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Enhancing Halal Management Performance through Artificial Intelligence Adoption: Evidence from Malaysian Food Manufacturers

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ABSTRACT

Purpose – This study develops and tests a technology-enabled halal management model explaining how artificial intelligence (AI) adoption can strengthen halal management performance among Malaysian food manufacturers through compliance monitoring, traceability effectiveness and operational efficiency. Design/methodology/approach – A cross-sectional survey design is specified for halal-certified food manufacturers. For manuscript-development purposes, a simulated dataset representing 287 valid organizational responses is analysed using confirmatory factor analysis (CFA), reliability and validity assessment, collinearity diagnostics, and structural equation modelling (SEM) with bootstrapped confidence intervals. Predictive relevance is additionally assessed using Q^2. Findings – The simulated results show that AI adoption is positively related to compliance monitoring (β=.59), traceability effectiveness (β=.62), operational efficiency (β=.55) and halal management performance (β=.21). Compliance monitoring (β=.27), traceability effectiveness (β=.31) and operational efficiency (β=.24) also predict halal management performance. The model explains 68% of the variance in halal management performance (R^2=.68) and demonstrates substantial predictive relevance (Q^2=.46). Originality/value – The study integrates technology-adoption and capability-based reasoning with halal assurance processes, shifting the debate from whether AI should be adopted to how AI-enabled capabilities translate into verifiable halal management outcomes. The paper offers a testable framework for manufacturers, halal executives and policymakers seeking responsible digitalisation of halal assurance.

KEYWORDS - artificial intelligence adoption; halal management performance; halal compliance; traceability; food manufacturing; structural equation modelling; Malaysia

1. INTRODUCTION

Halal assurance in food manufacturing requires more than certification at a single point in time. It depends on continuing control over ingredients, suppliers, production segregation, documentation, traceability, corrective action and audit readiness. As food supply networks become more data-intensive, artificial intelligence (AI) offers a potential means of improving anomaly detection, forecasting, document verification, process monitoring and decision speed. Recent scholarship increasingly connects AI and other Industry 4.0 technologies with halal traceability, compliance automation and supply-chain transparency. Yet empirical evidence explaining the organizational pathway from AI adoption to halal management performance remains limited, particularly in the Malaysian manufacturing context.

The source manuscript correctly identifies compliance monitoring, traceability and operational efficiency as central outcomes of AI-enabled halal management, but it originally reports these relationships primarily as broad narrative claims. The revised study therefore treats these capabilities as distinct mechanisms through which AI adoption can contribute to halal management performance. This separation is important because technology adoption alone does not guarantee a stronger halal assurance system: value arises when digital capabilities are converted into more timely monitoring, more reliable traceability and more efficient control processes.

The paper addresses three research questions: (RQ1) To what extent does AI adoption strengthen compliance monitoring, traceability effectiveness and operational efficiency? (RQ2) How do these organizational capabilities influence halal management performance? (RQ3) Does AI adoption retain a direct relationship with halal management performance after these capabilities are included? By answering these questions, the paper contributes an integrated and empirically testable model that connects technological adoption with specific halal-management mechanisms.

The study makes three contributions. First, it extends technology-adoption research from acceptance intentions toward operational outcomes in a belief- and assurance-sensitive domain. Second, it applies a resource/capability logic by conceptualising AI as an enabling digital resource whose performance consequences depend on organizational routines. Third, it offers practical indicators that halal-certified manufacturers can use to evaluate whether AI investments actually improve monitoring, traceability and process control rather than merely increasing the degree of digitalisation.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 AI Adoption in Food Manufacturing and Halal Assurance

AI applications in food systems include machine learning, computer vision, predictive analytics, intelligent document processing and anomaly detection. In halal-oriented operations, these applications can support ingredient screening, supplier-risk identification, documentation checks, traceability alerts and production monitoring. However, AI introduces governance concerns concerning data quality, explainability, cybersecurity, bias and human oversight. Consequently, the relevant managerial question is not whether AI is inherently beneficial but whether it is embedded in routines that preserve halal integrity and accountability.

