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TECHNOLOGY CHARACTERISTICS AND INTEGRATION CAPABILITIES TOWARDS THE ADOPTION OF BLOCKCHAIN IN HALAL FOOD SUPPLY CHAIN: A THEORETICAL FRAMEWORK

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Abstract:

The adoption of blockchain technology in halal food supply chains facilitates not only compliance with halal standards and improved operational efficiency, but also increased transparency, traceability, and heightened trust among supply chain stakeholders. However, the adoption of blockchain technology in halal food supply chains is still in its infancy. This paper aims to develop the theoretical framework for examining blockchain adoption factors, framed within the Technology-Organization-Environment framework and the Resource-based View theory, focusing on two primary constructs: technological characteristics and integration factors. This paper performs an extensive review and synthesis of prior literature on blockchain adoption, halal supply chains, and technology adoption theories. The proposed framework is expected to contribute to the advancement of research in halal logistics and the implementation strategies of blockchain. Future research is recommended to empirically test the proposed framework using quantitative, qualitative, or mixed-method approaches across different halal supply chain sectors and geographical contexts.

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Introduction

The halal sector has developed as one of the biggest economic drivers today in becoming a competitive global industry from an emerging industry. Halal Development Corporation (HDC, 2020) has projected that the global halal industry is anticipated to reach USD 5.0 trillion by 2030. On the other hand, the halal market in Malaysia is expected to achieve USD 113.2 billion. The greater halal market is influenced by the growth of the Muslim population in Malaysia, already reached 20.6 million (DOSM, 2023). One of the fastest-growing industries is the halal food sector, due to Muslim strict devotion to halal consumption (Antara et al., 2016). The food and beverage sector dominated the halal market in 2018 in Malaysia, accounting for USD 51.9 billion, and is expected to grow to USD 85.2 billion by 2030. With the increasing of halal food supply chain, it is challenging to maintain halal integrity.

The growing Muslim population and the increasing awareness of non-Muslim consumers drives the rapid expansion of the halal food sector (Lodhi, 2009). Numerous countries around the world recognize the halal sector as a significant contributor to economic development. However, maintaining the integrity of halal products in supply chain activities is not an easy task (Tiemen et al., 2012). It is more complex to maintain halal compliance standards since the expansion of the halal food supply chain. This effort requires tougher solutions.

In Malaysia, the government plays an important role in ensuring that the safety, quality and integrity of halal products are guaranteed. The Ministry of Health (MOH) introduced Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Points (HACCP) to ensure food safety and halal quality. The growth of using these certifications indicates that better control across supply chain networks (Tieman & Darun, 2018). Despite this effort, keeping the halal authentication still challenging due to attempted fraud of certification and use of fake halal logo cases are still occurring (Rahman et al., 2017).

Previously, there have been issues with counterfeit halal products that have made people worried. As a result, the investigations have been conducted. Then, actions have been taken to enforce the related law (Reduan & Mohd Anuar, 2018; Nordin, 2023). There are a lot of risks involved across halal supply chains. It includes cross-contamination, fraud, and the non-existence of a globally uniform halal certification system (Tieman et al., 2012). The news about some companies that allegedly utilize expired or unauthorized halal certifications points to the

absolute necessity of more stringent regulations as well as upgraded traceability provisions (Kaur, 2024). Consumer trust gets heavily influenced by such incidents; thus it has an impact on market confidence and the brand reputation (Al-Kwifi et al., 2020). Halal compliance is critical to prevent contamination or fraud at every stage of the process, from sourcing, processing, packaging, distribution, and retail. Consumer trust in product supply chains can have an effect on the marketability of a product. Finding a solution to such issues would then have great importance. To guarantee halal authenticity, it is necessary for businesses to not only be certified but also to use advanced technological solutions such as blockchain (Sim & Abdullah, 2022).

One possible way to overcome the issues of supply chains in halal supply chains is to use blockchain technology, which offers transparency, traceability, and security. With this system, halal compliance can be observed and confirmed in real time so that the products can comply with the international food safety standards as well as meet the requirements of the Islamic diet simultaneously (Ali et al., 2021). It has been announced that by establishing blockchain, the supply chain becomes less exposed to the wrongdoing such as fraud, contamination, and mislabelling, thus more efficient (Rohmah et al., 2019; Surjandari et al., 2021). However, the adoption of blockchain technology in Malaysia is still in low stage, even with the support of the government. It is due to the technology's complexity and the businesses' aversion (Ammar et al., 2023).

Furthermore, the traditional logistics systems are more complicated. This consists of numerous players. This consists of suppliers, shippers, carriers, and middlemen. This may heighten the risk of fraud, mishandling, and operational shortcomings (Zailani et al., 2019). Yet, particularly the challenges, blockchain technology has the potential to be disruptive in halal food supply chains. Blockchain technology improves the traceability and transparency of information, and more importantly, enhances the trust of the stakeholders (Wong et al., 2021). Additionally, the use of blockchain technology to address these issues has been suggested. The supply chain, using the blockchain due to the characteristics of decentralization and being almost impossible to alter, will increase the security, transparency, and traceability. Besides, the supply chain can ensure compliance with halal standards through real-time monitoring of production and the traceability of transactions all the way to the consumer.

