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Accelerating Halal Logistics Certification in Indonesia: A System Dynamics Approach

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Abstract: This study investigates how halal logistics certification in Indonesia can be accelerated using a system dynamics approach to sustainable logistics governance. Certification is conceptualized as a dynamic governance system rather than a static compliance process, addressing persistent challenges such as long lead times, high costs, limited auditor capacity, and uneven service quality. Service quality dimensions of Halal Inspection Body (LPH) were first assessed using SERVQUAL across 77 halal-certified logistics companies, while their relative importance was determined through the Analytic Hierarchy Process (AHP) based on expert judgments. These weighted indicators were then integrated into a system dynamics model, supported by a review of 32 peer-reviewed studies, to simulate policy intervention scenarios. Simulation results indicate that coordinated improvements in auditor capacity, service quality, digitalization, and regulatory coordination primarily drive certification acceleration. Integrated policy-mix interventions generate non-linear performance gains, significantly improve certification lead-time rates and cost rates, while enhancing system stability and stakeholder satisfaction. The study provides policy-relevant insights for regulators and logistics service providers to strengthen sustainable halal logistics governance in Indonesia.

Keywords: Halal Logistics Certification, System Dynamics, Sustainable Logistics Governance, Service Quality, Policy-Mix Intervention

INTRODUCTION

The rapid expansion of the global halal economy has increased the need for reliable and transparent halal logistics systems, extending halal assurance beyond production to transportation, storage, and distribution to protect supply chain integrity (Firmansyah et al., 2025; Noviyanti & Hakim, 2025). Consequently, halal logistics certification has evolved into a strategic institutional mechanism linking regulatory compliance, service quality, and consumer trust. Indonesia, as the world's largest Muslim-majority country, has strengthened halal governance through regulatory reforms and institutional development; however, certification performance remains suboptimal. Key challenges include prolonged lead times, high certification costs, limited auditor capacity, fragmented stakeholder coordination, and uneven

service quality (Harsanto et al., 2024). As illustrated in figure 1, the implementation of mandatory halal certification in October 2024 coincided with a slowdown in certification growth, suggesting that institutional and operational capacities have not yet fully adapted to the new regulatory regime.

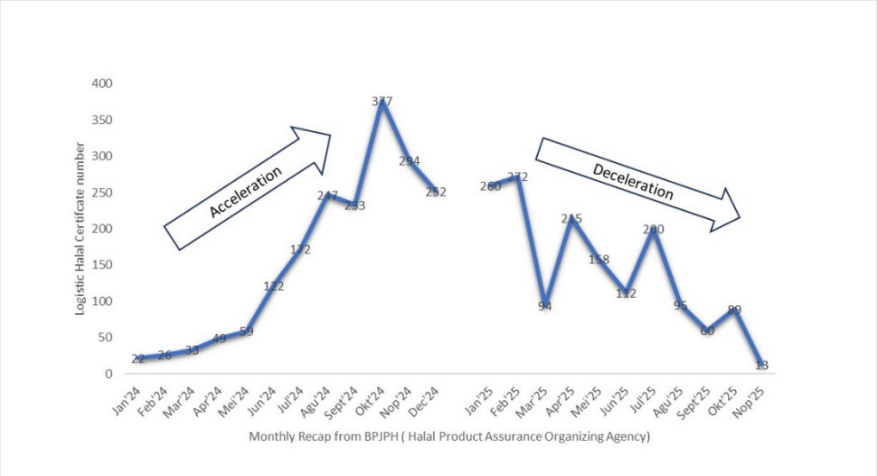

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Figure 1. **Halal Logistics Certification Trend 2024–2025**

From a governance perspective, halal logistics certification is inherently complex, as its performance is shaped by interactions among regulatory design, institutional capacity, service processes, technological readiness, and market demand. While prior studies show that service quality dimensions—such as assurance, reliability, and responsiveness—significantly influence satisfaction and trust in halal certification services (Abd Rahman et al., 2023; Kurniawan & Darmawan, 2024), improvements at the service level alone remain insufficient when institutional constraints and policy misalignment persist. Early halal supply chain research emphasized governance structures, regulatory frameworks, and socio-cultural dynamics (Hewege & Perera, 2020), later incorporating sustainability perspectives (Goga, 2020; Rejeb, Rejeb, & Zailani, 2021) and regulatory harmonization, certification standards, and comparative systems such as halal–kosher standardization and HGMP measurement approaches(Lestari et al., 2023; Shuhaimi et al., 2025).

