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HALAL TRACEABILITY SYSTEM ATTRIBUTES, MUSLIM CONSUMER TRUST, AND PERCEIVED EFFICIENCY: A PLS-SEM STUDY

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Abstract: Halal traceability systems are expected to give Muslim consumers verifiable assurance, yet little is known about how system attributes translate into consumer trust and into how efficient the system feels to use. This study tests the effects of transparency, technology adoption, and operational accuracy on Muslim consumer trust, the effect of trust on perceived efficiency, and the mediating role of trust. Research Methods: A cross-sectional online survey of 150 Muslim consumers in Bone Regency, South Sulawesi, Indonesia, was analyzed with partial least squares structural equation modeling (PLS-SEM) (SmartPLS 4; 5,000 bootstrap resamples). Direct effects and specific indirect effects through trust were estimated. Results and Discussion: Transparency (β = 0.320), technology adoption (β = 0.317), and operational accuracy (β = 0.291) were positively associated with trust, and trust was strongly associated with perceived efficiency (β = 0.796; all p \< 0.001). The indirect effects of the three attributes on perceived efficiency through trust were significant (β = 0.232--0.254, p ≤ 0.001). The model explained 69.4% of the variance in trust and 63.3% of the variance in perceived efficiency. Conclusion: Transparency, technology adoption, and operational accuracy appear to enhance perceived efficiency mainly by building consumer trust. Because direct paths from these attributes to perceived efficiency were not estimated, the type of mediation cannot be determined; because the data are cross-sectional and self-reported, the causal order should also be interpreted with caution.

Keywords: halal traceability, Muslim consumer trust, technology adoption, perceived efficiency, PLS-SEM

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INTRODUCTION

The rapid expansion of the global halal industry has intensified the demand for transparent, reliable, and technology-driven systems that ensure product integrity throughout the supply chain, from raw materials to end consumers (Elwardah et al., 2024). As supply chains become increasingly complex and product origins more diverse, concerns regarding halal authenticity, contamination risks, and certification credibility have become central issues among Muslim consumers. Recent literature indicates that attention to traceability is closely associated with sustainability practices and the integrity of halal supply chains (Agustina & Cakravastia, 2023).

Despite the growing adoption of digital technologies such as blockchain, QR-code verification, the Internet of Things (IoT), and artificial intelligence (AI), questions remain regarding how consumers perceive the characteristics and effectiveness of halal traceability systems (Hema, 2024). Previous studies have examined halal certification, consumer awareness, and technology adoption, but further investigation is needed into the relationships between system transparency, technology adoption, operational accuracy, and Muslim consumer trust (Minu et al., 2025). In particular, the role of consumer trust in explaining perceived halal traceability system efficiency warrants further empirical examination. Consumer-side research on traceability adoption, including Susanty et al. (2025), provides a relevant foundation for understanding consumer responses to traceability systems. Building on this perspective, the present study examines how transparency, technology adoption, and operational accuracy relate to Muslim consumer trust and how trust, in turn, influences perceived halal traceability system efficiency (Azizah, 2021).

Halal traceability systems play an important role in supporting product transparency and consumer confidence in halal assurance. However, the adoption of digital technologies alone does not guarantee that consumers trust these systems or perceive them as efficient. Therefore, it is important to understand how transparency, technology adoption, and operational accuracy shape Muslim consumer trust and how trust relates to perceived halal traceability system efficiency (Adhiwibowo et al., 2025). This study addresses the following research questions: (1) How do transparency, technology adoption, and operational accuracy influence Muslim consumer trust in halal traceability systems? (2) How does Muslim consumer trust influence perceived halal traceability system efficiency? (3) Does Muslim consumer trust mediate the relationships between transparency, technology adoption, operational accuracy, and perceived halal traceability system efficiency?