There are several factors affecting the decision to adopt blockchain. Hew et al. (2020) suggest technological, organizational and environmental as the main factors that contributing in affecting the blockchain technology adoption. First, in terms of a technological perspective, organizations need to evaluate the benefits of blockchain. It includes how it can improve traceability and reduce fraud. It must be performed before making a decision (Mahsun, 2023). Second, in terms of organizational perspective, the blockchain technology adoption may depend on the leadership and availability of resources (Junejo, 2023). Third, in terms of environmental perspective, factors that force companies to adopt the blockchain technology includes system of rules, laws, and guidelines established by a government or authority. Besides, the increasing number of consumers demanding transparency in business could be one of the environmental influences towards blockchain technology implementation in the halal food supply chain (Ismail et al., 2022). In order to overcome the challenges, there is a need of stakeholder’s collaborations. It includes the regulatory bodies and the industry players. (Talib et al., 2020; Rizki et al., 2023).

International Journal of Innovation and Industrial Revolution
IJIREV
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On the other hand, there are significant amount of research has been carried out to explore the potential of blockchain applications in halal supply chains. However, there is little attention has been given to the integration of blockchain in these chains (Kamilaris et al., 2019). Besides, knowledge gaps in this context should also be addressed for a successful implementation of the change (Wang and Yang, 2022). The objective of the study is to develop the theoretical framework for examining blockchain adoption factors, framed within the Technology-Organization-Environment (TOE) framework and the Resource-based View (RBV) theory. By using blockchain technology, businesses can not only improve the efficiency of the halal supply chain but also become a part of the transparent and trustworthy halal market, which is evolving (Muhamad et al., 2020). Moreover, even after being empowered with this potential, the adoption amount is still low. The two significant factors that this study focuses on are technology characteristics and integration capabilities, which influence blockchain adoption.

The remainder of this paper is organized into five sections. Section 2 reviews the literature to develop the theoretical framework, while Section 3 details the research methodology. Section 4 presents the discussion, and Section 5 offers concluding remarks and avenues for future research.

Literature Review

Blockchain in Halal Food Supply Chain (HFSC)

In 1991, Stewart Haber and W. Scott Stornetta introduced blockchain technology. It functions as a decentralised ledger system (Narayan et al., 2016). Blockchain technology differs from the traditional supply chain. Most supply chain networks are based on a single, vulnerable, and centralized administrator. In contrast, blockchain technology employs a distributed approach. It provides a way for multiple participants to securely record and share their transactions. Blockchain technology links data and has a unique numbering system. This creates a sequence that is unalterable and mitigates the risks of manipulation or delay (Derks et al., 2018). Additionally, blockchain technology enables devices to communicate directly over the internet, thereby avoiding the limitations of traditional systems (Bhardwaj et al., 2021).

Interest in blockchain, particularly in health care and finance, has been growing rapidly. Malaysia, currently in 12th place in the World Bank’s Ease of Doing Business, needs to incorporate more of these emerging technologies to remain competitive. Since 2015, Malaysia's regulatory frameworks, particularly those of the Securities Commission and Bank Negara Malaysia, have been more accommodating in order to streamline the country's fintech ecosystem. This was further elaborated in the National Blockchain Roadmap 2021-2025 (MOSTI), which aims to mainstream blockchain adoption in supply chain management. Besides, Hendayani & Fernando (2022) note that blockchain does more than provide transparency and validation of halal certification; it also enhances the firm's competitive and operational Performance. Therefore, it is Malaysia's ambition to champion the global blockchain and provide data integrity to all players in the ecosystem, especially the halal supply chain, which is more robust and trustworthy.

As the problems with the Halal Food Supply Chain and the crisis of trust in the Halal status have been going on for a long time, blockchain is not only a small step of innovation, but it is also a new way of building and keeping trust in the system. Its design can be the answer to the very fundamental and old problems of trust because of its distinctive capabilities to solve issues

of nontransparency, fraud, and disintegration. The use of blockchain technology is a gamechanger in improving the efficiency and effectiveness of the Halal food supply chains (HFSC). Quran 5:87 (Translation of meaning): "O you who have believed, do not make illegal the good things which Allah has allowed to you and do not exceed the limits. Surely, Allah does not love those who exceed the limits." Halal conformity issues are the main challenges that blockchain can solve by improving traceability, transparency, and trust of the stakeholders.

Halal is a sector where the authenticity of the product cannot be questioned, and thus, transparency in the supply chain is a must for gaining consumer trust. Through giving the possibility of product status and history in real-time to anyone, blockchain is making transparency more open (Hendayani & Fernando, 2022; Hew et al., 2020). The transparency achieved through blockchain technology thus complies with the requirements of the Halal standards and, at the same time, gives consumers confidence in the products they purchase (Sim, 2023; Duan et al., 2020). Moreover, the usage of blockchain technologies is at the same time very comfortable as it enjoys the instant tracking and transparency that are very important for maintaining Halal requirements in the supply chain (Rejeb, 2018; Hew et al., 2020).