Recent policy-oriented studies have emphasized community enablement, non-state actors, and digital governance within ASEAN halal ecosystems, reflecting a shift toward participatory and collaborative certification models (Hidayat & Musari, 2023; Nursita et al., 2024; Santoso & Rachman, 2023). Parallel to this governance stream, technological research has advanced digital traceability tools—such as blockchain, smart contracts, Radio Frequency Identification (RFID), and Quick Response (QR)-code systems—to strengthen halal integrity (Ahamed et al., 2024; Novianti et al., 2020; Tan et al., 2022; Tumiwa et al., 2023). At the operational level, scholars have examined logistics performance, contamination risk, and supply chain integration using bibliometric, analytical, and quantitative decision-support approaches, including fuzzy Best–Worst Method (BWM) for risk prioritization in Small and Medium Enterprises (SME) contexts (Abd Rahman et al., 2023; Husna et al., 2024; Karia, 2022; Khan et al., 2021, 2023; Rahardjo, 2023; Sarasi et al., 2025; Ziegler et al., 2022). These studies strengthen governance, technological, and operational perspectives but continue to treat policy, certification, and logistics as analytically separate domains.

Emerging contributions have incorporated ecosystem thinking, financing mechanisms, and advanced analytics into halal supply chain research, highlighting the roles of Research and Development (R&D), innovative financing instruments such as cash waqf-linked sukuk, and regulatory support in strengthening halal value chains (Harsanto et al., 2024; Hasibuan & Lubis,

2024) while qualitative reviews identify persistent barriers to integration, integrity, and sustainability (Aufi et al., 2024; Mulyana et al., 2024; Shariff et al., 2024). Subsequent studies have applied system dynamics and artificial intelligence to authentication, traceability, and performance prediction (Nawaz et al., 2025; Susanty et al., 2024). Nevertheless, much of the literature remains fragmented across governance, technological, and operational perspectives and relies heavily on qualitative, survey-based, or static performance assessments that provide limited insight into dynamic policy–operational interactions. In contrast to these approaches, this study adopts a system-level perspective that integrates certification governance, halal logistics acceleration, LPH service performance, and digital decision-support, modeling feedback loops, time delays, and non-linear dynamics to explain how certification systems evolve under Indonesia's mandatory halal regime (Rejeb, Rejeb, Simske, et al., 2021; Sterman, 2000)

Although previous studies have explored halal governance, technology adoption, and logistics performance, they remain fragmented and do not capture the dynamic policy–operational feedback mechanisms shaping the acceleration of halal logistics certification under Indonesia's mandatory regime. The novelty of this study lies in reframing halal logistics certification as a dynamic institutional ecosystem rather than a collection of separate governance, technological, or operational variables; by modeling policy–operational feedback mechanisms and institutional capacity constraints simultaneously, this research offers a systemic explanation of certification performance and identifies strategic leverage points for acceleration that have not been systematically examined in prior halal logistics studies.

METHOD

This study adopts an integrated mixed-method research design that combines service quality measurement, multi-criteria decision analysis and dynamic simulation to investigate and improve the performance of halal logistics certification in Indonesia. The methodological framework is structured into five main stages :

1. Problem formulation and system scoping.
2. Empirical data collection and service quality assessment.
3. priority weighting using the Analytic Hierarchy Process (AHP).
4. system dynamics model development and validation.
5. policy scenario simulation and analysis.

This design allows the research to capture both the behavioural and structural characteristics of the certification system while producing policy-relevant (Bala et al., 2017; Sterman, 2000).

The study population consisted of 641 halal-certified logistics companies in the JABODETABEK area as of the end of 2024. From this population, 77 companies were selected through purposive sampling, focusing on supervisors, managers, and owners directly involved in the certification process to ensure informed responses for the SERVQUAL analysis. Although representing a subset of the total population, the sample size satisfies the recommended minimum requirement for multivariate analysis based on the 10-times rule—at least ten times the maximum number of structural paths—while meeting statistical power and significance criteria (Hair et al., 2021, 2022). All 22 SERVQUAL indicators were validated as reliable research instruments ($n = 77$), with strong average Pearson correlations for both expectations ($\bar{r} = 0.901$) and perceptions ($\bar{r} = 0.861$), all significant at $p = 0.000$ and exceeding the validity threshold ($r \geq 0.30$). The reliability analysis indicates that the SERVQUAL instrument demonstrates excellent internal consistency, with Cronbach's Alpha values of 0.984 for the perception construct and 0.990 for the expectation construct. These results confirm that all indicators are highly reliable for measuring service quality dimensions within the halal logistics certification context.