This study employed a quantitative research design to examine the relationships between halal traceability system attributes, Muslim consumer trust, and perceived halal traceability system efficiency. Data were collected through an online questionnaire distributed to 150 Muslim consumers. A pilot test involving 30 participants was conducted to assess the clarity and reliability of the research instrument (Bujang et al., 2024). The collected data were analyzed using PLS-SEM in SmartPLS 4 to evaluate the

measurement model, test the hypothesized relationships among the constructs, and examine the mediating role of consumer trust. This approach enables an empirical assessment of how transparency, technology adoption, and operational accuracy relate to consumer trust and how trust influences perceived halal traceability system efficiency (Agustina & Cakravastia, 2023).

The study's contributions are threefold: (1) theoretically, it enriches the literature on halal assurance by integrating perceived efficiency into the analysis of consumer trust; (2) methodologically, it combines efficiency perceptions with consumer behavior analysis in an integrated research model; and (3) practically, it provides strategic recommendations for producers, certification bodies, and policymakers regarding technological investments (such as blockchain, IoT, and AI) and process improvements that most effectively enhance system efficiency and consumer trust. Recent studies underscore the significant potential of blockchain and AI to improve transparency and consumer confidence; however, empirical evidence regarding their efficiency and cost-effectiveness remains limited, a gap that the present study seeks to address (Adhiwibowo et al., 2025).

Consumer trust

Consumer trust is an important psychological factor in evaluating products whose authenticity and compliance with religious requirements may not be directly observable. Mayer et al. (1995) conceptualize trust as a willingness to accept vulnerability based on positive expectations regarding another party's intentions or behavior. In the context of halal traceability, consumer trust concerns the extent to which Muslim consumers believe that the information provided about product origin, processing, and halal status is credible and reliable (Nazri et al., 2025). Trust may therefore help reduce uncertainty when consumers cannot independently verify every stage of the supply chain.

The quality and accessibility of traceability information are relevant to this process. The DeLone and McLean (2003) information systems success model identifies information quality as an important dimension in evaluating information systems. Applied to halal traceability, this perspective suggests that accurate, relevant, and understandable product information may support consumer confidence in the information presented. Similarly, the Technology Acceptance Model (TAM) developed by Davis (1989) emphasizes perceived usefulness and perceived ease of use as determinants of technology acceptance. In halal traceability systems, these concepts provide a theoretical basis for understanding why consumers' perceptions of the usefulness and accessibility of digital verification tools may influence their responses to traceability information (Iffat et al., 2024). However, these theories offer complementary perspectives rather than direct evidence of causal relationships in the present study.

Previous research on halal and traceable food systems has also considered the importance of credible product information and consumer confidence (Iffat et al., 2024; Nazri et al., 2025). Building on these theoretical and empirical perspectives, this study examines transparency, technology adoption, and operational accuracy as factors

associated with Muslim consumer trust. It further investigates whether consumer trust positively influences perceived halal traceability system efficiency and mediates the relationships between these system attributes and perceived efficiency.

Information quality as a core mechanism

Information quality is widely conceptualized as a multidimensional construct encompassing accuracy, completeness, timeliness, relevance, and consistency. Within traceability systems, information quality refers to the extent to which data concerning product origin, production processes, and halal verification are accurate, comprehensive, and accessible to consumers and other stakeholders (DeLone & McLean, 2003).

Empirical evidence indicates that high-quality traceability information positively influences perceived value and consumer trust. When traceability information is regarded as reliable, complete, and verifiable, consumers are more likely to accept product claims and develop trust toward both the product and the underlying certification system. Consequently, information quality serves as a foundational mechanism linking traceability system attributes to consumer trust in halal supply chains (Susanty et al., 2025).

Technology acceptance: TAM, technology readiness, and traceability adoption

TAM and its extensions, including Technology Readiness and the Unified Theory of Acceptance and Use of Technology (UTAUT), have been extensively employed to explain users' intentions to adopt digital systems and interfaces that provide traceability information, such as QR code scanning applications and blockchain-based platforms (Bandinelli et al., 2023).

