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Artikel Penelitian

Halal Traceability Model: An Analysis of the Integration of Blockchain and IoT Technologies Using the CLD Approach

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A B S T R A K

System dynamics through CLD are expected to design an optimal implementation strategy for Blockchain and IoT technology in ensuring integrity and consumer confidence in halal products. The method used in this research is a qualitative method. With the Causal Loop Diagram (CLD) approach. Data collection techniques literature review, case studies, and interviews to understand the concept of Halal Traceability. The results showed that the development of a Halal Traceability system requires a comprehensive approach that includes functional, non-functional, technological aspects, as well as regulation and standardization. From the functional aspect, the system provides halal product tracking, data recording and validation, alerting to ensure supply chain security. These functions are interrelated, contributing to increased consumer confidence in halal products. From the non-functional aspect, the reliability of the system is determined by data security, operational efficiency, access transparency, regulatory compliance. This strengthens the foundation of the system so that it can be used optimally and reliably. In the technological aspect, the utilization of blockchain, IoT, smart contracts, and cloud computing is the key to the digital transformation of the halal system. This supports automation and recording, ensuring system efficiency, scalability, and transparency. Finally, in terms of regulation and standardization, the implementation of digital halal certification, compliance with food safety standards (HACCP, ISO 22000), and the Personal Data Protection Law strengthen system integrity and public trust in professional and guaranteed halal products.

INTRODUCTION

The importance of a halal traceability system in the food industry cannot be ignored, especially for Muslim consumers who want assurance that the products they consume meet halal standards in accordance with Islamic law. A halal traceability system enables the identification and monitoring of products in the food supply chain, including the identification of raw materials, production processes and all stages of distribution. The ultimate goal is to ensure that food products consumed by Muslims comply with Islamic halal principles and are not contaminated by ingredients that are considered haram or non-halal [1].

This platform was officially launched by Bank Indonesia at the Indonesia Sharia Economic Festival (ISEF) 2024 on October 30. Halal Traceability is the result of a collaboration between the Halal Product Guarantee Agency (BPJPH) and Bank Indonesia. The technology aims to boost consumer confidence in halal products and drive the growth of the Islamic economy in Indonesia. Given that Muslim consumer spending has been increasing year over year and is projected to rise further by 2025 [2].

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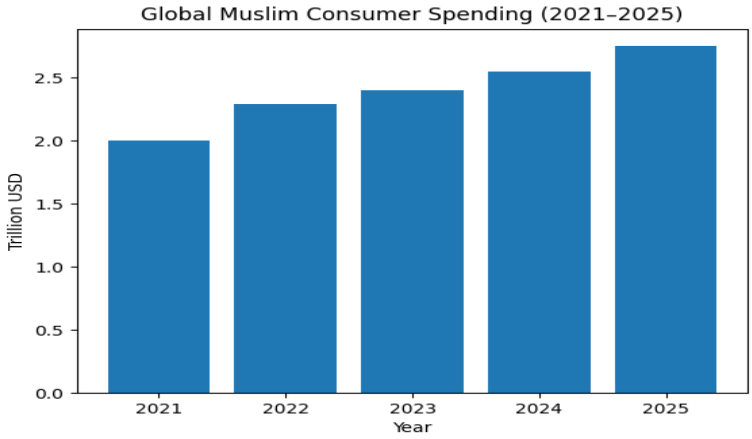

Source: State of the Global Islamic Economy (SGIE) 2025 & Global Economic Report (GER) 2019

Figure 1. Muslim Consumer Spending Data 2021-2025

In addition, the implementation of a halal traceability system can improve the integrity of halal food. This system is important because the status of halal food must be maintained even though it passes through a series of food supply chains consisting of suppliers, producers, distributors, and consumers. With a good traceability system, companies can minimize the number of products that are recalled due to not meeting halal criteria, and increase consumer confidence in these products [3].

Halal traceability systems play an important role in ensuring the authenticity and compliance of halal products throughout the supply chain. However, these systems still face various challenges that can affect the integrity and consumer confidence in halal products. One of the main challenges is the lack of transparency in the supply chain, where tracing the origin of raw materials is often complex and difficult to verify, making it difficult for manufacturers to prove the full halalness of products [4].

