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Blockchain Technology in the Halal Supply Chain: Comparative insights from Malaysian micro, small, and medium enterprises

Siti Fairuza Hassam*, **Adila Talip, Yanti Aspha Ameira Mustapha, Mohd Rizaimy Shaharudin**
**Corresponding Author*

Faculty of Business and Management,
Universiti Teknologi MARA (UiTM) Cawangan Kedah, Kampus Sungai Petani, Kedah, Malaysia

fairuza@uitm.edu.my, adila.talip@gmail.com, ameira574@uitm.edu.my, rizaimy@uitm.edu.my
Tel: +604 456 2170

Abstract
This study explores blockchain adoption in Malaysia's Halal supply chain, focusing on micro, small, and medium enterprises (MSMEs). It aims to identify key factors influencing adoption and examine challenges faced by these enterprises. Based on literature analysis and interviews, the findings highlight technological readiness and vendor support as critical determinants. While blockchain offers benefits such as enhanced transparency, traceability, and certification integrity, adoption remains limited due to high costs and integration barriers. This study contributes to the broader understanding of technology adoption in supply chains and provides insights for enhancing the effectiveness of blockchain implementation in Halal-related sectors.

Keywords: Blockchain; Halal Supply Chain; Technological Readiness; MSMEs

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1.0 Introduction

Blockchain technology has the potential to significantly enhance the efficiency and integrity of Malaysia's Halal supply chain by improving transparency and traceability in line with Islamic principles. According to Cui, Gaur, and Liu (2024), blockchain enables greater supply chain visibility, which is essential for Halal compliance. Despite various digital initiatives introduced by the Malaysian government to promote blockchain in Halal certification and fraud prevention, adoption among micro, small, and medium enterprises (MSMEs) remains limited (Ali et al., 2021). This limited uptake is primarily attributed to financial constraints, insufficient technical knowledge, and difficulties in integrating blockchain with existing systems (Karyani et al., 2024).

Balasubramani et al. (2024) emphasize that blockchain facilitates real-time tracking of products, thereby increasing consumer trust and ensuring Halal authenticity. Similarly, Stranier et al. (2021) note that blockchain can streamline operations through automation and reduce paperwork. According to Mehmood et al. (2024), the immutable nature of blockchain ledgers is particularly valuable in safeguarding the credibility of certification bodies such as JAKIM.

Despite these advantages, the adoption of blockchain among MSMEs is impeded by high implementation costs, technical constraints, and compatibility issues with existing infrastructure (Zulihuma & Shibghatullah, 2022). Regulatory uncertainty and the absence of standardized blockchain frameworks further exacerbate these challenges (Hendayani & Fernando, 2023). Concerns regarding data privacy and competitive risk also contribute to resistance (Ali et al., 2021).

This study aims to explore the current state of blockchain adoption in Malaysia's Halal supply chain, focusing on MSMEs, and to identify key influencing factors. The objective is to determine the technological, organizational, and external challenges affecting adoption. The findings contribute to broader knowledge on digital transformation in Halal supply chains and support future strategies for implementation.

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2.0 Literature Review

Blockchain technology has emerged as a revolutionary tool for enhancing transparency and security in the halal supply chain (Hassam et al., 2024). However, small and medium-sized enterprises (SMEs) face challenges in adopting this technology due to financial constraints and technical limitations (Ardiantono et al., 2024). Unlike large corporations, SMEs often lack the resources and expertise required for blockchain implementation, making it difficult for them to integrate blockchain into their existing supply chain management systems (Ardiantono et al., 2024). This highlights the importance of top management support in overcoming financial and technological barriers through strategic vision and resource allocation (Hendayani & Fernando, 2023). For large businesses, blockchain adoption has significantly improved traceability and transparency, which are essential in halal certification compliance (Hendayani & Fernando, 2023). Blockchain's decentralized ledger system ensures that data cannot be altered, thereby reducing fraud and unauthorized modifications within halal supply chains (Alsmadi et al., 2023). This not only strengthens consumer confidence in halal products but also enhances the credibility of halal certification bodies (Hendayani & Fernando, 2023). Moreover, blockchain facilitates operational efficiency, reducing the time and costs associated with traditional manual verification methods (Balasubramani et al., 2024).