Moreover, the use of blockchain technology also facilitates work processes as there is no need for intermediaries, the handling of documents is eliminated, and the transactions are executed by smart contracts automatically (Hastig & Sodhi, 2020; Duan et al., 2020). The study by Karudin et al. (2025) examines the critical role of the halal manufacturer as a strategic orchestrator in transforming Halal logistics from a compliance-driven function into a value-creating capability that enhances organizational performance. This transformation involves integrating Halal logistics with digital technologies, such as blockchain, to ensure transparency and operational efficiency (Mohamad Karudin et al., 2025a).

Sadiyah (2024) also challenges the Halal traceability system and maps out the role of blockchain in enabling Halal standardization. The study found that the system has a positive impact on the Halal sector of Micro, Small, and Medium Enterprises (MSMEs) performance. Findings of this study reiterated the fact that the use of blockchain makes an important contribution towards the performance of the Halal supply chains. Companies with advanced digital infrastructures, particularly those employing blockchain technology, are often better equipped to leverage Halal logistics service provider knowledge for operational improvements (Mohamad Karudin et al., 2025b).

To comprehend blockchain's transformative ability, it is crucial to recognize its three core pillars, each of which targets a significant flaw in traditional systems.

Decentralization

A blockchain is a distributed registry in contrast to traditional databases, which are centrally owned and managed by one party. It implies that the network stores an identical version of the complete transaction history in the possession of many network participants (or nodes) (Barliana et al., 2022; Zailani et al., 2022). This decentralized structure automatically removes the single point of failure that is so susceptible to centralized systems (Sharma, 2024). No central administrator can modify or delete records unilaterally, and the system can remain operational even when some of its participants are offline. This flow of information creates a more democratic and robust information ecosystem, with all parties having the same data, such

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IJIREV
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that no one party has a competitive advantage in any of the cases, and that nobody can control the record to favour their interest.

Immutability

The second, and perhaps the most important aspect of blockchain is immutability. After the network has verified a transaction, such as the transfer of a batch of raw materials between a supplier and a processor, and stored the transaction in a block, the block is cryptographically linked to the last block, creating a chronological chain. With this process, the data is virtually non-permanent and irreversible (Sharma, 2024; Tan et al., 2020; Zailani et al., 2022). To modify a previous transaction would involve modifying not just a single block in the chain, but all the following blocks would be required to be modified, a computationally impossible task which would be locally repudiated by the remainder of the network. This immutability gives data integrity like no other, which directly negates the threats of document falsification and fraudulent records-keeping that are widespread in paper-based systems (Zailani et al., 2022). The history of a product passed through the blockchain, once committed to a blockchain, can be considered a reliable and non-changeable record of the events.

Transparency and Auditability

By design, a blockchain is a transparent system to everyone who has the right to access it. The ledger can enable all the authorized parties in the supply chain, such as a farmer, an authority body, or even a final consumer, to get access in real-time (Kurniyani et al., 2025; Sharma and Singh, 2023; Zailani et al., 2022). Such visibility means that everyone is dealing with a single and common data set, thus there are no longer any data silos that were the conventional systems. In other words, the auditability of this nature is built in, which makes it very easy and fast to find a product's origin, determine its compliance rate at any time, and figure out the source of the problem, for instance, a contamination, in a much shorter time (Sharma and Meel, 2024). The trust this transparency gives to everyone is the main thing that would help people hold each other accountable.

These architectural pillars, when combined, create something more insightful than just a database. However, Haleem et al. (2020) conducted a comprehensive literature review on Halal supply chain management for sustainability purpose, they reported that the supply chain processes can be made very efficient through the use of blockchain technology. In this paper, it is suggested that blockchain adoption will help Halal organizations to adjust to the Halal value system and standards that need to be considered to remain competitive in the market (Pua Aizat et al., 2023).

In order to describe how it is practically applicable, we can use the example of a Halal meat product on a blockchain-based supply chain. It starts at the farm, where an animal is assigned a special digital identity, which is documented on the blockchain. At the time of transfer of the animal to a slaughterhouse, the transaction is registered, and a connection to the valid Halal certification of the facility is established. At the Halal-compliant slaughter and processing stages, new transactions like the time of slaughter, the slaughter process, and lot numbers of the resultant products are captured on the chain (Sharma, 2024; Zailani et al., 2022). The movement of the packaged meat is tracked as it is transported, and every handover between the logistics providers is immutably registered. When a product is received at a retail distribution center, a second transaction is made, and receipt is confirmed. Lastly, once the product is on

the shelf of the store, its entire and verifiable history to that specific shelf can be known (Kurniawan et al., 2025). This chain of custody is unbroken, and this end-to-end computer-based provenance trail offers a degree of traceability which simply is impossible with traditional systems.