On the other hand, there are differences in the interpretation of halal standards in various countries, which cause obstacles in the certification and export of halal products. Some companies have to undergo a double certification process to meet the applicable halal standards in the destination country, which ultimately increases production and distribution costs [5]. Therefore, innovative solutions such as the integration of Blockchain technology and the Internet of Things (IoT) are needed to improve the transparency, efficiency and reliability of the halal tracking system. Thus, the implementation of a more effective halal tracking system can ensure that products circulating in the market actually meet the established halal standards and increase Muslim consumers' confidence in the products they consume.

The halal traceability system functions as a medium to track the halal status of a food product by recording all activity information in the production process, from the origin of raw materials to the finished product. This ensures that the product is not contaminated with haram substances and meets the established halal standards [6]. Thus, the implementation of an effective halal traceability system that integrates Blockchain technology and the Internet of Things (IoT) in the food industry not only ensures compliance with halal standards, but also increases transparency, accountability, and consumer confidence in the products offered.

The integration of Blockchain technology and the Internet of Things (IoT) in halal tracking systems can significantly improve the transparency and efficiency of the halal product supply chain. Blockchain technology enables immutable and verifiable transaction records in real-time, thereby increasing reliability and reducing the risk of data manipulation in the supply chain. In addition, Blockchain also improves operational efficiency by reducing the need for manual reconciliation and repeated audits. Meanwhile, IoT enables automatic data collection through sensors that can track product conditions, such as temperature, location, and time during distribution, thus ensuring products remain halal compliant from the production stage until they reach consumers. Thus, the integration of these two technologies can form a more efficient and reliable halal tracking system [7].

Thus, the purpose of this study is to analyze the integration of Blockchain technology and the Internet of Things (IoT) in the halal tracking system using the Causal Loop Diagram (CLD) approach. The CLD approach allows mapping the cause-and-effect relationships between various elements in the system, so as to identify factors that affect the effectiveness of the integration of these technologies in increasing the transparency and efficiency of the halal supply chain [8]. By understanding the dynamics of the system through CLD, it is expected that an optimal implementation strategy for Blockchain and IoT technology can be designed to ensure integrity and consumer confidence in halal products.

LITERATURE REVIEW

Integration of Blockchain technology and Internet of Things (IoT)

The integration of Blockchain technology and the Internet of Things (IoT) in a halal traceability system with the Causal Loop Diagram (CLD) approach has been carried out by several researchers. One of the relevant studies is research by Vikaliana, Evita, and Komala (2021) entitled "Halal Traceability Model with CLD Approach in Food Supply Chain Management Using Blockchain Technology". This research emphasizes the importance of a halal traceability system to provide transparency of information about the food process, allowing customers to trace the origin of the product. Blockchain technology is identified as a solution to address the challenges of visibility and traceability, as well as ensuring food quality and safety. The CLD approach is used in this research to understand and model the halal traceability system of food commodities using Blockchain technology [9].

In addition, conducted research on Blockchain integration in ERP systems for traceability of halal beef products. This research highlights that the validity of halal products depends not only on raw materials and production actors, but also on the production process and supply chain. Problems such as mixing beef with pork and falsification of halal certificates often occur due to the lack of traceability capabilities in the supply chain. This research develops a traceability system that combines Blockchain technology and ERP to ensure the halalness of products, with results showing that the integration of Blockchain technology in ERP can improve data security and transparency in the halal product supply chain as a whole [10].

The integration of Internet of Things (IoT) and Blockchain technologies plays an important role in halal traceability systems by improving transparency and data accuracy along the supply chain. IoT sensors, such as temperature and location monitoring devices, can collect real-time data on product conditions during storage and transportation. This data is then securely and immutably stored in the Blockchain network, ensuring the integrity of the information and allowing all relevant parties to verify the halalness of the product while also strengthening consumer confidence [11].