The relative advantage of blockchain in the halal supply chain is evident in its ability to reduce operational delays and eliminate inefficiencies, particularly for large enterprises. Research shows that blockchain lowers operational costs by 15%, making supply chains more agile and responsive (Balasubramani et al., 2024). Additionally, blockchain's tamper-proof security mechanisms contribute to a 95% reduction in fraud cases and a 98% decrease in security incidents, demonstrating its potential to enhance supply chain security (Balasubramani et al., 2024). However, technological readiness remains a key factor as claimed by Zhang et al., (2023), as many businesses particularly SMEs which lack the infrastructure and skilled workforce needed for blockchain implementation (Raj et al., 2024). Despite these benefits, regulatory and compliance challenges remain major obstacles to blockchain adoption (Yeong et al., 2022). Businesses must navigate complex legal frameworks that regulate data privacy, halal certification, and supply chain transparency (Raj et al., 2024). Achieving a balance between transparency and confidentiality is crucial, as excessive openness can expose sensitive business information (Raj et al., 2024). Additionally, system integration and interoperability issues make it difficult to align blockchain solutions with existing Enterprise Resource Planning (ERP) systems used by halal supply chain actors (Hendayani & Fernando, 2023). The absence of standardized frameworks further complicates integration, necessitating greater industry collaboration.

Blockchain adoption is also hindered by complexity, user training requirements, and vendor support issues. Many businesses lack the technical knowledge to operate blockchain-based systems, resulting in a steep learning curve (Ardiantono et al., 2024). The high cost of training employees and upgrading systems increases the financial burden on businesses, particularly for SMEs (Raj et al., 2024). Vendor support plays a crucial role in providing technical assistance and troubleshooting blockchain-related challenges (Hendayani & Fernando, 2023). Businesses that partner with experienced blockchain service providers experience smoother adoption processes and better long-term sustainability (Balasubramani et al., 2024).

In conclusion, while blockchain technology offers immense benefits in improving transparency, efficiency, and security in halal supply chains, its adoption remains uneven across different business sizes (Thoumrungroje & Racela, 2021). Large enterprises benefit from cost savings, enhanced traceability, and stronger security, whereas SMEs struggle with financial and technical barriers (Ardiantono et al., 2024). Regulatory and system compatibility challenges further complicate adoption, requiring careful evaluation of blockchain integration strategies. Despite these hurdles, blockchain's potential to transform halal supply chains is evident, especially when combined with smart contract automation and IoT-based monitoring systems (Bhardwaj et al., 2021). Future research should focus on developing tailored blockchain solutions for SMEs, ensuring wider accessibility and industry adoption.

3.0 Methodology

This research utilizes two data sources: field interviews and journal publications, representing primary and secondary data, respectively. Before formulating the conceptual framework, the initial stage involved identifying key blockchain-related challenges in the halal supply chain. A comprehensive literature review on blockchain adoption determinants in the halal supply chain was conducted to uncover underlying constructs and potential research gaps. The field interviews were then structured based on quantitative content analysis derived from the literature review (secondary data).

This study examines the key factors influencing blockchain adoption in halal supply chains using the Integrative Model of Blockchain-Supply Chain Acceptance (IMBSA). As depicted in Figure 1, several determinants impact adoption, including top management support, which is essential for strategic vision and resource allocation to mitigate financial and technical constraints. The relative advantage of blockchain lies in its ability to improve efficiency and reduce costs, particularly benefiting large enterprises. However, technology readiness, encompassing infrastructure and skill levels, remains a significant challenge, particularly for SMEs. Security concerns, such as data privacy and threat mitigation, must be addressed to ensure compliance and build trust. Additionally, technology compatibility issues, including system integration and interoperability, create adoption barriers. The complexity of blockchain implementation necessitates extensive user training and technical adaptation, further influencing adoption rates. Vendor support, particularly in terms of technical assistance and service quality, plays a crucial role in successful blockchain integration. A questionnaire was employed to analyze these determinants, providing insights into blockchain adoption within halal supply chains.