In addition to mere record-keeping, blockchain also allows smart contracts. These are self-execution programs, when the conditions of an agreement between parties are coded (Kurniawan et al., 2025; Zailani et al., 2022). The code and the agreements therein are scattered throughout the distributed, decentralized blockchain network. A large number of processes within the HFSC can be managed by smart contracts, and efficiency is hugely improved, with the possibility of human error eliminated. As an example, a smart contract might be written in such a way that automatically confirms the Halal Certification of a supplier prior to a payment being released to that supplier to make a shipment of raw materials. When the certificate is on-chain and valid, a payment will be made immediately; when the certificate has expired or is invalid, the payment is not made, and a non-compliant ingredient does not enter the supply chain (Barlania et al., 2022). In the same manner, by offering officials access to a verifiable and tamper-proof digital record of the genesis and compliance of a product, smart contracts can streamline the customs clearance process, reducing paperwork, delays, and manual verification by intermediaries by large margins (Zailani et al., 2022). Smart contracts can streamline the complete supply chain by automating these key compliance and transaction processes and making them cheaper, faster, and safer.

Technological, Organizational, and Environmental (TOE) and Resource-based Value (RBV) Theory Lens

The Technology Organization Environment (TOE) is also one of the theories developed to investigate how new technologies could be adapted within organizations (Tornatzky and Fleischer, 1990). This theory includes three vital elements of technology adoption, which are the technology, organization, and environment contexts. Factors considered in the view of the technology context include things like complexity and the level of compatibility it has with the already established systems. The organizational context includes aspects of size, structure, and culture of an organization, which may influence the process of adoption. Environmental context is the external forces, such as competition in the market and regulations that can influence adoption decisions (Tornatzky & Fleischer, 1990). Research on the TOE structure has also been created at scale (Liu et al., 2019; Nawaz et al., 2019; Su & Shyu, 2020), even in the area of blockchain technology adoption. The advantage of the TOE framework is that it enables an analytical, yet flexible system of innovation to be studied, and has been previously applied widely to understand how technological forces may influence the adoption of Blockchain within the Halal food supply chain (HFSC), including this paper. This dimension pertains to the characteristics of that very technology, the technologies already existing in the firm, and the technologies available on the market that can be introduced. The major ones that are likely to be considered in this context are such factors as the perceived relative advantage of the new technology over the previous one, its compatibility with the existing systems and organizational values, its complexity or usability, and its security features (Guo & Liang, 2016; Malik et al., 2021). The context is important to evaluate the inherent value proposition of a technology such as blockchain. Examples of technological factors include the characteristics of the technology itself, including the integration capabilities with existing infrastructure.

International Journal of Innovation and Industrial Revolution
IJIREV
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Volume 8 Issue 26 (September 2026) PP. 162-181

Technology features refer to the characteristics of the blockchain that have a significant impact on the usage of the blockchain, for example, complexity, compatibility, relative advantage, and trialability (Hassam et al., 2025). These features follow the TOE framework. The TOE framework is the most cited model for understanding organizational-level technology adoption. However, for blockchain, an inherently inter-organizational technology, the framework must be expanded. This study integrates TOE with the Resource-Based View (RBV). RBV argues that technological characteristics alone are insufficient to generate competitive advantage; they must be combined with capabilities to bridge internal systems and external partners. In HFSC, technological compatibility with the current systems, ease of use, and, most of all, the benefits perceived by the user, for instance, better traceability and transparency, are the deciding factors of blockchain adoption.

Alternatively, the integration functionalities illustrate the system or technology ability to be integrated with an organizational internal systems and other partners. In this context, it refers to the potential of blockchain technology to be integrated with existing system used by organizations and other partners throughout the supply chain. Furthermore, advanced integration functionalities enable effortless data flow and cooperation throughout the supply chain. Regarding HFSC, effective integration fosters instantaneous data flow among producers, certifiers, distributors, and retailers. It is crucial to ensure halal compliance throughout the supply chain.

Characteristics of Blockchain Technology

The first of these are blockchain's technological attributes. Halal stakeholders' unique trust relationships will be dramatically impacted by decentralization, which designates no one group in complete control of the validation of a transaction. Compared to mainstream, centralized IT systems, blockchain's peer-to-peer infrastructure enables certification bodies, producers, logistics providers, and retailers to have a completely synchronized ledger. This drastically reduces the imbalances and the risks associated with the halal label fraud, as each participant can see the certification process and validate it, eliminating the need for intermediary organizations (Nugraha, Mangruwa, & Dzakiy, 2025; Mayor Vitoria, 2024). The same can be said for many halal supply chains that engage with numerous countries with different regulatory requirements. In these cases, decentralization can engage trust where a regulatory authority may be absent. This characteristic encourages SMEs to adopt blockchain solutions instead of the more expensive third-party audit systems.