Halal Traceability

In halal traceability research, it is important to involve regulations related to halal certification in Indonesia such as the Indonesian Ulema Council (MUI), and the National Sharia Council (DSN). In Indonesia, the main legal basis governing halal certification is Law No. 33 of 2014 concerning Halal Product Guarantee (JPH Law), which stipulates that all products circulating and traded in Indonesia must be halal certified. The implementation of this halal certification is managed by the Halal Product Guarantee Agency (BPJPH), with MUI playing a role in determining the fatwa on product halalness [12].

An in-depth understanding of regulations and the role of relevant agencies is essential in developing an effective halal traceability system, especially when integrating technologies such as Blockchain and the Internet of Things (IoT). This ensures that the implementation of such technologies is in line with applicable standards and regulations, thereby increasing transparency and consumer confidence in halal products [13].

Blockchain technology in food products is very important to take advantage of, as in Irfan Bahar Nurdin's research which states that Blockchain has significant decentralization and transparency properties in improving the integrity of the halal product supply chain. With decentralization, transaction data is stored in various nodes without a central authority, thereby reducing the risk of data manipulation. Blockchain transparency allows all parties in the supply chain to access the same information, ensuring product authenticity and halalness. Blockchain implementation in the halal industry can increase integrity, transparency, and consumer confidence in halal products [14].

Causal Loop Diagram (CLD)

The Causal Loop Diagram (CLD) approach is a method used to map and understand cause-and-effect relationships in complex systems. By depicting key variables and the interactions between them, CLD helps in identifying feedback loops that influence the overall system behavior. This enables a more in-depth analysis of the system dynamics and helps in the formulation of effective improvement strategies. For example, in the context of business process management, CLD can be used to identify factors that affect organizational performance and find leverage points for optimal intervention [15].

RESEARCH METHODS

This research employs a qualitative approach using the Causal Loop Diagram (CLD) method within the framework of System Dynamics to analyze the integration of Blockchain and Internet of Things (IoT) technologies in the Halal Traceability system. The qualitative approach was selected because this study aims to construct a conceptual model that maps complex cause-and-effect relationships between variables in the halal supply chain, rather than testing statistical hypotheses. The overall research design consists of three sequential stages: (1) systematic literature review, (2) variable identification and causal link mapping, and (3) CLD construction and feedback loop analysis.

RESULT AND DISCUSSION

The needs analysis of the Halal Traceability model that integrates Blockchain and IoT with the Causal Loop Diagram (CLD) approach can be grouped into several main aspects, namely functional needs, non-functional needs, and technological and regulatory needs. This research will examine in terms of technological needs. The Causal Loop Diagram (CLD) approach has several stages including identifying key variables, determining the causality relationship, visualizing CLD and analyzing the visual results.

1. Identification of Key Variables in the System
   a. Functional Requirements
      Functional requirements reflect the main features and functions that the Halal Traceability system must have, including:
      1) Halal Product Traceability: The system must be able to track products from raw materials to consumers.
      2) Data Recording and Validation: Using blockchain to record halal data which is immutable.
      3) Monitoring Automation: Using IoT to monitor product conditions, such as temperature, location, and humidity during distribution.
      4) System Interoperability: The system should be compatible with various platforms and accessible to stakeholders such as producers, distributors, and consumers.
      5) Early Warning: The system must be able to provide notification if there is a non-conformity of halal standards in the supply chain.
   b. Non-Functional Needs
      Non-functional requirements are related to system quality and performance, such as:
      1) Data Security: Blockchain must guarantee the integrity and security of halal information.
      2) Efficiency and Scalability: The system must be able to handle large amounts of data efficiently.
      3) Accessibility & Transparency: Consumers must be able to check the halal status of products easily through applications or QR codes.
      4) Regulatory Compliance: The system must comply with global halal standards and government regulations.
   c. Technology Needs
      The technology needed to implement this model includes:
      1) Blockchain: As a ledger that records halal transactions securely.
      2) IoT Devices: Sensors to monitor halal product parameters in real-time.
      3) Smart Contracts: For automation of verification and validation of halal compliance.
      4) Cloud Computing: For flexible and scalable data storage.
   d. Regulation and Standardization Needs

1) Digital Halal Certification: Integration with halal certification institutions such as MUI.
2) Food Safety Standards: Compliance with standards such as HACCP, ISO 22000.
3) Data Protection Policy: regulated in Law (UU) Number 27 of 2022 concerning Personal Data Protection (UU PDP).

