

Blockchain Readiness Model for Halal Logistics: An Empirical Study using PLS-SEM in the Indonesian Logistics Industry

MARHAENI^{1,2}, WAHIDAH BINTI MD SHAH¹, OTHMAN BIN MOHD¹

¹Faculty of Information and Communication Technology,
Universiti Teknikal Melaka Malaysia (UTeM),
Melaka,
MALAYSIA

²Information System,
Institut Sains dan Teknologi Nasional (ISTN),
Jakarta,
INDONESIA

Abstract: - To build trust among the parties involved in the supply chain, in addition to technological readiness, organizational readiness is also needed to maintain halal integrity in the applications of blockchain in halal logistics. This study developed and tested a blockchain readiness model for halal logistics by integrating the Technology-Organization-Environment (TOE) framework with halal readiness dimensions. 230 respondents from logistics service providers and halal warehousing and distribution managers in Indonesia, especially in Jakarta, completed a quantitative survey. The analysis used Partial Least Squares Structural Equation Modeling (PLS-SEM), and the data were processed in SmartPLS4. The result showed that technological readiness and organizational readiness significantly affected halal integrity. Meanwhile, technological readiness, environmental readiness and halal readiness significantly influence trust. In the next stage, halal integrity and trust were found to significant effect blockchain readiness. Trust significantly affect blockchain readiness ($\beta = 0.322$; $p = 0.001$). Findings in the assessment of blockchain readiness in halal logistics are based on technical and organizational readiness, environmental support, capabilities, the ability to integrate elements into logistics activities, and stakeholder trust. An analysis and processing model can expand the TOE framework by adding halal-aspect readiness, with halal integrity and trust outcomes as blockchain readiness factors in halal logistics.

Key-Words: - Blockchain, Halal Logistics, Blockchain Readiness, Technology-Organization-Environment (TOE), Halal Integrity, Trust, PLS-SEM.

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1 Introduction

The increasing demand for halal-certified products is driving growth in the global halal industry, especially in logistics, food, and pharmaceuticals. [1]. A long with these developments, fulfilling halal requirements must be addressed not only at the production stage but also during distribution and later in the supply chain. Therefore, halal logistics is an important part of post-production activities because halal status needs to be maintained during the transportation, storage, and distribution process [2]. In logistics operations involving handling and multiple stakeholders, the risk of contamination, cross-contact, and integrity violations increases significantly. This contrasts with manufacturing [3], [4].

In facing these challenges, blockchain technology emerged as a promising solution for transparency [5], traceability [6], and trust [7] in supply chain activities. . With a decentralized, immutable architecture, it enables secure, real-time data exchange, reduces information asymmetry, and increases accountability. [8], [9]. Despite these advantages, the implementation of blockchain in logistics systems, particularly in halal contexts, remains limited. This limitation is not solely due to technological constraints [10], but also due to insufficient organizational readiness, regulatory alignment, and integration with halal-specific requirements [11], [12].

Existing studies on blockchain in supply chains have predominantly focused on adoption intention,

technological benefits, and implementation challenges [8], [13]. Organizational readiness remains a basic requirement for organizational success, yet it is still limited, especially in industries with sensitive values such as halal logistics [14]. The integration of religious compliance dimensions with technology framework such as technology, organization, and environment (TOE) is often overlooked, leaving a lack of a comprehensive model linking technological readiness, organizational readiness, environmental support, and halal-specific factors. [15], [16].

In addition, the underlying mechanisms through which readiness factors influence blockchain implementation remain underexplored [17]. In particular, the roles of halal integrity and trust as mediating constructs have not been sufficiently examined, despite their critical importance in halal supply chains. Halal integrity reflects the extent to which products maintain their halal status throughout logistics processes, while trust represents stakeholder confidence in both the system and its participants [11], [18]. These constructs are essential in determining whether organizations are truly prepared to adopt blockchain technology in a halal-compliant manner.

To address these gaps, this research proposes a blockchain readiness model for halal logistics by integrating the TOE framework with halal-specific constructs [19]. The model examines the effects of technological, organizational, environmental, and halal readiness on halal integrity and trust, which subsequently influence blockchain readiness [20], [21]. The study emphasizes organizational readiness rather than only the intention to adopt technology. This approach makes the factors that support digital transformation in the halal supply chain clearer. This framework shows that technological, organizational, environmental, and halal readiness is related to halal integrity and trust. These two aspects then help determine readiness to apply blockchain to halal logistics. The conceptual framework of this study is presented in Figure 1.