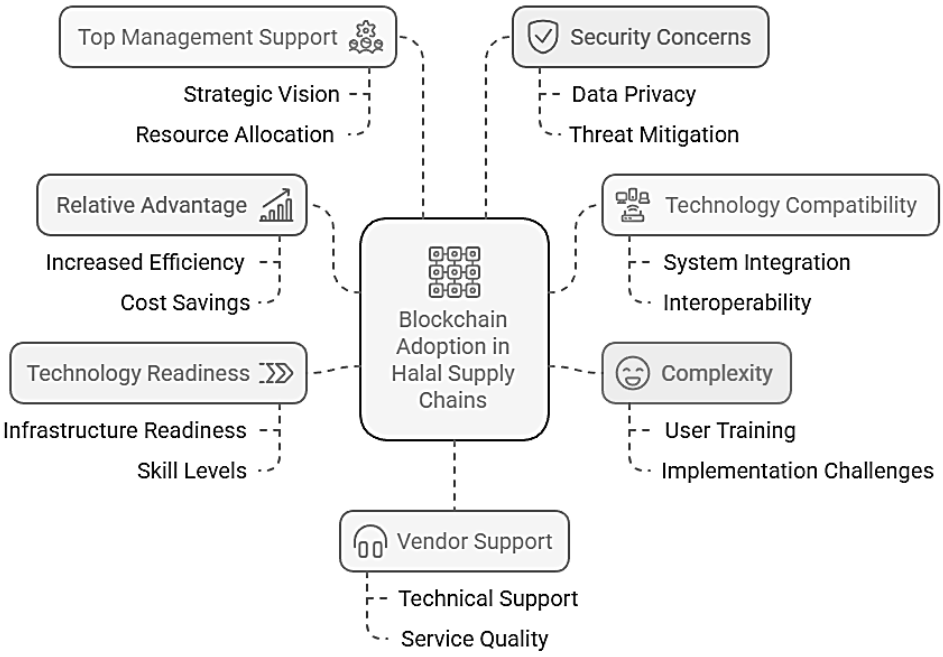

Fig. 1: Determinants of Blockchain Adoption in Halal Supply Chains

3.1 Interview Methodology

This study employed a semi-structured interview approach to gather insights from Halal Integrity personnel across various industries in Malaysia. Participants were randomly selected based on their expertise and involvement in halal supply chain operations, aiming to explore their perspectives on the adoption and practice of blockchain technology within Malaysia's halal supply chains. The interviews sought to assess respondents' awareness, understanding, and the challenges faced by micro, small, and medium enterprises (MSMEs) regarding blockchain implementation.

Key factors influencing blockchain adoption, such as Relative Advantage, Technology Compatibility, Complexity, Technology Readiness, Top Management Support, Security Concerns, and Vendor Support, were explored through open-ended questions. The objective was to identify both enablers and obstacles MSMEs encounter when integrating blockchain technology, thereby providing valuable insights to enhance transparency, efficiency, and halal compliance. Interviews were conducted in person with representatives from companies' halal supply chain departments, including Halal Integrity Managers, Trainers, and Specialists involved in halal certification and compliance. Following data collection, interview transcripts were meticulously coded and analyzed to extract relevant themes and keywords.

According to Sekaran and Bougie (2013), this purposive selection ensures participants possess the specialized knowledge necessary to contribute meaningful information. Respondents were identified during the Malaysia Halal International Showcase (MIHAS) 2023, a significant global platform for halal industry stakeholders. Their insights are crucial for understanding current practices, awareness levels, and challenges related to blockchain adoption within Malaysia's halal supply chain.