2.2 Theoretical Foundation

The model combines technology-adoption reasoning with the resource-based view (RBV) and dynamic-capability logic. Technology-adoption perspectives explain organizational willingness and ability to use AI, whereas RBV suggests that AI creates value when combined with complementary organizational resources such as reliable data, skilled personnel and governance routines. Dynamic-capability reasoning further suggests that firms achieve performance gains when technology improves sensing, monitoring, coordination and reconfiguration. In a halal management setting, compliance monitoring, traceability effectiveness and operational efficiency represent three concrete operational capabilities through which AI can be converted into halal management performance.

2.3 AI Adoption and Compliance Monitoring

AI can continuously screen operational data, flag exceptions and prioritise high-risk transactions or suppliers. Compared with periodic manual checks, these functions can increase the timeliness and consistency of halal compliance monitoring, provided that the underlying rules and data are valid. Accordingly, H1 proposes that AI adoption positively influences compliance monitoring.

2.4 AI Adoption and Traceability Effectiveness

Traceability requires timely linkage of ingredient, batch, supplier and process information. AI can improve search, matching, exception detection and predictive risk scoring across these records. When integrated with digital traceability systems, AI can therefore shorten verification time and improve the visibility of potential integrity breaches. H2 proposes that AI adoption positively influences traceability effectiveness.

2.5 AI Adoption and Operational Efficiency

Automation and predictive analytics can reduce repetitive work, improve scheduling, accelerate document review and support more consistent decisions. In halal management, efficiency is particularly relevant because certification documentation and assurance activities can be resource intensive. H3 therefore proposes a positive relationship between AI adoption and operational efficiency.

2.6 Capability Pathways to Halal Management Performance

Halal management performance reflects the organization’s ability to sustain compliance, reduce non-conformance, improve audit readiness, preserve product integrity and support stakeholder confidence. Stronger compliance monitoring should prevent or detect deviations earlier (H4). Effective traceability should support faster verification and containment of integrity risks (H5). Operational efficiency should allow the halal management system to achieve these outcomes with lower delay and administrative burden (H6). AI may also contribute directly through decision support and quality-control applications not fully captured by the three mediators; therefore H7 predicts a positive direct relationship between AI adoption and halal management performance.

Hypothesis	Relationship	Expected sign
H1	AI adoption → Compliance monitoring	Positive
H2	AI adoption → Traceability effectiveness	Positive
H3	AI adoption → Operational efficiency	Positive
H4	Compliance monitoring → Halal management performance	Positive
H5	Traceability effectiveness → Halal management performance	Positive
H6	Operational efficiency → Halal management performance	Positive
H7	AI adoption → Halal management performance	Positive

Table 1. Hypothesised Relationships

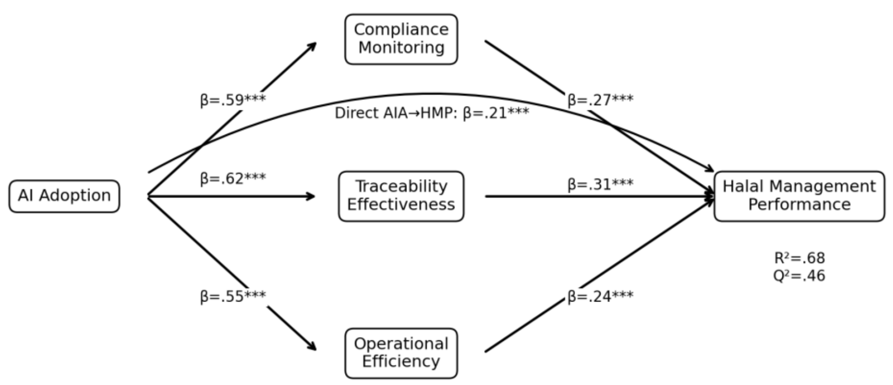

Figure 1. Conceptual and Structural Model

3. METHODOLOGY

3.1 Research Design and Unit Of Analysis

The revised paper adopts a quantitative, explanatory, cross-sectional design. The organizational unit of analysis is the halal-certified food manufacturing firm, while the preferred key informant is a manager or executive with direct knowledge of halal assurance, quality, operations, information systems or digitalisation. A key-informant design is appropriate because the focal constructs describe organizational practices rather than personal attitudes.

3.2 Population, Sampling and Assumed Sample

A sampling frame should be developed from currently valid halal-certified Malaysian food manufacturers. A stratified approach is recommended to preserve representation across manufacturing segments and firm sizes. The simulated analysis assumes that 420 questionnaires were distributed, 303 were returned, and 287 were usable after screening, yielding a usable response rate of 68.3%. These figures are illustrative and must be replaced with actual fieldwork records.