For the AHP analysis, five experts with extensive experience in halal logistics certification and LPH services were involved, consistent with AHP methodological guidance that emphasizes expertise quality over large sample size in pairwise comparison judgments. The prioritized dimensions and indicators generated from the SERVQUAL–AHP analysis are integrated into the system dynamics model as additional variables and policy-sensitive parameters, serving as strategic intervention points to simulate improvements in certification performance.

This methodological architecture is particularly appropriate because halal logistics certification constitutes a complex socio-technical system characterised by feedback loops, time delays and interdependencies among regulatory institutions, logistics companies, auditors, service quality mechanisms and market demand. Static analytical approaches are insufficient for capturing such dynamics, making system dynamics modelling essential for policy evaluation and governance design. The complete methodological architecture can be seen in figure 2.

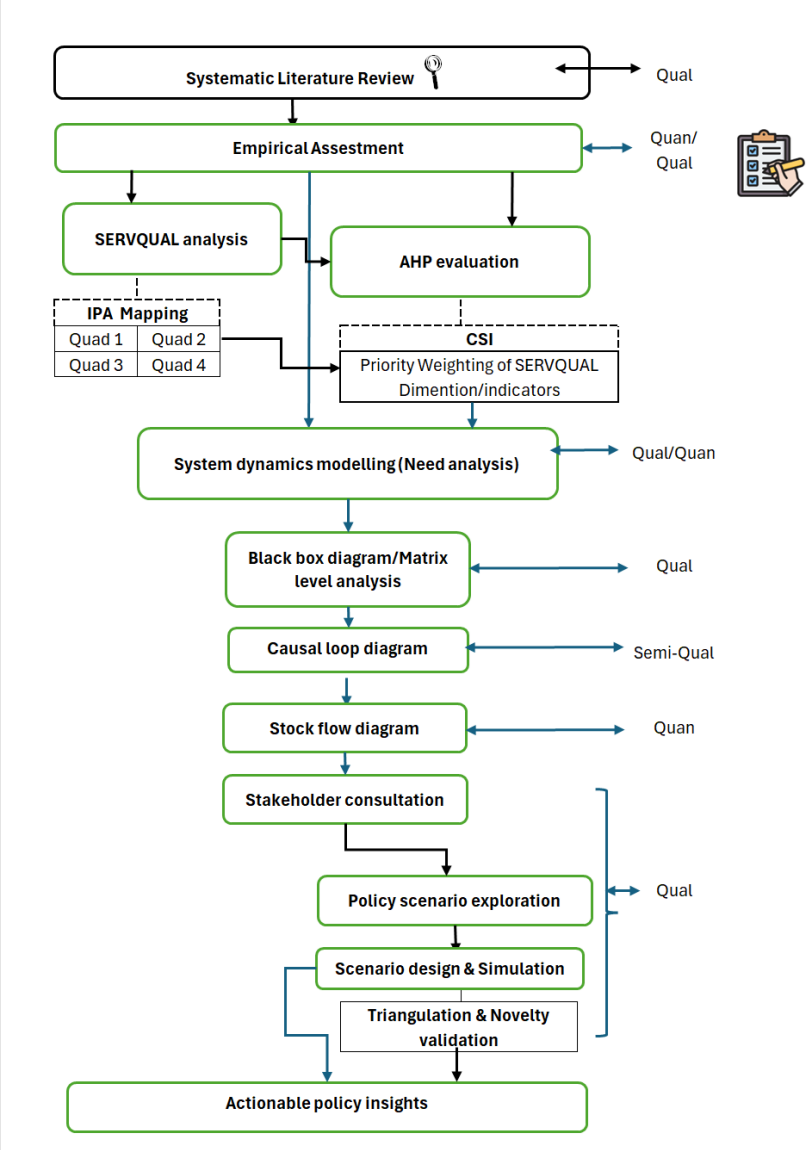

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Figure 2. Multi-stage research design.