4.0 Findings

The present study involved nine halal industry professionals representing micro, small, and medium enterprises (SMEs) in Malaysia, selected for their expertise in blockchain implementation and halal compliance within supply chains. These respondents participated in interviews conducted during the Malaysia Halal International Showcase (MIHAS), a key event within the global halal sector. Their profiles, detailed in Table 1, encompass a range of company sizes, annual incomes, industry sectors, and organizational roles, including Halal Integrity Managers, Compliance Officers, Blockchain Specialists, and Supply Chain Managers, thus providing a comprehensive perspective aligned with the research objectives.

Analysis of interview data yielded seven key determinants influencing blockchain adoption, which are summarized in Table 2 as open codes. These include leadership commitment (TM), perceived relative advantage (RA), technological readiness (TR), security concerns (SC), system compatibility (TC), implementation challenges (CX), and vendor support (VS). These categories establish a framework for understanding factors that facilitate or hinder blockchain integration within halal supply chains.

Table 3 presents an excerpt illustrating the presence or absence of these determinants across selected companies. For instance, Company A demonstrates strong leadership commitment (TM) and prioritizes security (SC) but lacks technological readiness (TR). Conversely, Company B exhibits leadership commitment but neither recognizes significant relative advantages nor technological readiness, suggesting a potential misalignment in blockchain adoption strategy. Company H shows comprehensive engagement with

most determinants except vendor support (VS), indicating advanced blockchain integration but a continued reliance on external technical assistance. Other firms, such as Company D and Company G, acknowledge several critical factors, including leadership, perceived benefits, security, and compatibility, yet face ongoing challenges related to technological readiness and vendor support.

Table 1. Respondent's Profile

Category	Criteria	Company	Industry Focus	Roles of Respondent
Micro	Annual Income <RM300,000 No. Of Employees 1-5	Company A	Halal Processed Foods	Halal Integrity Manager
		Company B	Halal Beverages	Compliance Officer
		Company C	Halal Ingredients	Blockchain Specialist
Small	Annual Income <RM300,000 – RM 15 million No. Of Employees 6 - 75	Company D	Halal Cosmetics	Supply Chain Manager
		Company E	Halal Pharmaceuticals	Halal Trainer
		Company F	Halal Logistics	Technology Manager
Medium	Annual Income RM 15 million – RM 50 million No. Of Employees 76 - 200	Company G	Halal Packaged Goods	Quality Assurance Officer
		Company H	Halal Frozen Foods	Operations Manager
		Company I	Halal Retail	Section Manager

Table 2. Open Codes for Determinants of Blockchain Adoption in Halal Supply Chains

Open Code	Determinants of Blockchain Adoption in Halal Supply Chains
TM	Commitment from leadership commitment through resource provision and strategic direction.
RA	Perceived improvements, such as efficiency gains and cost reductions.
TR	Availability of infrastructure and employee skills for blockchain use.
SC	Measures to ensure data protection and prevent threats.
TC	Seamless integration with existing systems and data-sharing capabilities.
CX	Challenges related to system implementation and user training.
VS	Technical assistance and service quality from technology providers.

Table 3. Excerpt/ Extract of Blockchain Adoption in Halal Supply Chains

Company	Open Code						
	TM	RA	TR	SC	TC	CX	VS
Company A	Y	N	N	Y	N	Ne	N
Company B	Y	N	N	Ne	Ne	N	N
Company C	Y	Y	N	Y	Y	N	N
Company D	Y	Y	Ne	Y	Y	Y	N
Company E	Ne	Y	N	Y	Y	Ne	Ne
Company F	Y	Y	Ne	Y	Ne	Y	N
Company G	Y	Y	Ne	Y	Y	Y	Y
Company H	Y	Y	Y	Y	Y	Y	Ne
Company I	Y	Y	Ne	Y	Y	Y	N

Note: Y- Yes, N- No, N/A – Not Applicable, Ne- Neither

Notably, the most often mentioned issues in the sample were vendor assistance and technological readiness, which were especially noticeable in micro-sized businesses. These smaller businesses' ability to successfully implement and maintain blockchain technologies seems to be hampered by a lack of financial and technical resources, a lack of digital maturity, and difficulty hiring qualified staff.