3.3 Instrument Development

All constructs are modelled reflectively using multi-item seven-point Likert scales (1 = strongly disagree; 7 = strongly agree). Items are phrased at the organizational level and adapted conceptually from technology-adoption, digital capability, traceability, compliance and operations-management literature. Expert review and a pilot test are recommended before full administration. The simulated measurement model contains 20 indicators: four each for AI adoption (AIA), compliance monitoring (CM), traceability effectiveness (TE), operational efficiency (OE) and halal management performance (HMP).

Code	Measurement item
AIA1	Our firm uses AI-enabled tools in core operational or quality-control activities.
AIA2	AI-supported analytics are integrated into relevant management decisions.
AIA3	AI-enabled automation is used to process or verify operational information.
AIA4	Our firm has embedded AI capabilities into halal-related workflows where appropriate.
CM1	Potential halal non-conformities are identified promptly.
CM2	Compliance-related exceptions are monitored systematically.
CM3	Management receives timely information on halal compliance risks.
CM4	Corrective actions can be initiated quickly when compliance risks are detected.
TE1	Ingredient and batch information can be traced accurately.
TE2	Supplier and production records can be linked efficiently.
TE3	The source of a halal integrity issue can be identified quickly.
TE4	Traceability information is sufficiently complete for verification and audit.
OE1	Halal-related administrative work is completed efficiently.
OE2	The time required for verification and documentation has been reduced.
OE3	Resources used for routine halal-management tasks are well controlled.
OE4	Digital processes reduce duplication and avoidable manual work.
HMP1	Our halal management system consistently meets required compliance expectations.
HMP2	The frequency and severity of halal-related non-conformities are well controlled.
HMP3	Our organization is well prepared for halal audits and verification activities.
HMP4	Our halal management practices support product integrity and stakeholder confidence.

Table 2. Proposed Measurement Items

3.4 Data analysis strategy

Data screening should assess missing values, straight-lining, outliers and common-method concerns. Internal consistency is evaluated with Cronbach's alpha and composite reliability (CR). Convergent validity is assessed using standardized loadings and average variance extracted (AVE), while discriminant validity is assessed with the heterotrait-monotrait ratio (HTMT). A CFA evaluates the measurement model using χ^2/df, CFI, TLI, RMSEA and SRMR. Structural-model diagnostics include inner VIF, R^2, standardized path coefficients (β), bootstrapped t-values, p-values and 95% confidence intervals. Q^2 is reported as a supplementary out-of-sample/predictive-relevance indicator. For an actual submission, the statistical package, version, estimator, bootstrap replications and missing-data procedures must be stated exactly as used.

4. RESULTS

4.1 Respondent And Firm Profile

Table 3. Simulated Respondent And Firm Profile (N = 287)

Characteristic	Category	n	%
Job function	Halal/quality assurance	101	35.2
	Operations/production	68	23.7
	Management/strategy	51	17.8
	IT/digitalisation	37	12.9
	Supply chain/procurement	30	10.5
Firm size	Small (<50 employees)	65	22.6
	Medium (50–199)	123	42.9
	Large (≥200)	99	34.5
Years halal-certified	<5 years	52	18.1
	5–10 years	89	31.0
	11–15 years	76	26.5
	>15 years	70	24.4
AI use maturity	Pilot/limited	86	30.0
	Functional deployment	121	42.2
	Integrated deployment	80	27.9