Based on Figure 1, the conceptual framework illustrates the relationships between technological, organizational, environmental, and halal readiness as exogenous variables, with halal integrity and trust acting as mediating constructs leading to blockchain readiness for halal logistics.

Accordingly, the objectives of this research are threefold: (1) to develop an integrated blockchain readiness model tailored to halal logistics, (2) to examine the influence of technological, organizational, environmental, and halal readiness on halal integrity and trust, and (3) to analyze the

role of these constructs in shaping blockchain readiness. The findings are expected to contribute to both theory and practice by extending the TOE framework and providing empirical insights for stakeholders seeking to implement blockchain in halal logistics systems.

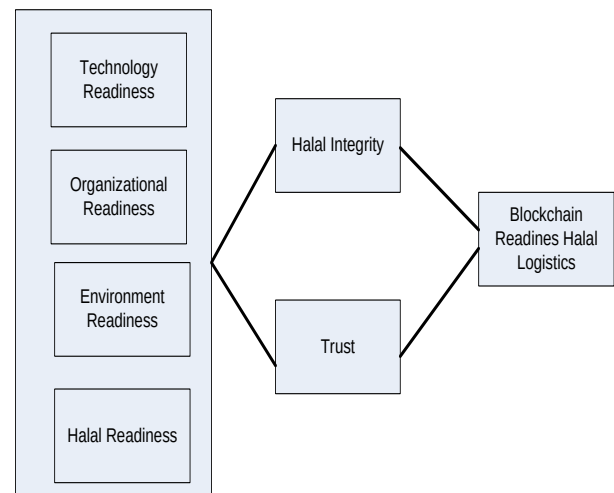


Fig. 1: Conceptual Framework of Blockchain Readiness for Halal Logistics

Source: Created by the authors.

This study makes three primary contributions. First, it extends the Technology Organization Environment (TOE) framework by incorporating halal-specific readiness constructs into blockchain readiness assessment, providing a context-sensitive perspective for halal logistics. Second, this study tested the readiness framework using PLS-SEM based on data from organizations in Indonesia involved in halal logistics.. Third, the model result show that trust has a greater influence than halal integrity on blockchain readiness. In addition, environmental readiness and halal readiness significantly affect trust.

2 Literature Review

2.1 Theoretical Foundation

In organizational innovations, the three contextual dimensions of the TOE framework explain the state of technology, organizational capabilities and environmental pressures [2]. In organizational context, the TOE framework has been widely used to assess organizational readiness and blockchain implementation in the supply chain [8], [14], [19], [22]. Technology implementation must also meet halal-specific requirements, including traceability, separation, documentation, and halal assurance

across the entire logistics operations chain, to fulfil the halal logistics context [23], [24], [25]

Accordingly, the TOE framework is extended in this study by incorporating halal readiness as a context-specific dimension. Halal integrity and trust are positioned as intermediate constructs because blockchain readiness in halal logistics is not determined solely by the availability of technology. Maintaining halal status and building trust among stakeholder depend on the organization's capabilities [9], [11], [18]. In my research, I propose a framework that integrates technological, organizational, environmental, and halal-specific dimensions to explain readiness for blockchain implementation in halal logistics..

2.2 Technological and Organizational Readiness

Supporting blockchain implementation requires technological readiness, including available infrastructure capabilities such as system compatibility, interoperability, technical complexity, and the ability to integrate blockchain in with existing organizational systems [26], [27], [28]. Transparent information exchange, accurate product tracking, and reliable traceability throughout the logistics process can support these technological capabilities [6], [8], [27]. Reliable technology can increase stakeholder confidence in the accuracy and security of the information presented [20], [29]. The hypothesis is proposed as follows:

H1: Technological readiness has a positive effect on halal integrity.

H2: Technological readiness has a positive effect on trust.

Implementing blockchain also requires internal readiness. This depends not only on management support but also on employees' digital capabilities, available resources, and the organization's readiness to integrate the technology into its operations [10], [14], [30]. In halal logistics management support and employee competence enable organizations to consistently execute halal procedures and coordinate the processes associated with their implementation [31], [32]. These internal capabilities are also linked to trust, as blockchain implementation requires an organization that can manage the technology and the accompanying operational processes [33], [34].

Therefore,

H3: Organizational readiness has a positive effect on halal integrity.

H4: Organizational readiness has a positive effect on trust.