Another important characteristic of blockchain is immutability. This form of cryptographic assurance guarantees that once a transaction block is added to the chain, it is final and cannot be changed. In halal, it offers a permanent record of the different stages a product (and its inputs) undergoes (and how they are treated) from the farm to the end user. In halal, this covers the different methods of slaughter, ingredient sourcing, storage and logistical segregation as well as the different logistics routes. Any change to halal certification, expiration and contamination records is permanent and, as a result, can be easily identified. The absence of immutable halal records for substitution of non-halal ingredients or the mislabeling of post-slaughter products has created supply chain insecurities for halal. Immutability addresses these concerns. In a market protection sense, immutability provides the greatest benefit to halal product suppliers, as it addresses the ethical concerns of supply chain participants. The technology also offers a strong incentive to market penetration in supply chains that are religiously confined.

International Journal of Innovation and Industrial Revolution
IJIREV
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Volume 8 Issue 26 (September 2026) PP. 162-181

The third technological component is called transparency and gives consumers an instantaneous view of the origin of halal products and the conditions under which they have been handled. The structure of blockchain technology is transparent and remains pseudonymous, which allows stakeholders to trace individual batches to their origins, maintaining sensitive competitive information through permissioned access controls (Matusin, 2026; Rejeb, Keogh, Zailani, and Rejeb, 2020). In halal food supply chain logistics, transparency solves the "black box" issue, with the original halal status becoming obscured after multiple exchanges involving several firms. Research shows that greater transparency enhances the ability of consumers to verify halal food claims using a quick response (QR) code and results in an increase of market demand for those firms who adopt blockchain technology (Ali, Chung, Kumar, and Tan, 2021). As a result, transparency utilizes the technical potential of blockchain beyond differentiation to a cutting-edge strategic asset of halal brands to generate consumer trust.

Integration Capabilities

Apart from independent technical characteristics, the capacity for integration of blockchain with established supply chain systems is a strong determining factor for the acceptance of a technology. Multiple halal food supply chains utilize legacy enterprise resource planning (ERP) systems, along with warehouse management systems and electronic data interchange (EDI) systems. Integration capability describes the level of effort, expense, and reliability with which blockchain could work with those legacy systems, which would not require completely new technology (Hendayani & Fernando, 2023; Khan, Falahat, Ullah, & Van, 2026). The integration of technology makes the adoption of the new technology easier, preserves the work that has already been completed, and allows the technology to be introduced in a modular way. For example, it could be used first to provide halal certification, and only later for the management of logistics. Evidence from Indonesian halal SMEs indicates that the level of integration perceived to be possible was the most important predictor of the adoption of the technology. The integration of the technology acts both to provide the means for adoption and to provide the limits of the adoption of blockchain technology.

Integration capabilities include the ability to ensure interoperability across all supply chain tiers and multiple blockchain platforms. A typical halal food supply chain involves multiple players and systems. Farms may rely on lightweight mobile apps, while large, multinational distributors may possess advanced, integrated, cloud-based systems. The exchange and usage of blockchain data across different protocols (e.g. Hyperledger Fabric, Ethereum, Quorum, etc.) is the interoperability required to facilitate seamless data transfer across blockchain networks and eliminate the "halal data silos" (Dai & Lu, 2026; Mangruwa, Yunani, Nugraha & Foon, 2024). The lack of interoperability may result in each supply chain tier using its own blockchain. This may result in a loss of the fundamental purpose, which is traceability. There have been numerous proposals to help network-wide adoption by lowering integration barriers through the standardization of smart contract templates and application programming interfaces (APIs) for halal certification events (Imad & Obaidullah, 2026). Thus, the integration capability of interoperability provides insight as to whether the application of blockchain technology provides full halal visibility across the entire supply chain, or only localized improvements in supply chain visibility.

International Journal of Innovation and Industrial Revolution
IJIREV
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Volume 8 Issue 26 (September 2026) PP. 162-181

Last, process integration capability describes how interwoven blockchain will be in everyday halal compliance practices (e.g., certification renewals, audit triggers, exception handling). Halal compliance is more complicated than generic supply chain apps. Religious practices surrounding halal mean that there are guidelines around the transportation and handling of non-halal goods, as well as compliance requiring periodic recertifications and sudden cessation of services when there is a lack of compliance. Process integration capability entails that blockchain smart contracts will carry out compliance checks and automatically flag shipments when temperature logs compromise the shipment's halal status (Khan et al., 2026; Nugraha et al., 2025). This capability is appealing because it eliminates a substantial amount of manual oversight, enables rapid corrective action, and produces auditable records for regulators. Research on the logistics practices of halal firms reveals that companies with more advanced digital business processes perceive greater possibilities with blockchain technology and will be the first to adopt it (Ali et al., 2021). Process integration capability, therefore, reveals how blockchain can enhance halal business processes beyond the theoretical benefit of making transactions more traceable.