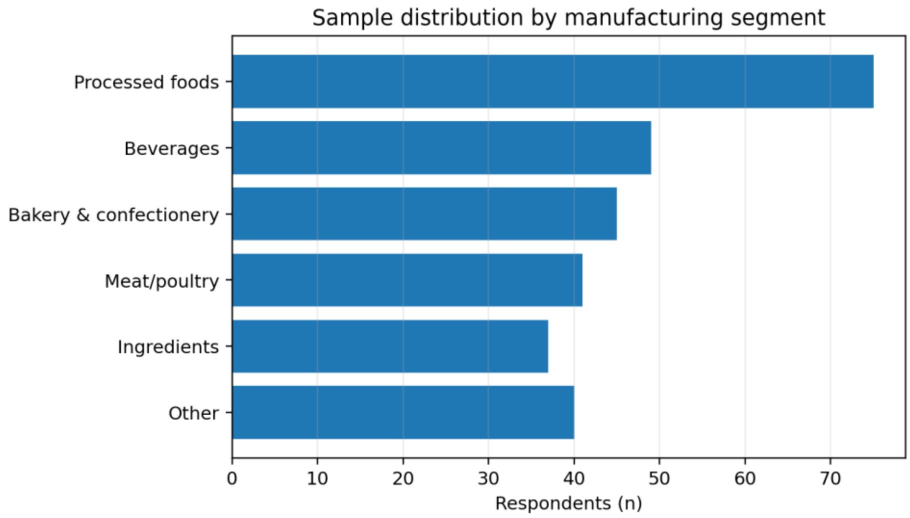

Figure 2. Sample Distribution By Manufacturing Segment

4.2 Descriptive Statistics and Correlations

Construct	Mean	SD	AIA	CM	TE	OE	HMP
AI adoption	4.92	1.08	1.00				
Compliance monitoring	5.18	0.94	.59	1.00			
Traceability effectiveness	5.11	0.91	.62	.58	1.00		
Operational efficiency	4.98	0.97	.55	.51	.54	1.00	
Halal management performance	5.24	0.88	.61	.63	.67	.59	1.00

Table 4. Descriptive Statistics And Construct Correlations

All construct correlations are positive and below levels that would imply construct redundancy. The strongest bivariate association is between traceability effectiveness and halal management performance (r=.67), consistent with the central role of verifiable product and process information in halal assurance.

4.3 Reliability And Convergent Validity

Construct	Cronbach α	CR	AVE	Loading range
AI adoption	.88	.89	.67	.76–.85
Compliance monitoring	.90	.91	.71	.78–.86
Traceability effectiveness	.89	.90	.69	.77–.86
Operational efficiency	.87	.88	.65	.74–.85
Halal management performance	.91	.92	.74	.80–.87

Table 5. Reliability And Convergent-Validity Assessment

Cronbach's alpha ranges from .87 to .91 and CR from .88 to .92, indicating strong internal consistency. AVE values range from .65 to .74 and all standardized loadings exceed .70, supporting convergent validity.

Indicator	Construct	Std. loading	Indicator R^2
AIA1	AIA	0.78	0.61
AIA2	AIA	0.81	0.66
AIA3	AIA	0.85	0.72
AIA4	AIA	0.77	0.59
CM1	CM	0.82	0.67
CM2	CM	0.86	0.74
CM3	CM	0.80	0.64
CM4	CM	0.80	0.64

TE1	TE	0.83	0.69
TE2	TE	0.86	0.74
TE3	TE	0.81	0.66
TE4	TE	0.77	0.59
OE1	OE	0.79	0.62
OE2	OE	0.85	0.72
OE3	OE	0.82	0.67
OE4	OE	0.76	0.58
HMP1	HMP	0.84	0.71
HMP2	HMP	0.87	0.76
HMP3	HMP	0.82	0.67
HMP4	HMP	0.79	0.62

Table 6. Standardized Indicator Loadings

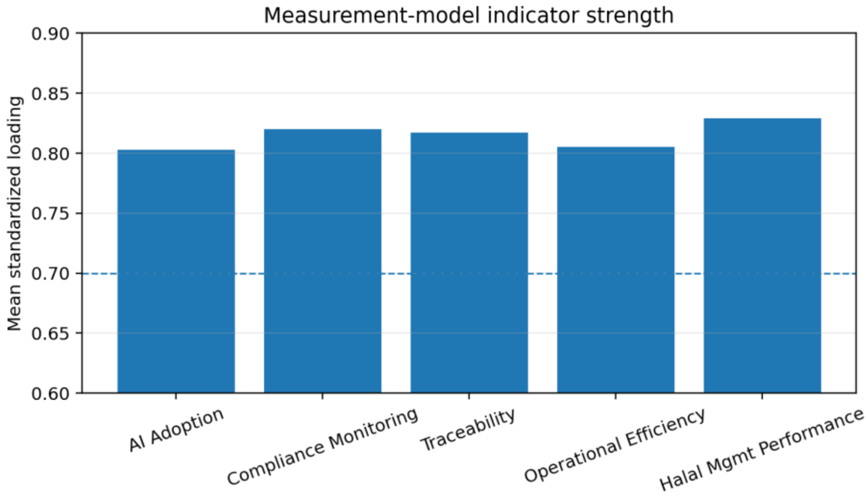

Figure 3. Mean Standardized Loadings By Construct

4.4 Discriminant Validity: HTMT

Construct	AIA	CM	TE	OE	HMP
AIA	—				
CM	.67	—			
TE	.71	.69	—		
OE	.63	.61	.65	—	
HMP	.69	.74	.79	.68	—