2.3 Environmental and Halal Readiness

Blockchain implementation depends not only on an organization's internal conditions. External factors-such as regulatory support, institutional pressure, industry demands, and competitive dynamics-shape environmental readiness [17], [19], [22], [35]. In halal logistics, applicable regulations and standards provide a foundation for organizations to manage compliance in logistics operations. This links to the need for adequate documentation and product traceability to meet halal requirements [23], [36]. Institutional legitimacy may also enhance trust because stakeholders are more likely to accept a blockchain system when its implementation is supported by regulations and recognized industry practices [17], [35].

Therefore:

H5: Environmental readiness has a positive effect on halal integrity.

H6: Environmental readiness has a positive effect on trust.

Halal readiness reflects an organization's capability to integrate halal requirements into logistics activities. Product traceability, implementing halal requirements in operations, and understanding halal principle are part of an organization's halal readiness [11], [25], [32], [37], [38]. This role becomes crucial as products move through various logistics stage, as halal status must be maintained throughout handling, storage, transportation, and distribution. Effective halal traceability and compliance practices may reduce the risk of cross-contamination, improper handling, and information inconsistency, thereby supporting halal integrity [9], [25], [39]. Halal readiness may also strengthen trust by providing assurance that logistics processes are aligned with recognized halal requirements [11], [40].

Therefore,

H7: Halal readiness has a positive effect on halal integrity.

H8: Halal readiness has a positive effect on trust.

2.4 Halal Integrity, Trust and Blockchain Readiness

Blockchain readiness refers to the extent to which an organization is strategically and operationally prepared to implement blockchain technology [17], [29], [33], [41]. In halal logistics, readiness depends not only on technological infrastructure but also on the organization's ability to maintain halal integrity and establish stakeholder confidence.

Halal integrity represents the preservation of halal status throughout the logistics process and provides an operational foundation for blockchain-based traceability and verification [9], [18], [39].

Trust is required when multiple parties use blockchain in a supply chain. This trust include confidence in the technology, the organizations involved, and the logistics information exchange [7], [40], [42]. In the process, each party must exchange and verify information used together to support logistics activities. . Greater trust may reduce uncertainty and strengthen organizational preparedness to implement blockchain [20], [29].

Therefore:

H9: Halal integrity has a positive effect on blockchain readiness.

H10: Trust has a positive effect on blockchain readiness.

3 Methodology

This study uses a quantitative approach through a cross-sectional survey [12], [14]. The research is situated within the positivist paradigm, and it tests hypotheses deductive based on the relationships formulated in the research model [9], [14], [23]. This approach is appropriate as it allows for the empirical examination of relationships among latent constructs within the proposed blockchain readiness model.

Data were collected from 230 respondents involved in logistics operations, warehousing, and halal assurance activities [12]. These respondents were selected due to their direct involvement in halal logistics processes and their familiarity with digital technologies. Respondents were selected using purposive sampling, considering their involvement in and experience with halal logistics activities. Subsequently, respondents who met the criteria helped the researcher connect with other professionals with similar characteristics through snowball sampling. The study used a combination of these two technique because the population was specialized and no complete list of individuals meeting the criteria was available. This study recruited and included 230 respondents in the analysis. This figure exceeded the minimum requirement based on the 10 times rule for the PLS-SEM model tested in this study. The research instrument was developed by adapting measure used in previous studies. Respondents rated each statement on a five-point likert scale, from 1 (strongly disagree) to 5 (strongly agree) [23]. We measured seven constructs are technology readiness,

organizational readiness, environmental readiness, halal readiness, halal integrity, trust and blockchain readiness. The measurement constructs used in this study were adapted from established literature in blockchain adoption, technology readiness, and halal logistics. Each construct was operationalized using multiple indicators measured reflectively. The detailed construct measurement is presented in Table 1 (Appendix).

Data analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4, including measurement model and structural model evaluation [4], [29], [34], [43]. The selection of PLS-SEM is justified by several methodological considerations. First, the research model involves multiple latent constructs and complex relationships. Second, the study emphasizes predictive analysis rather than purely confirmatory testing. Third, PLS-SEM was also selected because it suits non-normally distributed data and moderate sample sizes [9], [25]. The analysis began by examining the measurement model to assess construct validity and reliability. The next stage is to analysis the structure model to examine the relationship between constructs based on the research hypothesis..