The Development of the Theoretical Framework

The Technology–Organization–Environment (TOE) framework is the primary theoretical lens of this study. Originally proposed by Tornatzky and Fleischer in the early nineties, this framework has been frequently utilized and expanded in the study of technology adoption at the organizational level, including frameworks for emerging digital tools such as blockchain. The TOE framework is the most cited framework when the author needs to address technological, environmental, and organizational factors influencing adoption decisions. Yet, the focus of this paper is largely on technological factors. Prior literature has suggested that, in developing economies, technological factors are most likely to hinder the adoption of blockchain in halal food supply chain frameworks.

To begin with, this paper emphasizes the adoption of blockchain technology as a special case. The study refers to technological attributes as positive characteristics of blockchain. These include relative advantage, complexity, compatibility, security, transparency, and traceability. These attributes are also perceived as factors that are viable and useful to assist in maintaining the integrity of the Halal supply chain in the mitigation of fraud, cross-contamination, and certification. In addition, the authors cite the studies of Hew et al. (2020) and Vanany et al. (2024) as examples to support the assertion that the adoption of blockchain technology is most likely to occur when the operational practices coupled with the halal assurance and the technology attributes.

This study considers integration capabilities as the second main element of the technological components of the TOE. Integration capabilities are examined for a reason. This is because integration capabilities define the blockchain technology ability to be merged with existing internal systems, such as ERP, inventory management, logistics, and external supply chain partners. Strong technical features of a blockchain supply chain network are constrained if there is unable to integrate the technology across. Numerous studies, such as Rajaguru and Matanda (2019) and Wang et al. (2020), have argued in favor of integration capabilities because they lead to real-time data sharing, collaboration, and traceability across a network (Foo et al., 2021). These features are needed to preserve halal integrity across supply chains.

International Journal of Innovation and Industrial Revolution
IJIREV
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Volume 8 Issue 26 (September 2026) PP. 162-181

The current study aims to construct a conceptual framework that identifies Technology Characteristics (decentralization, immutability, transparency) and Integration Capabilities (system interoperability, legacy compatibility, process embedding) as dual precursors to Blockchain Adoption in the Halal Food Supply Chain. This is the first study to our knowledge to analyze both the intrinsic technology characteristics of blockchain and the characteristics of the halal certification environment as interrelated. The framework also argues that Integration Capabilities affect the relationship of Technology Characteristics to Adoption. Integration Capabilities, if intensive, can strengthen the relationship of the Transparency and Immutability. If Integration Capabilities are weak, that relationship is also weak. This approach provides a new perspective to the existing body of research, where most (e.g. Mayor Vitoria, 2024; Mehmood et al., 2024; Vanany et al., 2024) focus on the technical/technology side or the organizational side and the readiness, but not the combined effect. The framework combines both sides to articulate the complexities of the halal supply chain, from meat and poultry to processed foods and pharmaceuticals.

Drawing from the above theories, this study develops a framework where the technological attributes of the blockchain and the integration capabilities are direct antecedents of the adoption of blockchain in the halal food supply chain (BHFSC). The incorporation of these two variables in the TOE framework allows this study to enrich the existing literature on blockchain adoption by stating that for the adoption of blockchain in the halal food supply chain to be successful, there must be more than just favorable technology; there must also be substantial system integration capabilities.

Besides, it provides a structured theoretical foundation for examining blockchain adoption factors in the halal food supply chain context (Figure 1).

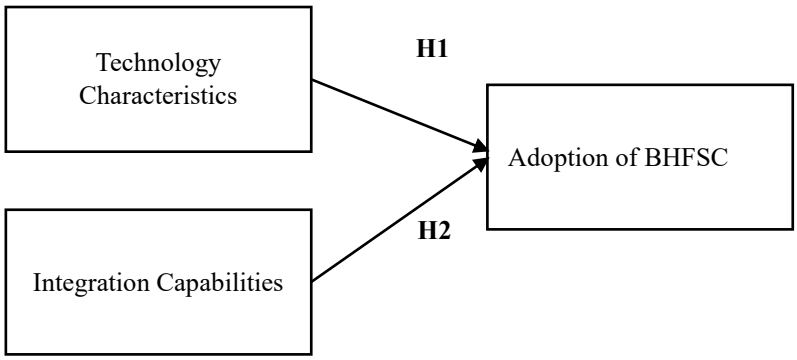

Figure 1: Proposed Theoretical Framework
Source: Authors' original conceptualization

Technology Characteristics and BHFSC Adoption

Previous studies offer insights into blockchain applications in supply chains and the effects of blockchain on different aspects of supply chain management. However, the usage of blockchain technology in the Halal food supply chain would necessitate an understanding of how the characteristics of blockchain technology serve the needs and work processes conducted in the Halal food supply chain.

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972 IJIREV
Volume 8 Issue 26 (September 2026) PP. 162-181

According to Park and Li (2021), blockchain technology shows great potential to improve sustainability performance on supply chains, and they found a positive relationship between blockchain implementation and supply chain sustainability. Their findings indicate the relationship between blockchain characteristics, such as transparency, traceability, and basic supply chain performance, resulting to enhance supply chain performance as well as halal food. Furthermore, Hew et al. (2020) examine the adoption of blockchain-based Halal traceability systems using a unified model drawing from the Halal orientation strategy, institutional theory, and the diffusion of innovation theory. The study underscores the successful adoption of matching the characteristics of blockchain with the requirements of the Halal food supply chain, especially with regards to steps involving system integration and traceability.