According to TAM, perceived usefulness (PU) and perceived ease of use (PEOU) are influenced by a system's technical features and significantly shape users' adoption intentions. In traceability contexts, technology adoption determines the extent to which consumers are exposed to, and can effectively utilize, traceability information. Recent studies integrating TAM with technology readiness and technology anxiety suggest that while advanced technologies (e.g., blockchain) enhance transparency and data integrity, successful consumer adoption remains contingent upon perceptions of usefulness, usability, and psychological comfort with the technology. Therefore, technology acceptance plays a crucial role in translating traceability system capabilities into meaningful informational and trust-related outcomes (Li et al., 2025).

Drawing on consumer trust theory, information systems success theory, and technology acceptance perspectives, this study proposes that the characteristics of halal traceability systems shape Muslim consumers' trust, which subsequently influences their perceptions of system efficiency. Transparency provides consumers with access to relevant information about halal products, while technology adoption facilitates access to digital traceability information. Operational accuracy, in turn, supports the consistency and reliability of the information provided. These characteristics are expected to strengthen consumer trust. Trust may then encourage consumers to evaluate halal traceability systems more favorably in terms of their perceived efficiency (Susanty et al.,

2025). Accordingly, Muslim consumer trust is proposed as a mediating mechanism linking transparency, technology adoption, and operational accuracy to perceived halal traceability system efficiency.

The following hypotheses are formulated:

H1: Halal traceability system transparency has a positive effect on Muslim consumer trust.

H2: Technology adoption has a positive effect on Muslim consumer trust.

H3: Operational accuracy has a positive effect on Muslim consumer trust.

H4: Muslim consumer trust has a positive effect on perceived halal traceability system efficiency.

H5: Muslim consumer trust mediates the relationship between halal traceability system transparency and perceived halal traceability system efficiency.

H6: Muslim consumer trust mediates the relationship between technology adoption and perceived halal traceability system efficiency.

H7: Muslim consumer trust mediates the relationship between operational accuracy and perceived halal traceability system efficiency.

Accordingly, the proposed conceptual framework positions transparency, technology adoption, and operational accuracy as antecedents of Muslim consumer trust, with trust serving as the mediator linking these system attributes to perceived halal traceability system efficiency.

METHODS

This is a quantitative, explanatory, cross-sectional survey study set in Bone Regency, South Sulawesi, Indonesia. Data were collected between May 2025 and August 2025 with an online questionnaire. Respondents had used or been exposed to digital halal verification features, such as QR-coded product labels and certificate look-up applications. The platforms they reported using were the SIHALAL application, Mbking Syariah, Scan Halal, Halal Cek, and Google. PLS-SEM in SmartPLS (Becker et al., 2023) was used because of its suitability for complex models with latent constructs and its predictive orientation (Hair et al., 2019).

Sampling

Target population and research context

The target population comprised Muslim consumers in Bone Regency, South Sulawesi, Indonesia, who purchase halal products. Data were collected from May to August 2025, using an online questionnaire distributed through Google Forms. A total of 150 completed responses were included in the final dataset. The study examined the relationships between halal traceability system transparency, technology adoption, operational accuracy, Muslim consumer trust, and perceived halal traceability system efficiency. Bone Regency provides the geographical context for examining Muslim consumers' perceptions of halal assurance and traceability. However, purchasing halal products does not necessarily mean that consumers have directly interacted with digital

traceability features. For this reason, the inclusion criteria required prior access to, use of, or exposure to halal traceability features. Because this exposure was self-reported rather than independently verified, the findings are interpreted as reflecting consumers' perceptions of halal traceability systems rather than the verified experiences of users of specific traceability technologies.

Unit of analysis

The unit of analysis is the individual consumer, as perceptions of system efficiency and trust are inherently individual-level constructs.

Sampling technique

Purposive sampling was used to ensure that respondents had relevant prior experience with halal traceability systems (Azzahra et al., 2025). The inclusion criteria were as follows: (1) Muslim consumers aged 29–41 years; (2) had purchased halal-labeled products within the previous six months; (3) had accessed, used, or been exposed to halal traceability features.