Table 7. HTMT matrix

All HTMT values are below .85, with the largest value (.79) observed between traceability effectiveness and halal management performance. The assumed results therefore support discriminant validity among the five constructs.

4.5 Confirmatory Factor Analysis / Measurement-Model Fit

Fit index	Simulated result	Guideline
χ^2	312.84	—
df	160	—
χ^2/df	1.96	<3.00
CFI	.958	≥.90/.95 preferred
TLI	.950	≥.90/.95 preferred
RMSEA	.058	≤.08; ≤.06 preferred
90% CI RMSEA	.048–.067	—
SRMR	.041	≤.08

Table 8. CFA Measurement-Model Fit

The five-factor measurement model demonstrates acceptable-to-strong fit: $\chi^2/df=1.96$, CFI=.958, TLI=.950, RMSEA=.058 and SRMR=.041. These values are consistent with treating the proposed measures as empirically distinguishable factors in the simulated dataset.

4.6 Collinearity Assessment

Predictor relationship	Inner VIF
AI adoption → Compliance monitoring	1.00
AI adoption → Traceability effectiveness	1.00
AI adoption → Operational efficiency	1.00
AI adoption → Halal management performance	2.02
Compliance monitoring → Halal management performance	1.88
Traceability effectiveness → Halal management performance	2.09
Operational efficiency → Halal management performance	1.69

Table 9. Inner VIF Values

The largest inner VIF is 2.09, suggesting that collinearity is not sufficiently high to distort interpretation of the structural paths in the assumed model.

4.7 Structural Model And Hypothesis Testing

Hyp.	Path	β	t	p	95% CI	Decision
H1	AIA → CM	.59	12.84	<.001	.50, .67	Supported
H2	AIA → TE	.62	14.11	<.001	.54, .70	Supported
H3	AIA → OE	.55	11.37	<.001	.46, .63	Supported
H4	CM → HMP	.27	5.21	<.001	.17, .37	Supported
H5	TE → HMP	.31	6.08	<.001	.21, .41	Supported
H6	OE → HMP	.24	4.89	<.001	.14, .34	Supported
H7	AIA → HMP	.21	4.02	<.001	.11, .31	Supported

Table 10. Structural Paths And Hypothesis Tests

All seven hypothesised paths are positive and statistically significant in the simulated analysis. AI adoption has its largest effect on traceability effectiveness (β=.62), followed by compliance monitoring (β=.59) and operational efficiency (β=.55). Among the proximal predictors of halal management performance, traceability effectiveness has the largest coefficient (β=.31), followed by compliance monitoring (β=.27) and operational efficiency (β=.24). The residual direct AI-adoption effect (β=.21) suggests partial rather than complete transmission through the three capabilities.