This study examined three aspects of the measurement model: internal consistency, convergent validity, and discriminant validity. Internal consistency values above 0.70, assessed using Cronbach's Alpha and Composite Reliability (CR), meet the acceptance criteria, while convergent validity values must exceed 0.50, as assessed using Average Variance Extracted (AVE). . Indicator reliability was confirmed through outer loadings, with values above 0.70 considered satisfactory. Empirical differences between constructs are determined using the Fornell–Larcker criteria and Heterotrait–Monotrait ratio (HTMT) values. For HTMT, we use a threshold of 0.85, indicating that the measured constructs do not overlap. The analysis then focuses on the relationships between constructs in the structural model. We assessed the significance of each relationship through bootstrapping with 5,000 resampling. If the t-value exceeds 1.96 at the 0.05 level the relationship is significant. The model's R^2 indicates how much variation it explains in the endogenous construct, values of 0.25, 0.50, and 0.75 represent weak, moderate, and substantial level, respectively.

Effect size (f^2) was examined to determine the impact of each exogenous construct, while predictive relevance was assessed using the Stone–Geisser Q^2 value through blindfolding procedures.

4 Result

4.1 Measurement Model Evaluation

As shown Table 1 (Appendix), all indicator loadings exceed 0.70. The CR values also exceed 0.70, and the AVE values for each construct are above 0.50, while Cronbach's Alpha meets the criteria for internal consistency. Discriminant validity was further assessed using the Fornell–Larcker criterion and HTMT, with no issues identified. Thus, the measurement model meets the criteria for reliability and validity before proceeding with the structural model analysis.

4.2 Structural Model and Hypothesis Testing

We used bootstrapping with 5,000 resamples to test the relationships between constructs in the structural model. The model obtained R^2 values of 0.326 for Halal Integrity, 0.503 for Trust, and 0.505 for Blockchain Readiness. Based on these values, the model explains 32.6% of the variation in Halal Integrity, 50.3% in Trust, and 50.5% in Blockchain Readiness. Overall, the model's explanatory power is moderate. Table 2 presents the hypothesis-testing results.

Table 2. Structural Model Assessment and Hypothesis Testing

Hypothesis	Structural Path	β	p-value	Decision
H1	TR $\rightarrow$ HI	0.344	0.001	Supported
H2	TR $\rightarrow$ T	0.155	0.037	Supported
H3	OR $\rightarrow$ HI	0.197	0.010	Supported
H4	OR $\rightarrow$ T	0.005	0.937	Not Supported
H5	ER $\rightarrow$ HI	0.066	0.450	Not Supported
H6	ER $\rightarrow$ T	0.353	0.001	Supported
H7	HR $\rightarrow$ HI	0.065	0.498	Not Supported
H8	HR $\rightarrow$ T	0.286	0.001	Supported
H9	HI $\rightarrow$ BCR	0.322	0.001	Supported
H10	T $\rightarrow$ BCR	0.528	0.001	Supported

Source: Created by the authors based on SmartPLS 4 analysis.

The hypothesis testing results indicate that seven of the ten proposed hypotheses are supported, whereas three hypotheses are not supported. Technological readiness significantly influences both halal integrity and trust, indicating that technological capability forms a fundamental basis for blockchain readiness. Organizational readiness significantly affects halal integrity but does not significantly influence trust. Environmental readiness significantly enhances trust but does not have a significant direct effect on halal integrity.

Halal Readiness significantly reinforces trust, although it does not affect halal integrity. Furthermore, halal integrity and trust can significantly and positively affect blockchain readiness, with trust showing the strongest effect ($\beta=0.528$). My findings indicate that blockchain readiness in halal logistics is not shaped solely by technological readiness, organizational, environmental, and halal-specific readiness can also strengthen stakeholder trust.

5 Discussion

These findings show that blockchain readiness in halal logistics is a multidimensional construct influenced by technological, organizational, environmental, and halal-specific readiness. Technological readiness shows a positive, significant relationship with Halal Integrity and Trust. These results align with the TOE framework and indicate that technological conditions-including compatible digital infrastructure and adequate technological capabilities-are linked to traceability, transparency, and information reliability in halal logistics activities [9], [20], [44], [45]. These findings can also be viewed through the lens of the Resource-Based View (RBV), which positions technological capabilities as organizational resources that support operational performance and digital transformation. Conversely, Organizational Readiness shows a significant relationship with Halal Integrity but not with Trust.. Based on these findings, an organization's internal capabilities including top management support and digital competence contribute far more to operational compliance than to stakeholder trust. Conversely, environmental readiness significantly influences trust, but it does not affect halal integrity. Blockchain implementation will proceed smoothly with full support from regulations, institutional legitimacy, and external stakeholder expectations. These findings also align with Institutional Theory, which emphasizes that institutional pressures and regulatory legitimacy strongly shape organizational adoption of new technology [3], [11], [41]. Halal readiness significantly boosts trust but does not directly enhance halal integrity. Its primary function is to strengthen organizational credibility, which in turn can affect operational performance. Organizations with strong halal awareness, integrated compliance, and traceability are more likely to earn stakeholder trust, whereas preserving halal integrity ultimately depends on effective, efficient operational execution. The significant effects of halal integrity and trust on blockchain

