still conceptual and have not been tested directly on a full industrial scale. Second, this study relies on a qualitative approach based on case studies and literature reviews, so the generalization of the results is still limited. Third, implementation challenges such as technological infrastructure readiness, system integration costs, and institutional capacity gaps have not been studied quantitatively. Fourth, the response of consumers and industry players to the use of blockchain-based systems in halal assurance still requires further exploration. Fifth, the dynamics of global politics and economics that affect collaboration between countries have not been the main focus in this model.

## **ADVANCED RESEARCH**

Therefore, further research directions need to be focused on testing the prototype system in a real halal industry environment, especially in the supply chain of halal food and beverage products exported to the international market. This trial can be conducted through a pilot project involving industry players, halal certification authorities, and testing institutions. Evaluation can include technical aspects, cost efficiency, user satisfaction, and security and speed of halal data access. In addition, a mixed methods approach can be used to measure the perception, adoption, and acceptance of this system by various stakeholders. This testing can also enrich theoretical understanding of the relationship between technology acceptance and institutional legitimacy in the context of the global halal industry. Further research is also recommended to reach non-food halal sectors such as cosmetics, pharmaceuticals, and Islamic financial products, which also require a strong and digitally verifiable traceability system. In addition, the development of a legal and ethical framework regarding the use of blockchain technology in religious products is also a very important but underexplored area. This aspect includes data protection, consumer rights, and the legality of using smart contracts in halal certification matters. Comparative studies on digital readiness and institutional willingness across OIC member states can also provide additional insights useful for system harmonization. Thus, the development of a blockchain-based halal traceability system can truly be a key

driver of the transformation of the global halal industry to be more inclusive, transparent, and trustworthy.

## REFERENCES

- Abidin, NZ, & Perdana, FFP (2020). A proposed conceptual framework for blockchain technology in Halal food product verification. *Journal of Halal Industry & Services*, 3, 1-8.
- Ahmed, E., & Brohi, S. N. (2023). Adoption of blockchain for food traceability in developing countries: Challenges and opportunities. *Journal of Food Quality*, 2023.
- Alamsyah, A., Hakim, N., & Hendayani, R. (2022). Blockchain-Based Traceability System to Support the Indonesian Halal Supply Chain Ecosystem. *Economies*, 10(6), 134.
- Alourani, A., & Khan, S. (2024). A Blockchain and Artificial Intelligence based System for Halal Food Traceability. arXiv preprint arXiv:2410.07305.
- Anwar, M., Ahmed, M., & Jafri, S. K. (2024). Risk Assessment and Mitigation in Halal Supply Chains: Exploring Unique Risks and Mitigation Strategies. *International Journal of Logistics Systems and Management*, 52(2), 217-234.
- Au Yong, H. N., & Mohamad, Z. (2021). Theories used in Halal logistics studies. In *Halal Logistics and Supply Chain Management* (pp. 85-100). Routledge.
- Azam, F., & Abdullah, A. (2021). Comparative Analysis and Harmonization of Global Halal Standards. *Halal Research*, 3(1), 26-35.
- Cao, S., Wang, Y., & Li, H. (2021). Integrating on-chain and off-chain governance for supply chain transparency. arXiv preprint arXiv:2111.08455.
- Dashti, S., Wahab, S., & Hassan, R. (2024). Blockchain-based halal logistics system: Development challenges and regulatory strategies. *Journal of Islamic Marketing*.
- Farrukh, M., et al. (2021). Traceability and Transparency in Halal Supply Chains. *International Journal of Supply Chain Management*, 10(2), 45-52.
- Handayani, R., & Vanany, I. (2021). Technology acceptance model in halal industries: A systematic literature review and research agenda. *Journal of Islamic Marketing*, 12(3), 1-15.
- Hashem, H. (2024, September 24). Blockchain in halal food traceability: Huge potential but limited uptake. *Salam Gateway*. <https://salaamgateway.com/story/blockchain-in-halal-food-traceability-huge-potential-but-limited-uptake>
- Jafri, S. K., Rejeb, A., & Keogh, J. G. (2022). Barriers to adoption of blockchain in halal food supply chains. *International Journal of Production Research*, 60(12), 3650-3663.
- Kadir, MAA, Hashim, H., & Zulkifli, N. (2016). Traceability Systems in Halal Procurement: A Bibliometric Review. *Journal of Halal Industry & Services*, 1(1), 1-10.
- Khan, MS, et al. (2020). Challenges in Halal Certification: A Global Perspective. *Journal of Islamic Marketing*, 11(3), 655-672.