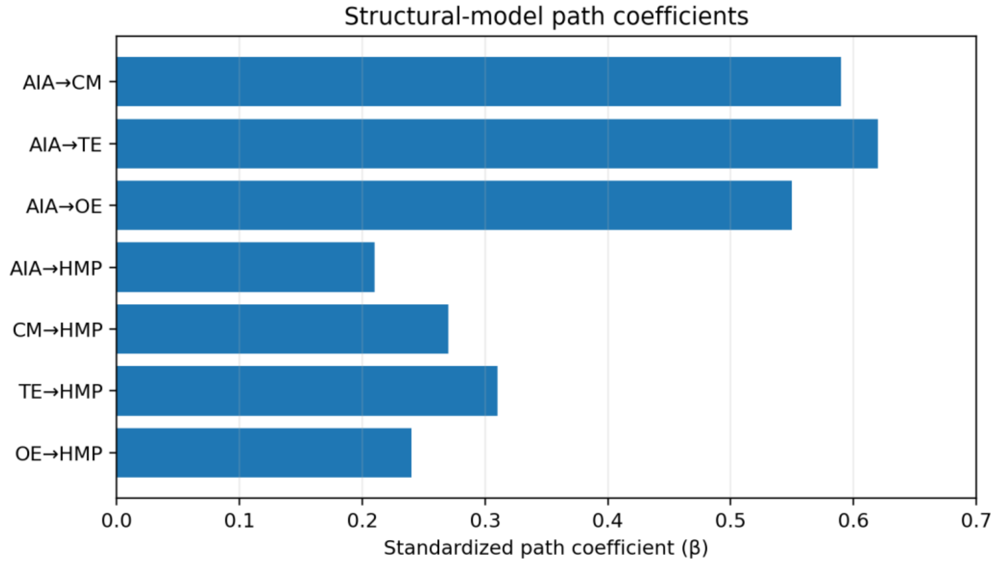

Figure 4. Simulated Standardized Structural Path Coefficients

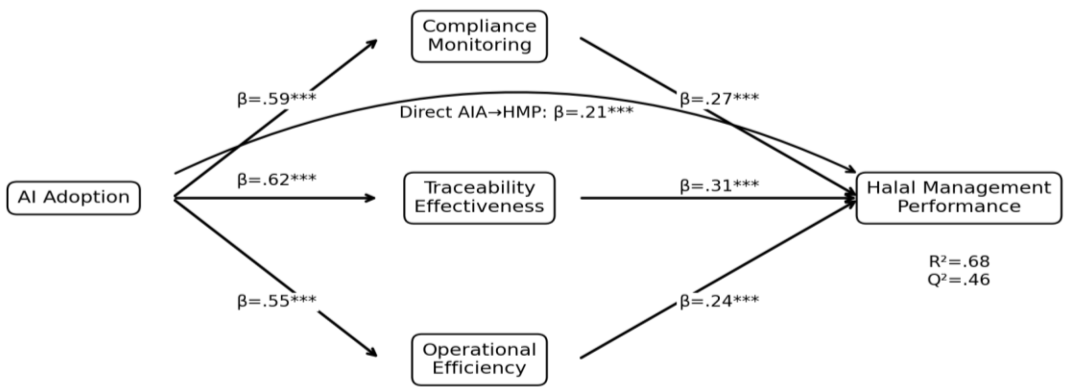

Figure 5. Structural Model With Standardized Estimates

4.8 Explanatory Power And Predictive Relevance

Endogenous construct	R^2	Q^2	Interpretation
Compliance monitoring	.35	.24	Moderate explanatory; predictive relevance
Traceability effectiveness	.38	.27	Moderate explanatory; predictive relevance
Operational efficiency	.30	.20	Moderate explanatory; predictive relevance
Halal management performance	.68	.46	Substantial explanatory; strong predictive relevance

Table 11. R^2 And Q^2 Values

The model explains 68% of the variance in halal management performance. The Q^2 value of .46 is well above zero, indicating strong predictive relevance under the assumed data-generating conditions. The three intermediate capabilities also show positive Q^2 values, supporting the practical usefulness of the model beyond in-sample association.