readiness further confirm that successful blockchain implementation requires not only operational compliance but also stakeholder confidence, with trust emerging as the strongest determinant of blockchain readiness.

Integrating halal readiness into the TOE framework provides a more appropriate scope for assessing blockchain readiness within the context of halal logistics. The results show that readiness is not solely dependent on technological and organizational conditions; environmental and halal readiness also play a role by fostering trust, and Halal Integrity and trust are, in turn, significantly linked to blockchain readiness. Technological, organizational, environmental, and halal aspects are complementary components in preparing to implement blockchain in halal logistics operations. Blockchain readiness is viewed as an organizational capability rather than merely a matter of technological conditions.. While an organization may possess adequate infrastructure, success ultimately depends on institutional support, organizational readiness, halal compliance capabilities, and stakeholder trust. This perspective broadens the understanding of blockchain readiness by emphasizing the interaction between technological and socio-institutional dimensions in value-sensitive supply chains.

6 Conclusion

This study developed and empirically validated a blockchain readiness framework for halal logistics by integrating the Technology–Organization–Environment (TOE) framework with halal-specific readiness constructs. The findings demonstrate that technological readiness significantly strengthens halal integrity and trust, while organizational readiness primarily supports halal integrity. Environmental readiness and halal readiness contribute significantly to trust, whereas trust and halal integrity both positively influence blockchain readiness, with trust emerging as the strongest determinant.

From a theoretical perspective, this study extends the TOE framework by incorporating halal-specific readiness into blockchain readiness assessment and highlighting the importance of stakeholder trust in value-sensitive supply chains. From a practical perspective, the proposed framework provides guidance for logistics organizations and policymakers in strengthening technological capability, regulatory support, halal compliance, and stakeholder confidence prior to

blockchain implementation. The cross-sectional research design and focus on Indonesia's halal logistics organizations limit this study, potentially affecting the generalizability of the findings. Future research should use a longitudinal design, include additional organizational and institutional variables, and conduct comparative studies across countries or industry sectors to strengthen the validity of the proposed framework. Accordingly, the proposed framework may serve as a practical reference for organizations and policymakers in evaluating organizational preparedness prior to large-scale blockchain implementation within halal logistics ecosystems.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the author(s) utilized artificial intelligence (AI) technologies solely for the purpose of linguistic refinement and grammatical correction. Following the application of these tools, the author(s) comprehensively reviewed, verified, and edited the resulting text. The author(s) maintain full accountability and responsibility for the accuracy, integrity, and final content of the publication.

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- Marhaeni conceptualized the research framework, developed the model, conducted data collection and analysis using PLS-SEM, and prepared the original draft of the manuscript.
- Wahidah contributed to the research design, provided theoretical guidance, supervised the study, and critically reviewed and revised the manuscript for important intellectual content.
- Othman contributed to methodology validation, data interpretation, and manuscript refinement, as well as providing technical and analytical insights throughout the research process.

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APPENDIX

Table 1. Measurement Model Assessment

Construct	Description	Sample Indicators	Source
Technological Readiness (TR)	Capability of blockchain infrastructure	Compatibility, complexity, interoperability	[8], [14], [26] [27], [28]
Organizational Readiness (OR)	Internal organizational support	Management support, digital literacy	[8], [14], [19], [30], [31],
Environmental Readiness (ER)	External pressure and regulation	Regulatory support, market pressure	[2], [8], [19], [20], [22], [35]
Halal Readiness (HR)	Halal compliance capability	Traceability, halal awareness	[11], [23], [25], [32], [37]
Halal Integrity (HI)	Preservation of halal status	Authenticity, compliance	[9], [36], [39], [43]
Trust (T)	Stakeholder confidence	System trust, partner trust	[40], [41], [42]
Blockchain Readiness (BCR)	Overall readiness level	Strategic and operational readiness	[8], [14], [17], [29], [33]

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