5.0 Discussion

The findings of this study underscore the pivotal role of leadership commitment (TM) in the successful adoption of blockchain technology within halal supply chains. Consistent with extant literature on technology adoption, firms with engaged and supportive top management are more likely to allocate adequate resources, align organizational strategies, and cultivate a conducive environment for digital innovation. The criticality of leadership is particularly salient given the complex, cross-functional nature of blockchain implementation. Perceived relative advantage (RA) also functions as a significant motivator for adoption. Organizations that recognize blockchain's potential to enhance operational efficiency, reduce costs, and improve traceability demonstrate a higher propensity to invest in this technology. Nevertheless, variation in this perception across firms suggests differing levels of awareness and strategic prioritization, reflecting the heterogeneous nature of the halal industry's digital transformation.

Technological readiness (TR) and security concerns (SC) are identified as both enablers and barriers to blockchain integration. Companies possessing robust IT infrastructure and cybersecurity capabilities are better equipped to implement blockchain solutions effectively. Conversely, firms, especially micro-enterprises, that lack these foundational resources face considerable challenges. This aligns with broader findings in supply chain digitalization research, which emphasize the necessity of technological infrastructure and skilled personnel for successful innovation uptake (Bharadwaj et al., 2021). Vendor support (VS), while recognized as critical for technical assistance and service quality, remains insufficiently addressed by many firms. The absence of reliable and accessible vendor partnerships may impede the effective deployment and sustainability of blockchain initiatives, highlighting an area for improvement within the halal technology ecosystem. Furthermore, system compatibility (TC) and implementation challenges (CX), including user training and integration with legacy systems, represent additional barriers that must be overcome to realize blockchain's full potential. These operational hurdles necessitate comprehensive change management strategies and investments in workforce capacity building.

Micro-sized enterprises face disproportionate difficulties compared to their larger counterparts. Their limited access to capital, digital skills, and infrastructure reduces their ability to adopt emerging technologies, a disparity echoed in the literature on SME innovation (Thoumrungroje & Racela, 2021). Addressing these limitations through targeted policy interventions, capacity-building programs, and industry collaborations could enhance blockchain adoption rates and overall halal supply chain performance. From a policy and managerial perspective, the findings advocate for enhanced support mechanisms, including knowledge-sharing platforms, regulatory incentives, and facilitation of partnerships between SMEs and technology providers. Such measures would alleviate resource constraints and foster an environment conducive to innovation diffusion within the halal industry.

In summary, this study contributes to a deeper understanding of blockchain adoption within halal supply chains by emphasizing the interrelated influence of leadership, technological readiness, data security, and external support. These determinants play a critical role in facilitating or constraining implementation. Future research should investigate the longitudinal effects of blockchain integration and consider broader contextual variables. Effectively addressing these factors will enable stakeholders to leverage blockchain technology to enhance transparency, operational efficiency, and trust across the halal supply chain.

6.0 Conclusion

This study underscores the critical determinants influencing blockchain adoption in halal supply chains, highlighting the pivotal roles of top management commitment, technological readiness, security concerns, and vendor support. The results indicate that while blockchain technology offers numerous advantages, its implementation faces challenges, particularly among micro-sized companies due to resource limitations and digital capability gaps. Addressing these barriers through targeted support, training, and infrastructure development is crucial for widespread adoption. Additionally, fostering collaboration between stakeholders, including government agencies, industry players, and technology providers, can facilitate smoother blockchain integration. Future research should explore innovative strategies to enhance blockchain adoption, ensuring its full potential in improving transparency, efficiency, and trust in halal supply chains.

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Paper Contribution to Related Field of Study

This study contributes to the literature by exploring blockchain adoption in halal supply chains, focusing on Malaysian MSMEs. It identifies key determinants such as leadership commitment, technological readiness, security concerns, and vendor support. The research highlights challenges faced by micro-sized firms, including limited resources and digital capacity. It also underscores the need for stakeholder collaboration, offering a sector-specific perspective that informs future research and policy to support effective blockchain integration.

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