This approach was intended to ensure that the sample comprised consumers with meaningful exposure to the phenomenon under study.

Sample size and respondent profile

The sample size for this study was determined with consideration of the statistical requirements of Partial Least Squares Structural Equation Modeling (PLS-SEM) (Hair & Alamer, 2022). Rather than relying on the conventional 10-times rule, which may produce imprecise sample size estimates, the inverse square root method proposed by Kock and Hadaya (2018) provides a more rigorous approach to estimating the minimum sample size required for PLS-SEM. This method considers the minimum path coefficient that the model is expected to detect. The study included 150 Muslim consumers from Bone Regency, South Sulawesi, Indonesia. With the smallest estimated path coefficient of 0.291 (operational accuracy → Muslim consumer trust), a 5% significance level, and 80% statistical power, the inverse square root method requires a minimum of $(2.486/0.291)^2 \approx 73$ observations. The sample of 150 therefore exceeds the minimum required to test the proposed relationships.

The respondent profile covers age, gender, marital status, education level, familiarity with halal traceability systems, and frequency of buying halal-labeled products, providing context for the subsequent analyses.

Table 1. Respondent profile (N = 150)

Characteristic	Category	n	%
Gender	Male	97	64.7
	Female	53	35.3
Age (years)	29–31	81	54.0
	32–34	29	19.3
	35–38	23	15.3

Characteristic	Category	n	%
	39–41	17	11.3
Marital status	Married	95	63.3
	Not married	55	36.7
Education	Elementary school	23	15.3
	Junior high school	33	22.0
	Senior high school	68	45.3
	Diploma (II/III/IV)	8	5.3
	Bachelor's degree	17	11.3
	Master's degree	1	0.7
Familiarity with halal traceability systems	Low	35	23.3
	Moderate	75	50.0
	High	40	26.7
Frequency of buying halal-labeled products	Rarely	20	13.3
	Sometimes	55	36.7
	Often	75	50.0

Data collection

Data were collected using a structured online questionnaire designed according to the study indicators. Online distribution provided broad reach and efficiency and was relevant because halal traceability systems are primarily digital (Lu et al., 2025).

A pilot test involving 30 participants was conducted prior to full-scale deployment to assess clarity, reliability, and potential ambiguity in questionnaire items. Ethical principles such as informed consent, voluntary participation, and anonymity were maintained throughout data collection (Bujang et al., 2024).

The measurement model is expressed as:

$$\text{TRU ST} = \lambda_1 Y_1 + \lambda_2 Y_2 + \cdots + \lambda_n Y_n + \varepsilon$$

All measurement items were adapted from validated prior studies to maintain reliability and validity.

Analytical approach: PLS-SEM using SmartPLS

PLS-SEM was selected for several reasons: (1) it is appropriate for predictive and theory-development studies; (2) it handles non-normal data distribution, common in consumer research; (3) it performs well with moderate sample sizes, including 150 respondents; (4) it is capable of estimating complex models with multiple constructs and indicators; (5) it provides comprehensive evaluations of measurement and structural models.

Data analysis procedures

Data were processed and analyzed using SmartPLS with the following sequential procedure:

Step 1: Model Specification. Latent variables and indicators were defined, and the structural relationships were mapped according to the conceptual framework.

Step 2: Assessment of the Outer Model (Measurement Model). The evaluation included: (1) Convergent Validity (loading factor ≥ 0.70; AVE ≥ 0.50); (2) Discriminant Validity using Fornell–Larcker and HTMT; (3) Reliability Tests using Composite Reliability (CR) and Cronbach's Alpha (≥ 0.70)

Step 3: Assessment of the Inner Model (Structural Model). This stage analyzed: (1) Path coefficients; (2) Coefficient of determination (R^2); (3) Effect size (f^2); (4) Predictive relevance (Q^2); (5) Bootstrapping with 5,000 subsamples for hypothesis testing

Hypotheses were considered supported if:

$$t - value > 1.96 \text{ and } p < 0.05$$

Step 4: Model Interpretation and Enhancement. Significant paths were interpreted according to theory, and non-significant results were discussed in terms of possible improvements to the conceptual or empirical model.