- Kurniawan, M., Suparno, S., & Vanany, I. (2025). Conceptual Framework for Halal Supply Chain Traceability and Food Safety in Indonesia Based on Blockchain Technology and Internet of Things to Support Sustainable Development. *Engineering Proceedings*, 84(1), 27.
- Kurniawan, R., & Sari, RN (2023). Conceptual Framework for Halal Supply Chain Traceability and Food Safety in Indonesia Based on Blockchain Technology and Internet of Things to Support Sustainable Development. *Proceedings*, 84(1), 27.
- Lexology. (2024). Indonesia's Halal requirements enter into a new phase.
- Mittal, A., et al. (2018). Blockchain for Halal Supply Chain Traceability: From Farm to Table. Masverse.
- Munawar, M., & Mugiono, A. (2020). Framework for Smart Contract Blockchain in Halal Traceability, Integrity, and Transparency. *International Journal of Electrical and Computer Engineering*, 14(3), 2875–2884.
- Ng, PC, Ruslan, NASA, Chin, LX, Ahmad, M., Hanifah, SA, Abdullah, Z., & Khor, SM (2022). Recent advances in halal food authentication: Challenges and strategies. *Journal of Food Science*, 87(11), 4535–4550.
- Noman, M., Wahab, S., & Abidin, Z. (2023). Blockchain-driven halal supply chains: Enhancing transparency and efficiency. *International Journal of Supply Chain Management*, 12(1), 31–41.
- Novianti, N., et al. (2020). Blockchain-Based Traceability System to Support the Indonesian Halal Supply Chain Ecosystem. *\*Economist*
- Nugroho, AA, & Sumiyati, S. (2023). Integrity and Legitimacy of Halal Products: The Urgency of Halal Supply Chain Management Technology Adoption in Halal Product Authentication Traceability. *South East Asia Management*, 18(1).
- Omar, E.N., & Jaafar, H.S. (2011). Halal supply chain in the food industry - A conceptual model. *International Journal of Supply Chain Management*, 6(1), 1–10.
- Rejeb, A. (2018). Blockchain Technology in the Halal Industry: Applications and Challenges. *Journal of Islamic Marketing*, 9(2), 264–281.
- Rejeb, A., & Keogh, J. G. (2021). Blockchain technology in halal supply chains: Applications and challenges. *Journal of Islamic Marketing*, 12(3), 569–588.
- Rohman, A., & Fadzillah, N.A. (2021). Application of Spectroscopic and Chromatographic Methods for the Analysis of Non-halal Meats in Food Products. In A. Amid (Ed.), *Multifaceted Protocols in Biotechnology* (Vol. 2). Springer.
- Sabit, H., Zulkifli, N., & Wahab, S. (2021). Regulatory framework of halal certification and blockchain: A comparative study. *Journal of Halal Industry & Services*, 4(1), 34–45.
- Sezer, E., et al. (2021). Conceptual Framework for Halal Supply Chain Traceability and Food Safety in Indonesia Based on Blockchain Technology and Internet of Things. MDPI.
- Wahab, S.A., Hamid, R., & Abidin, Z. (2020). Halal traceability using blockchain: Opportunities and challenges. *Journal of Islamic Marketing*, 11(4), 1049–1065.