Cause and Effect Relationship System (Causal Links)

Causal Loop Diagram the Descriptive Schematic Diagram is divided into four groups of needs (Functional, Non-Functional, Technological, Regulatory) that interact with each other.

Table 1. Causal Links in the System

No	Cause Variable	Effect Variable	Type of Relationship	Short Description
1	Blockchain Technology	Halal Data Recording	(+)	Enhances data security and reliability
2	Halal Data Recording	Trusted Halal Assurance	(+)	Immutable data increases trust
3	IoT Devices	Automation of Monitoring	(+)	Real-time monitoring of temperature, location, etc.
4	Automation of Monitoring	Early Warning	(+)	Provides notifications in case of anomalies
5	Early Warning	Supply Chain Security	(+)	Reduces the risk of halal non-compliance
6	System Interoperability	Access to Information for All Stakeholders	(+)	The system can be used across different actors (producers, MUI, etc.)
7	Access to Information	Consumer Trust	(+)	The more transparent the system, the more consumers trust it
8	Consumer Trust	Demand for Halal Products	(+)	Trust increases purchase intent
9	Data Security	Trusted Halal Assurance	(+)	Secure data adds credibility
10	Efficiency & Scalability	System Performance	(+)	Smooth handling of large data
11	System Performance	Adoption by All Stakeholders	(+)	Widespread use increases system efficiency
12	Accessibility & Transparency	Ease of Checking Halal by Consumers	(+)	Through QR Code or a simple app
13	Ease of Checking Halal by Consumers	Consumer Trust	(+)	Easy access to information increases trust
14	Digital Halal Certification	Compliance with Regulations	(+)	MUI integration supports system legality
15	Regulatory Compliance	Trust of Regulators & Consumers	(+)	Legal compliance enhances legitimacy
16	HACCP/ISO 22000 Standards	Halal Product Quality	(+)	High standards lead to strict quality control
17	Personal Data Protection Law (UU PDP)	Consumer Data Protection	(+)	Ensures the safety of personal information

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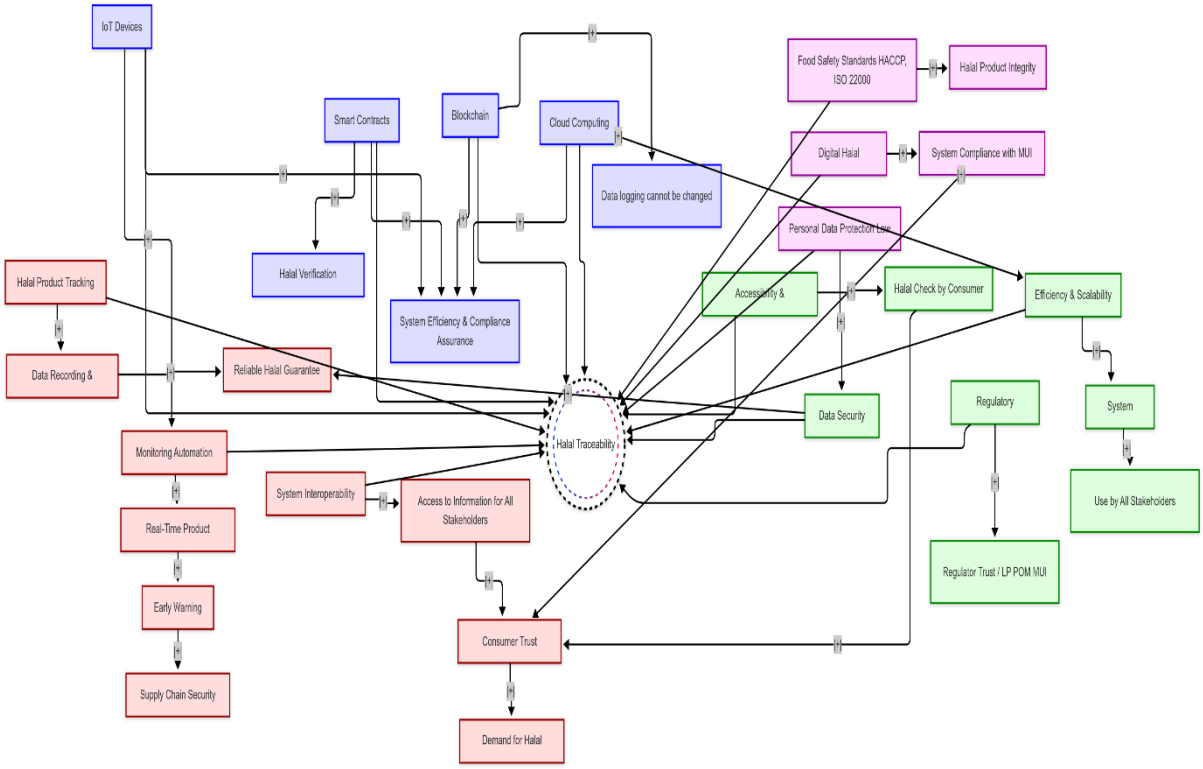
18	Smart Contracts	Halal Verification Automation	(+)	Faster processes without manual intervention
19	Cloud Computing	Scalability of Data Storage & Access	(+)	Can handle large data with cost efficiency