On the contrary, Sharma et al. (2023) have identified the primary cause of the adoption of blockchain technology in the agri-food supply chain using the most comprehensive Unified Theory of Acceptance and Use of Technology (UTAUT) model, outlining the variables. With the inclusion of interfirm trust and transparency, the author emphasizes the importance of understanding the features of blockchain in relation to adoption in supply chains. Moreover, Vanany et al. (2024) used Halal blockchain as a measurement tool in the Indonesian food industry and stressed that its deployment was essential to all the stakeholders in the supply chain to maintain its integrity. This study highlights the critical role of blockchain features, such as immutability and transparency, in ensuring authenticity and compliance of Halal products.

Thus, it is clearly observed that the technology adoption of the Halal food supply chain based on the characteristics of technology defines the requirements for Halal supply chain management (e.g., transparency, traceability, security). Hence, it can be hypothesized that:

H1: The technology characteristics have a significant relationship with the adoption of BHFSC.

Integration Capabilities and BHFSC Adoption

Integration is an important part of new technologies being integrated with existing systems. As Rajaguru and Matanda (2019) have argued, elaborating on the role of resource integration mechanism in the acquisition of supply chain capabilities, enhancements of operational performance, and thus associated competitive benefits of supply chain partners. Through their findings, it is determined that compatibility and supply chain process integration are the key aspects for strengthening supply chain capabilities and supply chain performance. According to Rajaguru & Matanda (2019), organizations can increase their operational efficiency and retain a competitive advantage by organizing technological potentials to supply chain processes.

Technologies such as IoT, big data analytics, and automation, associated with Industry 4.0, significantly enhance supply chain performance by improving coordination and integration. These technologies enable real-time data sharing and process optimization, which are critical for sustainable supply chain management (Mohaghar et al., 2026).

In addition, Wang et al. (2020) built a model to understand the possible influence of blockchain technology on increasing supply chain integration abilities. The research suggests that the blockchain stimulates collaboration with supply chain partners, which results in an extensively

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 8 Issue 26 (September 2026) PP. 162-181
integrated and more sustainable supply chain with low environmental impact. The research illustrates that using technologies leads not only to increased productivity in both parts of the supply chain but also contributes to sustainability goals simultaneously (Wang et al., 2020).
On the other hand, Rajaguru and Matanda (2019) agreed that both compatibility and integration of supply chain processes are needed to increase supply chain capabilities and performance. In order to achieve optimal supply chain logistics, supply chain partners should also align technological systems and operational frameworks. The capabilities of integration are significant to the adoption of blockchain in the supply chain of Halal food since they would enable the effective flow of information and communication between blockchain systems, resulting in greater efficiency of the supply chain. Thus, it was hypothesized that:

H2: The integration capabilities have a significant relationship with the adoption of BHFSC.

Methodology

This paper aimed to develop a theoretically grounded framework in order to understand the blockchain adoption in the halal food supply chain. Since this paper seeks to synthesize existing theories and empirical findings rather than test hypotheses using primary data, a conceptual approach is appropriate. This paper adopts a conceptual research design, specifically the "Model" approach defined by Jaakkola (2020). This approach aims to propose new relationships to explain a phenomenon. The development of the framework involved a systematic literature review (SLR) and synthesis of prior literature (2011–2025).

The systematic review protocol followed PRISMA guidelines which are the inclusion criteria, quality evaluation and synthesis (Jaakkola, 2020). The articles reviewed include industry reports, conference apapres, peer-reviewed journal articles in English language and relevant to “Blockchain”, “Halal”, “Supply Chain” and “Technology Adoption Theories”. Besides, the sources were selected based on their Sum of Citations (>100) or H-Index (>50) to ensure the "provenance" of the theoretical pillars. Then, pattern identification was used to detect the "Integration Gap" in current halal logistics research.

This analysis identified three main technological adoption drivers which are technological, organizational and environmental factors. However, this paper discusses the most critical factor which are technological factors itself in driving the adoption of blockchain technology in Halal food supply chain. The discussion in this paper will focus on two technological or contextual blockchain adoption drivers in halal food supply chains: technology characteristics and integration capability. These two variables were the most significant of the technology adoption drivers. These variables were defined and justified based on the literature on supply chain management, information systems and halal logistics. The relationships of the variables were defined to inform the hypothesized relationships (H1 and H2).

The proposed framework is an adequate starting point for future empirical studies. It clarifies the relationships of the variables which contributes to theory development. It also situates adoption of blockchain technology in the halal food supply chain in its proper context.