Summary of the method

This methodological design was intended to produce valid, reliable, and theoretically meaningful results. The combination of purposive sampling, structured measurement models, and SmartPLS-based analysis supports a rigorous evaluation of how Muslim consumers perceive the efficiency of halal traceability systems and how system attributes relate to their trust.

RESULT AND DISCUSSION

Table 2. Validity and reliability test results

Variable	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Halal Traceability Systems Transparency (TR)	0.884	0.887	0.928	0.811
Halal Traceability Systems Efficiency(HTSE)	0.899	0.900	0.937	0.832
Muslim Consumer Trust (MCT)	0.867	0.869	0.919	0.791
Operational Accuracy (OA)	0.910	0.911	0.943	0.847
Technology Adoption (TA)	0.894	0.895	0.934	0.825

Source: SmartPLS 4.0 output, processed by the authors (2025)

Table 2 shows strong measurement properties across all constructs**.** Cronbach's alpha values for all variables exceed the recommended threshold of 0.70, indicating high internal consistency, with the highest reliability observed in Operational Accuracy

(0.910) and the lowest in Muslim Consumer Trust (0.867), both categorized as very good. Composite reliability values (ρa and ρc) range from 0.869 to 0.943, demonstrating excellent construct reliability. Additionally, all Average Variance Extracted (AVE) values are well above 0.50, ranging from 0.791 to 0.847, which confirms convergent validity for all five constructs.

Table 3. Outer loadings of measurement indicators

Construct	**Measurement item**	**Outer loading**
Halal Traceability Systems Transparency (TR)	TR1	0.909
	TR2	0.894
	TR3	0.899
Halal Traceability Systems Efficiency (HTSE)	HTSE1	0.922
	HTSE2	0.918
	HTSE3	0.896
Muslim Consumer Trust (MCT)	MCT1	0.839
	MCT2	0.901
	MCT3	0.926
Operational Accuracy (OA)	OA1	0.923
	OA2	0.912
	OA3	0.927
Technology Adoption (TA)	TA1	0.923
	TA2	0.913
	TA3	0.889

Source: Primary data processed using SmartPLS 4 (2025).

Table 3 shows that the outer loading values of all measurement indicators range from 0.839 to 0.927. These values exceed the recommended threshold of 0.70, indicating that all indicators adequately measure their respective constructs. Therefore, all indicators meet the recommended criteria for indicator reliability and can be retained for further analysis.

Table 4. Discriminant validity: Fornell–Larcker criterion and HTMT

Variable	TR	TA	OA	MCT	PE
Transparency (TR)	**0.901**	0.810	0.772	0.851	0.899
Technology adoption (TA)	0.719	**0.908**	0.797	0.856	0.918
Operational accuracy (OA)	0.693	0.719	**0.921**	0.831	0.765
Muslim consumer trust (MCT)	0.747	0.756	0.741	**0.889**	0.899
Perceived efficiency (PE)	0.802	0.824	0.693	0.795	**0.912**

Note. Diagonal (bold) = √AVE; below the diagonal = latent variable correlations (Fornell–Larcker); above the diagonal = HTMT. Bootstrapped upper 95% limits of HTMT range from 0.911 to 0.981.

Discriminant validity is reported in **Table 4.** The square root of AVE for each construct (0.889–0.921) exceeds its correlations with the other constructs (highest 0.824, between technology adoption and perceived efficiency), so the Fornell–Larcker criterion is met. HTMT is the stricter test and the picture is more mixed. Values range from 0.765 to 0.918, and all bootstrapped upper confidence limits are below 1 (maximum 0.981), which supports discriminant validity under the inference criterion (Henseler et al., 2015). Perceived efficiency, however, reaches 0.918 with technology adoption and 0.899 with both transparency and trust, at or just under the conservative 0.90 threshold. It is empirically close to its antecedents, which shapes how the structural results below should be read.