CLD Visualization (Diagram Structure)

The Causal Loop Diagram (CLD) approach can be used to understand the cause-and-effect relationships in the Halal Traceability system that integrates Blockchain and IoT. The following is the identification of the above analysis into the system with CLD:



Source: Primary Data, 2024

Figure 2. Causal Loop Diagram

Feedback Loop Analysis in the CLD

A fundamental characteristic that distinguishes a Causal Loop Diagram (CLD) in System Dynamics from a conventional mind-map or network diagram is the explicit identification and analysis of feedback loops (Sterman, 2000). Feedback loops capture the circular causality that drives system behavior over time and are classified into two types: Reinforcing Loops (R), which amplify change and generate growth or collapse dynamics, and Balancing Loops (B), which counteract change and drive the system toward equilibrium or a goal. The following sub-sections identify and analyze the key feedback loops embedded in the CLD of the Halal Traceability system.

Reinforcing Loop R1: Consumer Trust Growth

When consumer trust in halal products increases, the demand for halal products grows accordingly (Causal Link 8). This rising demand creates a market incentive for producers and institutions to accelerate the implementation of a more robust Halal Traceability system. As the system is implemented more broadly, its performance improves (Causal Link 10–11), enabling consumers to check halal status more easily through QR codes and mobile applications (Causal Link 12). This improved accessibility and transparency, in turn, reinforces consumer trust (Causal Link 13), completing the reinforcing cycle.

This loop represents a virtuous growth cycle: each improvement in system performance feeds back positively into consumer confidence, which then drives further investment and adoption of the halal tracking infrastructure. From a

policy perspective, this loop suggests that interventions aimed at improving system usability and transparency will generate compounding returns in terms of market trust and demand.

Reinforcing Loop R2: Technology Adoption and System Quality

The deployment of Blockchain technology enhances the security and immutability of halal data recording (Causal Link 1–2). As recorded data becomes more trustworthy, the overall halal assurance offered by the system is strengthened. This increased reliability encourages broader adoption by all stakeholders including producers, distributors, and regulatory bodies (Causal Link 11). As more stakeholders participate, network effects emerge and the system's operational performance improves further (Causal Link 10), which in turn justifies and incentivizes further investment in upgrading the underlying blockchain infrastructure. This self-reinforcing dynamic echoes Metcalfe's Law, wherein the value of the network grows with the square of the number of participants.

Reinforcing Loop R3: Regulatory Compliance and Institutional Legitimacy

The integration of digital halal certification particularly with institutions such as MUI and compliance frameworks such as HACCP and ISO 22000 ensures that the Halal Traceability system meets established regulatory requirements (Causal Link 14). Regulatory compliance, in turn, generates institutional legitimacy, increasing trust among both government regulators and consumers (Causal Link 15). This elevated trust drives further consumer demand for certified halal products (Causal Link 8), which exerts pressure on producers to expand and deepen their adoption of the digital certification infrastructure. This completes a reinforcing cycle at the governance layer of the system.