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Volume 8 Issue 26 (September 2026) PP. 162-181

Discussion

While developing the framework, the paper contributes to the literature on the adoption of blockchain technology in halal food supply chains by incorporating the relevant theory. In this paper, the halal food supply chain is focused on the technology characteristics and integration of blockchain technology based on the adoption of the halal food supply chain. The proposed framework provides a robust theoretical bridge between blockchain's technical attributes and the operational realities of the Halal industry. By synthesizing the TOE Framework and RBV, this study offers a deeper explanation for why technological brilliance is insufficient for adoption without an aligned integration ecosystem.

Unlike previous studies that treat blockchain as a monolithic entity, this framework suggests that Technology Characteristics (TC) must be analyzed as a direct response to the "Halal Integrity" crisis. Within the technological context of TOE, attributes such as immutability, decentralization, and transparency are not merely features; they are functional requirements for mitigating risks of Halal fraud and cross-contamination (Hew, et al., 2020; Vanany et al., 2024). However, the findings indicate that these characteristics are "static" resources. According to RBV, while a decentralized ledger is "valuable" and "rare," it does not provide a competitive advantage unless it is "organized" to be utilized effectively (Attia & Eldin, 2018; Rajaguru & Matanda 2019). Therefore, the technological context of blockchain is intrinsically linked to how these characteristics align with the specific needs of the Halal supply chain, such as real-time auditability and tamper-proof certification (Mohamad Karudin et al., 2025). In addition, this strengthens the framework's assumption that the adoption of blockchain technology is most likely to occur when some stakeholders in the system recognize the system's distinct advantages over others. These studies are consistent with other studies based on the TOE framework (Hew et al., 2020; Park & Li, 2021).

On the other hand, the most significant weakness in previous Halal logistics research is the failure to distinguish between the mere possession of a technology and the capacity for its integration (Tornatzky & Fleischer, 1990; Rajaguru & Matanda, 2019). In this framework, Integration Capabilities (IC) represent the critical intersection between the Technological and Organizational contexts of the TOE framework. First is the Internal Integration. For a firm to adopt blockchain, it must possess the organizational capability to bridge decentralized ledgers with existing internal legacy systems, such as ERP or inventory management (Mohaghar et al., 2026). Second is the External Integration. Since blockchain is inherently inter-organizational, IC acts as a dynamic capability that allows a firm to reconfigure its external supply chain relationships (Hew et al., 2020).

This explains the paradox in the Malaysian context: despite strong government environmental pressure through the National Blockchain Roadmap 2021-2025, adoption remains low because SMEs lack the Integration Capability to merge these high-tech characteristics into their traditional organizational workflows (Talip et al., 2024). This synthesis demonstrates that blockchain adoption is not a linear event but a socio-technical alignment where integration capabilities (IC) meet technological characteristics (TC) to satisfy environmental mandates.
The integration of the two describing factors within the technology dimension of the TOE model offers a more sophisticated framework for explaining the adoption of blockchain technology within HFSC. This paper posits that for the organization to reap the advantages of the technology; there must be a favorable attitude of the organization towards the blockchain technology and sufficient capacity to integrate the systems. This explains the overall adoption

of the technology within the supply chain of the organizations and the dynamics conducive for the adoption of blockchain technology within the supply chain of the halal supply chain.

Conclusion and Future Direction

In conclusion, the halal food supply chain's adoption of blockchain technology will be shaped primarily by halal supply chain blockchain users' appraisal of the technology's characteristics and the extent to which they believe the technology's integration will support the halal supply chain. With respect to the Technology-Organization-Environment (TOE) framework, the adoption of blockchain technology by halal food organizations will, for the most part, be influenced by the behavioral dimensions of the context in which they operate.

First, to the best of our knowledge, this is the first of such frameworks to offer technology characteristics and integration capabilities as the key drivers of halal food supply chain blockchain technology adoption. Blockchain technology is characterized by transparency, traceability, and immutability. The framework suggests that while very few of the characteristics of blockchain are relevant in addressing halal supply chain integrity, it is the organization's integration of blockchain technology with systems and supply chain partners that is most critical.

Second, the adoption of blockchain integration technology within the TOE framework that is being applied to the halal food supply chain is the first of its kind. It attempts to address the gap in the assumption within the literature that adoption of a given technology is primarily based on the perceived usefulness of the technology and then considers integration as a factor under the technology dimension. While the framework is not without limitations, it is an important step toward advancing the understanding of halal logistics and supply chain digitization.

Third, halal food industry stakeholders, tech providers, and policymakers can benefit from these findings. Organizations can estimate potential tech benefits from blockchain placement and evaluate their intended internal integration. Policymakers can aid tech adoption by designing integration outlines for MSMEs and providing flexible modular infrastructure and training. Technology providers can concentrate on designing blockchains for particular supply chain needs.

Lastly, empirical support for the framework should be the aim for the future studies. This can be done using quantitative, qualitative, or mixed methods in one or multiple divisions of the halal supply chain. To gain better insight, it would also be helpful to do comparative studies among countries and halal and non-halal supply chains.

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