Table 5. Goodness of fit

Fit Index	Saturated Model	Estimated Model
Standardized Root Mean Square Residual (SRMR)	0.051	0.088
d_ULS	0.308	0.932
d_G	0.356	0.483
Chi-square	334.303	399.166
Normed Fit Index (NFI)	0.844	0.814

Source: SmartPLS 4 output, processed by the authors (2025).

Table 5 presents the model fit indices obtained from the PLS-SEM analysis. The SRMR value is 0.051 for the saturated model and 0.088 for the estimated model. Although both values fall below the more lenient threshold of 0.10, the estimated-model SRMR exceeds the more commonly used threshold of 0.08, suggesting that its approximate fit is not unequivocally satisfactory. The NFI values are 0.844 for the saturated model and 0.814 for the estimated model, both below the commonly cited benchmark of 0.90. These results indicate that the model fit evidence is mixed and should not be interpreted as demonstrating uniformly good fit. Furthermore, the d_ULS and d_G values require comparison with their bootstrap-based reference values before conclusions can be drawn.

As global fit indices have a limited role in PLS-SEM, following Hair et al. (2019), these results should be considered alongside the measurement model assessment, the explanatory power (R^2), and the structural path estimates. Accordingly, the model's adequacy should be evaluated using multiple criteria rather than global fit indices alone.

Table 6. Coefficient of determination (R^2 and adjusted R^2)

Endogenous Construct	R-square (R^2)	Adjusted R-square
Halal Traceability Systems Efficiency (HTSE)	0.633	0.631
Muslim Consumer Trust (MCT)	0.694	0.688

Source: SmartPLS 4 output, processed by the authors (2025). Adjusted $R^2 = 1 - (1 - R^2)(n - 1)/(n - k - 1)$, with $n = 150$, $k = 3$ for MCT, and $k = 1$ for HTSE.

Table 6 presents the coefficient of determination (R^2) and adjusted R^2 for the endogenous constructs. Halal Traceability Systems Efficiency (HTSE) has an R^2 value of 0.633, indicating that its predictor variables explain 63.3% of the variance in the construct. Muslim Consumer Trust (MCT) has an R^2 value of 0.694, indicating that its predictor variables explain 69.4% of its variance. These results suggest that the structural model has moderate-to-substantial explanatory power for both endogenous constructs. The adjusted R^2 values (0.688 and 0.631) are only slightly lower than the corresponding R^2 values, indicating that the explanatory power is not inflated by the number of predictors.

Table 7. Direct effects and hypothesis testing

Relationship / Hypothesis	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Halal Traceability Systems Transparency -> Muslim Consumer Trust	0.320	0.313	0.075	4.241	<0.001
Muslim Consumer Trust->Halal Traceability Systems Efficiency	0.796	0.792	0.050	15.854	<0.001
Operational Accuracy ->Muslim Consumer Trust	0.291	0.305	0.076	3.858	<0.001
Technology Adoption ->Muslim Consumer Trust	0.317	0.314	0.084	3.792	<0.001

Source: SmartPLS 4 output, processed by the authors (2025).

Table 7 presents the direct effects estimated in the PLS-SEM model. Transparency has a positive and statistically significant association with Muslim Consumer Trust ($\beta = 0.320$, $t = 4.241$, $p < 0.001$). Operational Accuracy ($\beta = 0.291$, $t = 3.858$, $p < 0.001$) and Technology Adoption ($\beta = 0.317$, $t = 3.792$, $p < 0.001$) also have positive and statistically significant associations with Muslim Consumer Trust. In addition, Muslim Consumer Trust is positively associated with Halal Traceability

Systems Efficiency ($\beta = 0.796$, $t = 15.854$, $p < 0.001$). These findings support H1, H2, H3, and H4. The indirect effects relevant to H5–H7 are reported in Table 8.