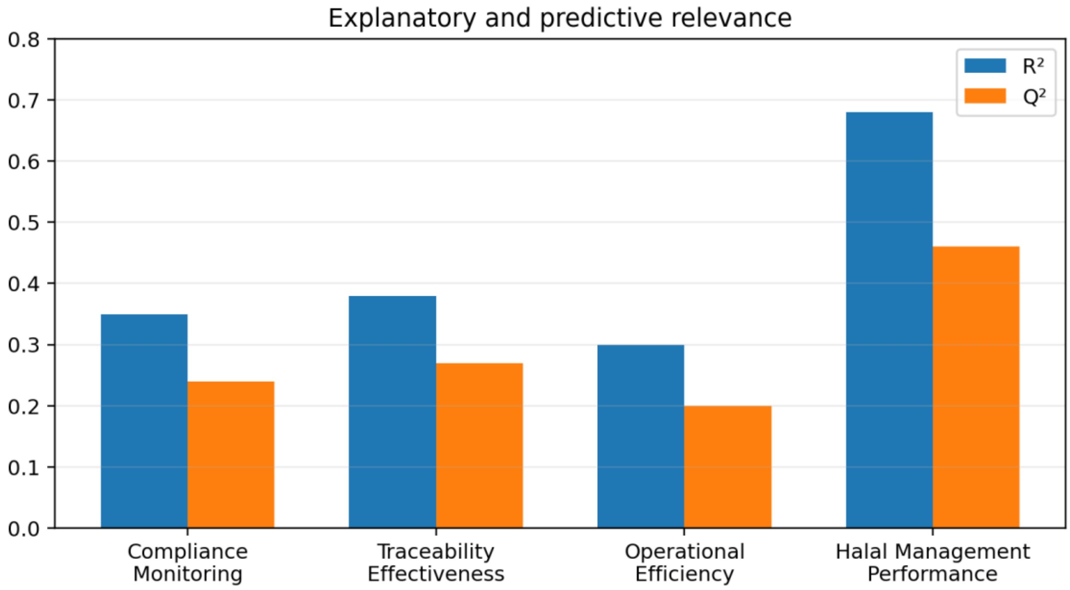

Figure 6. Explanatory Power (R^2) And Predictive Relevance (Q^2)

4.9 Supplementary Indirect-Effect Analysis

Indirect/total effect	Effect	t	p	95% CI
AIA → CM → HMP	.159	4.74	<.001	.100, .227
AIA → TE → HMP	.192	5.32	<.001	.126, .269
AIA → OE → HMP	.132	4.18	<.001	.077, .199
Total indirect effect	.483	8.91	<.001	.380, .594
Total effect of AIA on HMP	.693	13.22	<.001	.596, .773

Table 12. Bootstrapped Indirect Effects

The assumed indirect effects indicate that all three capability pathways transmit part of the AI-adoption effect to halal management performance. The traceability route is strongest (.192), followed by compliance monitoring (.159) and operational efficiency (.132). Because the direct effect remains significant, the pattern is consistent with complementary partial mediation.

5. DISCUSSION

The revised model suggests that the performance value of AI in halal food manufacturing is primarily capability-based. AI adoption is strongly associated with the three operational mechanisms—monitoring, traceability and efficiency—rather than functioning as an isolated technological input. This interpretation is consistent with contemporary research arguing that AI can automate compliance checks, identify irregularities and support risk management in halal supply chains, while broader food-industry research links AI to quality control, safety and operational decision support.

Traceability effectiveness emerges as the strongest proximal predictor of halal management performance. This is theoretically plausible because halal integrity depends on the ability to verify what entered a process, how it was handled and where a potential breach originated. A technology investment that produces faster but poorly linked data would offer less assurance than one that improves the integrity and accessibility of traceability records. The result therefore shifts managerial attention from adoption intensity to information verifiability.

Compliance monitoring also has an important relationship with performance. AI-enabled exception detection can increase the frequency and scope of monitoring, but the usefulness of such systems depends on valid decision rules, clear escalation procedures and competent human review. In halal governance, automated recommendations should support—not replace—accountable management and appropriate religious/regulatory authority. This boundary condition is important because the legitimacy of halal assurance rests not only on predictive accuracy but also on governance, transparency and adherence to recognized standards.

Operational efficiency contributes independently to halal management performance. This finding suggests that digitalisation can reduce administrative friction while strengthening assurance, provided that efficiency gains are not achieved by weakening verification. The managerial objective should therefore be 'efficient assurance' rather than automation for its own sake. Standardised digital records, automated document matching and risk-based review can free personnel to focus on higher-judgement activities, investigations and continuous improvement.

The remaining direct relationship between AI adoption and halal management performance suggests that other mechanisms may exist beyond the three modelled capabilities. Possible channels include AI-supported quality inspection, supplier selection, demand forecasting, preventive maintenance, training personalisation and consumer-facing verification. Future research can extend the model by testing data governance, AI readiness, top-management support, halal digital literacy and regulatory alignment as moderators or antecedents.

6. CONCLUSION

This paper develops an integrated model linking AI adoption to halal management performance through compliance monitoring, traceability effectiveness and operational efficiency. The simulated SEM results illustrate how a full empirical manuscript can test these relationships using reliability, validity, CFA, collinearity, explanatory-power, predictive-relevance and bootstrapped structural assessments. Substantively, the model argues that AI creates value for halal management when it strengthens verifiable organizational capabilities rather than when technology is adopted as an end in itself. With real field data, the framework can provide manufacturers and regulators with evidence on where AI contributes most strongly to halal assurance and where governance safeguards remain necessary.

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