The implication for policymakers is significant: an early commitment to regulatory integration and formal compliance standards creates a self-sustaining loop of legitimacy, demand, and system expansion that is difficult to reverse once established.

Balancing Loop B1: Regulatory Constraint on System Expansion

As the Halal Traceability system expands its data collection capabilities particularly through IoT sensors collecting consumer location, behavior, and personal transaction data it increasingly falls under the scope of Law Number 27 of 2022 concerning Personal Data Protection (UU PDP). Compliance with the UU PDP introduces additional legal, technical, and administrative requirements for data processors (Causal Link 17). These requirements add complexity and cost to system deployment, particularly for smaller stakeholders such as SME food producers, effectively creating friction that moderates the pace of system adoption. This balancing loop prevents the system from expanding unchecked in ways that would compromise individual privacy rights, acting as a necessary governor on the reinforcing growth loops described above.

This finding highlights a critical design challenge: system architects must ensure that privacy-by-design principles are embedded from the outset, so that compliance with the UU PDP does not become a bottleneck that throttles the system's beneficial network effects.

Balancing Loop B2: Quality-Cost Trade-off in Technology Implementation

As consumer and regulatory expectations for system quality increase driven by reinforcing loops R1 and R3 there is intensified pressure to invest in more sophisticated technology solutions, including enterprise-grade blockchain networks, dense IoT sensor arrays, and automated smart contract verification. However, such investments substantially increase the operational and capital costs of system deployment. For small and medium-sized food producers and distributors, who constitute the majority of Indonesia's halal supply chain participants, these cost barriers can prevent adoption, thereby creating a gap between system aspiration and system reach. This gap, in turn, partially relieves the demand pressure for universal high-quality compliance, establishing a balancing dynamic.

Addressing this balancing loop requires intervention on the cost side: through subsidized technology access programs, government-funded cloud infrastructure shared among SMEs, and tiered compliance frameworks that match regulatory requirements to the scale of the enterprise. Cloud computing, as identified in Causal Link 19, plays a pivotal role here by reducing marginal costs through shared infrastructure.

Balancing Loop B3: Information Overload and System Complexity

As the Halal Traceability system integrates increasingly complex technological components blockchain transaction records, IoT sensor logs, smart contract audit trails, and multi-standard compliance documentation the resulting information architecture becomes difficult for the average consumer to interpret meaningfully. This cognitive burden undermines the accessibility and transparency that the system is designed to provide (Causal Link 12), which, if left unaddressed, can erode rather than build consumer trust (Causal Link 13). The weakening of consumer trust then generates corrective pressure to simplify the user-facing interface of the system, restoring the balance between technical completeness and user accessibility.

This loop underscores the importance of human-centered design in halal traceability platforms. The technical robustness of the underlying blockchain and IoT infrastructure must be paired with intuitive consumer interfaces such as single QR code scanning with plain-language summaries to ensure that the system's complexity remains invisible to end-users while its trustworthiness remains visible and verifiable.

Summary of Feedback Loops Identified in the CLD

Table below consolidates all feedback loops identified in the CLD analysis, specifying their type, constituent variables, and primary systemic implications.

Table 2. Summary of Feedback Loops in the Halal Traceability CLD

Loop	Type	Key Variables	Effect on System	Policy Implication
R1	Reinforcing (R)	Consumer Trust → Halal Demand → System Implementation → Performance → Ease of Checking → Consumer Trust	Growth/Virtuous Cycle	Prioritize UX and consumer-facing transparency tools
R2	Reinforcing (R)	Blockchain → Halal Data → Trusted Assurance → Stakeholder Adoption → System Performance → Blockchain Investment	Technology Adoption Flywheel	Incentivize early adoption to trigger network effects
R3	Reinforcing (R)	Digital Certification → Regulatory Compliance → Institutional Trust → Halal Demand → Certification Expansion	Governance Legitimacy Cycle	Integrate MUI/BPJPH early in system design
B1	Blancing (B)	System Expansion → UU PDP Compliance → Cost & Complexity → Adoption Rate → System Expansion (moderated)	Privacy Regulation Governor	Embed privacy-by-design; avoid compliance bottleneck
B2	Blancing (B)	Quality Demand → Tech Investment → Cost Increase → SME Adoption Barrier → Quality Demand (eased)	Cost-Quality Trade-off	Subsidize SME access; use shared cloud infrastructure
B3	Blancing (B)	System Complexity → Consumer Cognitive Burden → Reduced Ease of Checking → Weakened Trust → Simplification Pressure	Complevity-Usability Tension	Pair technical depth with simple consumer UI (QR code)