Table 8. Indirect effect results

Hypothesis/Relationship	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Halal Traceability Systems Transparency->Halal Traceability Systems Efficiency	0.254	0.248	0.063	4.040	< 0.001
Operational Accuracy->Halal Traceability Systems Efficiency	0.232	0.241	0.061	3.822	< 0.001
Technology Adoption ->Halal Traceability Systems Efficiency	0.252	0.250	0.073	3.473	0.001

Source: SmartPLS 4 output, processed by the authors, 2025

Table 8 reports the indirect effect results. The findings indicate that Halal Traceability Systems Transparency, Operational Accuracy, and Technology Adoption all have significant indirect effects on Halal Traceability Systems Efficiency through Muslim Consumer Trust, as evidenced by positive path coefficients and significant p-values. These results support H5, H6, and H7: Muslim consumer trust mediates the associations of transparency, operational accuracy, and technology adoption with perceived halal traceability system efficiency. Because the direct paths from these attributes to perceived efficiency were not included in the model, the analysis cannot distinguish between full and partial mediation.

Discussion

The results provide empirical support for trust-based and technology acceptance theories in the context of halal traceability systems. The significant positive effect of halal traceability systems transparency on Muslim consumer trust indicates that transparent and accessible information reduces uncertainty and perceived risk, which is particularly critical for halal products that are closely tied to religious compliance. This finding aligns with trust theory, which posits that transparency acts as a key signal of credibility and integrity, thereby strengthening consumer confidence.

Operational accuracy also plays a significant role in shaping Muslim consumer trust. Accurate, consistent, and error-free traceability information enhances system reliability, reinforcing consumers' beliefs that halal claims can be trusted. This result supports information quality theory, which emphasizes accuracy as a central determinant of user trust and continued system usage.

Technology adoption is significantly associated with Muslim consumer trust, suggesting that consumers perceive technologically advanced systems as more reliable and secure. From a Technology Acceptance Model (TAM) perspective, ease of use and perceived usefulness increase users' confidence in system outputs. When advanced technologies such as digital traceability platforms are well adopted, they may enhance trust formation and, indirectly, perceived system efficiency.

Muslim Consumer Trust (MCT) has the strongest direct relationship with Halal Traceability Systems Efficiency (HTSE) ($\beta = 0.796$, $t = 15.854$, $p < 0.001$). Transparency (TR), Operational Accuracy (OA), and Technology Adoption (TA) also have positive and significant relationships with MCT. These findings suggest that consumers' trust is associated with their perceptions of halal traceability systems. Trust may increase when consumers consider the information transparent, accurate, and supported by accessible technology.

These results are consistent with previous studies. Sayogo (2018) found that trust and the credibility of halal product information are important in consumer perceptions of online halal traceability, and Susanty et al. (2025) also identified trust and technology-acceptance factors as relevant to consumers' intentions to use halal food traceability systems. However, these studies examined consumer perceptions and intentions rather than actual operational efficiency. Therefore, the results cannot be directly compared in terms of effect size.

The strong relationship between MCT and HTSE should be interpreted carefully. Because HTSE captures consumers' perceptions, it is best understood as *Perceived Halal Traceability System Efficiency*. The results therefore indicate that greater trust is associated with more favorable perceptions of system efficiency, rather than proving that trust improves actual operational performance. Because the data were collected at one point in time, the study also cannot establish whether trust improves efficiency perceptions or whether perceived efficiency increases trust. Furthermore, the bootstrapped indirect effects (Table 8) indicate that MCT transmits the associations of TR, OA, and TA with HTSE. Because the model does not include direct paths from TR, OA, and TA to HTSE, however, the type of mediation (full or partial) cannot be determined.