1. Functional Aspects

   The functional aspects of the Halal Traceability system include various key capabilities that directly support the purpose of tracking and guaranteeing product halalness. The first stage starts from halal product tracking, which is the main basis of the system. This process aims to identify and follow the movement of halal products from the beginning of production to the hands of consumers. With this tracking system, the data obtained can be accurately recorded and validated.

Data recording and validation then becomes the next important element. When data regarding raw materials, production processes, and product distribution are recorded and validated properly, a reliable halal guarantee will emerge. This means that consumers and authorities can confidently state that the product has met the established halal standards. This system becomes stronger when the data is not only available, but has also been verified and authorized by the competent authority.

Furthermore, through monitoring automation, the system can continuously monitor the condition of the product and its production process in real-time. This leads to the availability of real-time product information, which allows various parties to immediately know the current condition of a product in the supply chain. This capability not only improves efficiency but also provides a quick response to possible deviations or violations of halal standards. Then, this real-time information supports early warning, which is a system that can identify potential risks or violations before serious impacts occur. Early warning is crucial in maintaining supply chain security, as it prevents products of questionable halalness from reaching consumers. This makes the system more proactive and preventive, rather than just reactive to problems that have already occurred.

Another important function is system interoperability, which is the ability of various systems (e.g., those of producers, distributors, regulators) to exchange information. This allows access to information by all stakeholders, including producers, consumers, auditors and governments. This open access increases consumer confidence, and ultimately leads to increased demand for halal products. In other words, these functions are logically interconnected and form a comprehensive system in ensuring the halalness of a product.

2. Non-Functional Aspects
Based on the context of the Halal Traceability system, non-functional requirements act as a supporting foundation that ensures the system runs reliably, safely, and is acceptable to all parties. One of the main aspects is data security, which is very important in protecting sensitive information, such as raw material data, production processes, and distribution. When data security is guaranteed, the validity and reliability of the halal information provided by the system is also guaranteed, thus strengthening the reliable halal assurance for consumers and authorities.

Another important aspect is system efficiency and scalability. An efficient system allows halal data processing to be done quickly and resource-efficiently, while scalability allows the system to handle increases in data volume or users over time. These two things contribute directly to the overall performance of the system. A system that works well and is responsive will be more easily adopted and used by various parties in the halal ecosystem.

Optimal system performance is a key prerequisite for the system to be used by all stakeholders, including producers, distributors, auditors, regulators and consumers. When all parties can access and use the system smoothly, the halal ecosystem becomes more synergistic. Coordinated interaction between these actors is important to ensure the smooth running of the halal tracking and verification process as a whole.

Another non-functional factor that is no less important is accessibility and transparency, which allows consumers to directly check the halalness of products through available digital systems. With this ease of access, consumers can verify independently without having to rely entirely on third parties. The availability of transparent and easily accessible information increases consumer participation and awareness of the importance of consuming halal products.

Finally, compliance with regulations is an important indicator in non-functionality, especially in relation to certification bodies such as LP POM MUI. A system that complies with applicable legal provisions and standards will increase the trust of regulators, and at the same time provide more assurance to the public that the system is legitimate, credible and in accordance with the rules. Thus, non-functional aspects strengthen public trust and make the digital halal system more widely accepted.

3. Technological Aspects
Based on the Halal Traceability system, technology is the main backbone that allows the halal traceability and verification process to be carried out accurately, quickly and safely. One of the key technologies is blockchain, which enables permanent and immutable data recording. This technology is very relevant in maintaining the

integrity of halal data because every transaction or process recorded on the blockchain is transparent and can be traced back, thus strengthening trust in the information provided by the system.

In addition, the use of IoT (Internet of Things) devices contributes to the automation of monitoring in the halal supply chain. Sensors and smart devices can be used to monitor real-time product conditions, such as temperature, humidity, or storage and shipping locations. The data generated by these devices is then sent directly to a central system, reducing reliance on manual reporting and minimizing the possibility of errors or data manipulation.

Smart contracts technology, which also runs on the blockchain, allows for automation in halal verification. With smart contracts, a halal rule or condition can be programmed for the system to automatically reject or approve a process or product based on predefined parameters. This saves time and reduces the potential for human bias, and ensures that halal certification procedures are consistent and objective.

Cloud computing is also an important technology component in this system. With cloud computing, the system can be flexibly scaled according to the growth in the amount of data or users. This means that the halal system can be accessed by more stakeholders without experiencing performance degradation. In addition, the cloud eases the integration of data from multiple sources and allows system access from multiple locations with customizable security.

Overall, the four technologies-blockchain, IoT, smart contracts, and cloud computing-contribute greatly to system efficiency and assurance of compliance with halal standards. The use of these technologies not only speeds up processes, but also makes them more reliable, transparent and auditable. Thus, this technology-based system is able to provide a modern solution to the complex challenges of tracking and verifying halal products across supply chains.

4. Regulatory and Standardization Aspects

Based on the development of the Halal Traceability system, the regulatory and standardization aspects function as a legal framework and technical guidelines that ensure the system runs in accordance with applicable regulations. One important element in this case is digital halal certification, which allows the certification process to be carried out electronically and integrated. With the adoption of this digital system, system compliance with the procedures and policies of the Indonesian Ulema Council (MUI) can be ensured more consistently and monitored, thus accelerating the verification process and strengthening the legitimacy of the system in the eyes of the public and related institutions.

Compliance with MUI standards is an important indicator that reflects the seriousness of business actors in maintaining product halalness. When a halal system has fulfilled MUI provisions digitally and well documented, consumer confidence in the product increases significantly. Consumers will feel confident that the products they consume have actually passed a strict and transparent verification process in accordance with the values of Islamic law.

In addition to MUI, Halal Traceability systems also need to comply with international standards such as HACCP (Hazard Analysis and Critical Control Point) and ISO 22000, which focus on food safety. The implementation of these standards ensures that every stage in the production and distribution of halal products not only pays attention to the halal aspect, but also the quality and safety of the product itself. Thus, the integrity of halal products is not only guaranteed from a religious perspective, but also from the perspective of consumer health and safety.

Furthermore, the implementation of the Personal Data Protection Law (PDP Law) is very important in maintaining the security of consumer information. A digital-based halal tracking system will store various personal data of consumers and stakeholders, so it is mandatory to have policies and technology that guarantee confidentiality and protection against data misuse. Compliance with the PDP Law not only prevents legal violations, but also builds a sense of security and trust among system users.

Taken together, the regulatory and standard elements provide the legal, ethical and technical foundations that strengthen the credibility of the halal system. The integration of digital halal certification, food safety standards, and consumer data protection creates an ecosystem that is not only legally and Shariah compliant, but also

technologically and governance feasible. That way, the Halal Traceability system can be widely accepted by regulators, business actors, and the general public.

CONCLUSIONS AND IMPLICATION

The development of a Halal Traceability system requires a comprehensive approach that includes functional, non-functional, technological aspects, as well as regulation and standardization. From a functional aspect, the system must be able to provide halal product tracking, data recording and validation, to provide early warning to ensure supply chain security. All of these functions are interrelated and contribute to increasing consumer confidence in halal products. From the non-functional aspect, system reliability is determined by data security, operational efficiency, access transparency, and regulatory compliance. This strengthens the foundation of the system so that it can be used by all stakeholders optimally and reliably.

In the technological aspect, the utilization of blockchain, IoT, smart contracts, and cloud computing is key to the digital transformation of the halal system. These technologies not only support automation and immutable records, but also ensure system efficiency, scalability and transparency. Finally, in terms of regulation and standardization, the implementation of digital halal certification, compliance with food safety standards (HACCP, ISO 22000), and the Personal Data Protection Law strengthen system integrity and public confidence in the professional and guaranteed governance of halal products.

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