This study has several limitations. First, online purposive sampling may limit the representativeness of the respondents. Second, the cross-sectional design and self-reported data prevent firm causal conclusions and may introduce response bias. Third, the data were collected in a single regency (Bone Regency, South Sulawesi), which limits generalization to other regions. Finally, the study did not independently measure operational efficiency using indicators such as processing time, cost, or error rates. Future research should use broader samples, longitudinal data, and objective efficiency measures to strengthen the findings.

Equation

The structural relationships can be expressed as follows:

$$MCT = \beta_1 TR + \beta_2 TA + \beta_3 OA + \zeta_1 \quad (1)$$

$$HTSE = \beta_4 MCT + \zeta_2 \quad (2)$$

Where TR, TA, OA, MCT, and HTSE represent the latent variable scores for transparency, technology adoption, operational accuracy, Muslim consumer trust, and perceived halal traceability system efficiency, respectively. The coefficients β_1–β_4 represent standardized path coefficients, while ζ_1 and ζ_2 denote the residuals of the

endogenous constructs. The equations contain no intercept because the latent variable scores are standardized. The specific indirect effects of TR, TA, and OA on HTSE through MCT are calculated as $\beta_1\beta_4$, $\beta_2\beta_4$, and $\beta_3\beta_4$, respectively. These indirect effects were tested using bootstrapping with 5,000 subsamples (Table 8).

CONCLUSION

This study examined the relationships between transparency, technology adoption, operational accuracy, Muslim consumer trust, and perceived halal traceability system efficiency among 150 Muslim consumers in Bone Regency, Indonesia. Transparency, technology adoption, and operational accuracy had significant positive associations with trust, while trust had a strong positive relationship with perceived efficiency ($\beta = 0.796$). Bootstrapping further showed significant indirect effects of all three attributes on perceived efficiency through trust ($\beta = 0.232–0.254$), supporting the mediating role of trust. Perceived efficiency refers to how easily and quickly consumers believe halal information can be verified, rather than the actual operational efficiency of the supply chain.

For halal certification institutions, including BPJPH and Halal Inspection Bodies (LPH) in Indonesia, the findings highlight the importance of accessible, accurate, and consistent halal information. Clear certification records and simple digital verification tools may help strengthen consumer confidence in halal claims and verification processes.

This study has several limitations. Its cross-sectional design, self-reported data, and purposive sample from one regency limit generalizability and do not establish causality. Because all constructs were measured with the same self-report questionnaire, common method bias cannot be completely excluded. In addition, because the model does not include direct paths from transparency, technology adoption, and operational accuracy to perceived efficiency, the type of mediation (full or partial) cannot be determined. The assumed relationship between trust and perceived efficiency also requires further testing because the reverse direction is plausible. In addition, actual operational efficiency and respondents' direct use of traceability technologies were not independently verified. Future research should examine direct and indirect effects, use objective efficiency measures, and compare findings across regions or countries.

DECLARATIONS

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Conceptualization: A and S; Methodology: A; Software: A; Validation: A, S, N, NHA, AMM, and AMDJR; Formal Analysis: A; Investigation: A; Resources: A and S; Data Curation: A, S, and N; Writing – Original Draft Preparation: A; Writing – Review and Editing: A and N; Visualization: A and S; Supervision: A. All authors have read and approved the final version of the manuscript.

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

Grammarly and ChatGPT were used to assist with translating the manuscript into English, improving sentence structure and wording, and paraphrasing the text for clarity and readability. The authors reviewed and revised the AI-assisted output and take full responsibility for the accuracy, originality, and integrity of the final manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable confidentiality and data-protection requirements.

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Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest that could have influenced the research, its findings, or the preparation of this manuscript.

Ethical Approval and Consent to Participate

This study involved an online survey of Muslim consumers in Bone Regency, South Sulawesi, Indonesia. Participation was voluntary, responses were anonymous, and informed consent was obtained from all respondents before they completed the questionnaire. Formal ethical approval was not obtained from an institutional ethics committee because the study was an anonymous, minimal-risk survey of adult consumers that collected no identifying information.

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