RESULTS AND DISCUSSION

The empirical results demonstrate that the performance of halal logistics certification services in Indonesia is influenced by service quality dimensions with varying degrees of

performance gaps. As all SERVQUAL dimensions exhibit negative gaps, indicating that perceived performance consistently falls below expectations. The largest gaps are observed in the tangibles (–0.23), responsiveness (–0.22), and empathy (–0.20) dimensions, followed by reliability (–0.18) and assurance (–0.15). The IPA classification further reveals that several critical indicators, particularly those related to completeness of documents, ease of communication, data security, individual attention, and convenience of service hours, are positioned in Quadrant 1 (Q1), High importance, low performance (HILP), signalling priority areas for improvement. These findings suggest that weaknesses in procedural clarity, auditor-related assurance, and service responsiveness remain key constraints in certification performance, consistent with prior evidence highlighting the role of service reliability and assurance in building trust in halal certification systems (Abd Rahman et al., 2023).

The SERVQUAL results indicate negative gaps across all five dimensions, with an overall gap (SQ = P − E) of -0.19, meaning perceived performance (6.41) slightly falls below expectations (6.22), with the largest gaps observed in Tangibles and Responsiveness. IPA analysis identifies five high-importance–low-performance attributes requiring priority improvement, namely Complete Documents (CD), Data Security (DS), Credibility (CR), Individual Attention (IA), and Convenience of Service Hours (COSH). Attributes categorized as high-importance–high-performance and therefore to be maintained include Precision of Service (POS), Consistency of Promises (COP), Auditor Reliability (AR), Clear Information (CI), Fast Process (FP), Quick Response (QR), Friendly Service (FS), Auditor's Knowledge (AK), Courtesy (CO), Flexibility (F), and Accessibility (A). Meanwhile, Assistive Devices (AD), Customer Empathy (CE), and Neatness of Employees (NOE) fall into the lower-priority quadrant, while Physical Facilities (PF), Availability of Facilities (AOF), and Ease of Communication (EOC) indicate relatively high performance despite lower perceived importance.

Measured using 22 items on a seven-point Likert scale. Dimension scores were calculated through weighted aggregation, and overall service quality was derived from the sum of all dimensions. Based on IPA results, five high-importance–low-performance indicators were prioritized for improvement and eleven high-importance–high-performance indicators were maintained, while the remaining quadrants were excluded.

The SERVQUAL-AHP results shown in Table 1 and Figure 3.

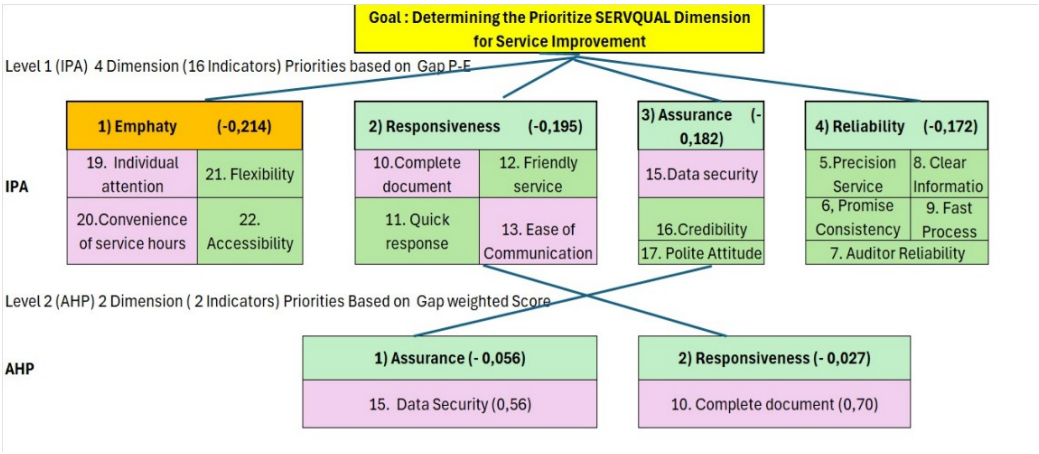
Table 1. AHP Normalised Analytic Hierarchy Process (AHP) weight

Dimension	Weight	Perception	Wi x Pi
TAN	0.18	6.00	1.06
REL	0.23	6.30	1.45
RES	0.14	6.26	0.86
ASS	0.31	6.29	1.93
EMP	0.15	6.24	0.94
		Total	6.23

Source : Research results

Note(s) : Wi = AHP weight of the i-th dimension; Pi = average perception score. For TAN,REL,RES,ASS,EMP see note on table 1.

The normalisation results indicate that assurance dimension with indicator of Data security (DS) (0.56) and Responsiveness with indicator of Complete document (0.70) are the most influential service quality dimensions in halal logistics certification services become priority to be improved . Assurance (-0.056) , and responsiveness (-0.027). This prioritisation pattern is consistent with earlier research emphasising the centrality of trust and responsive halal governance systems.

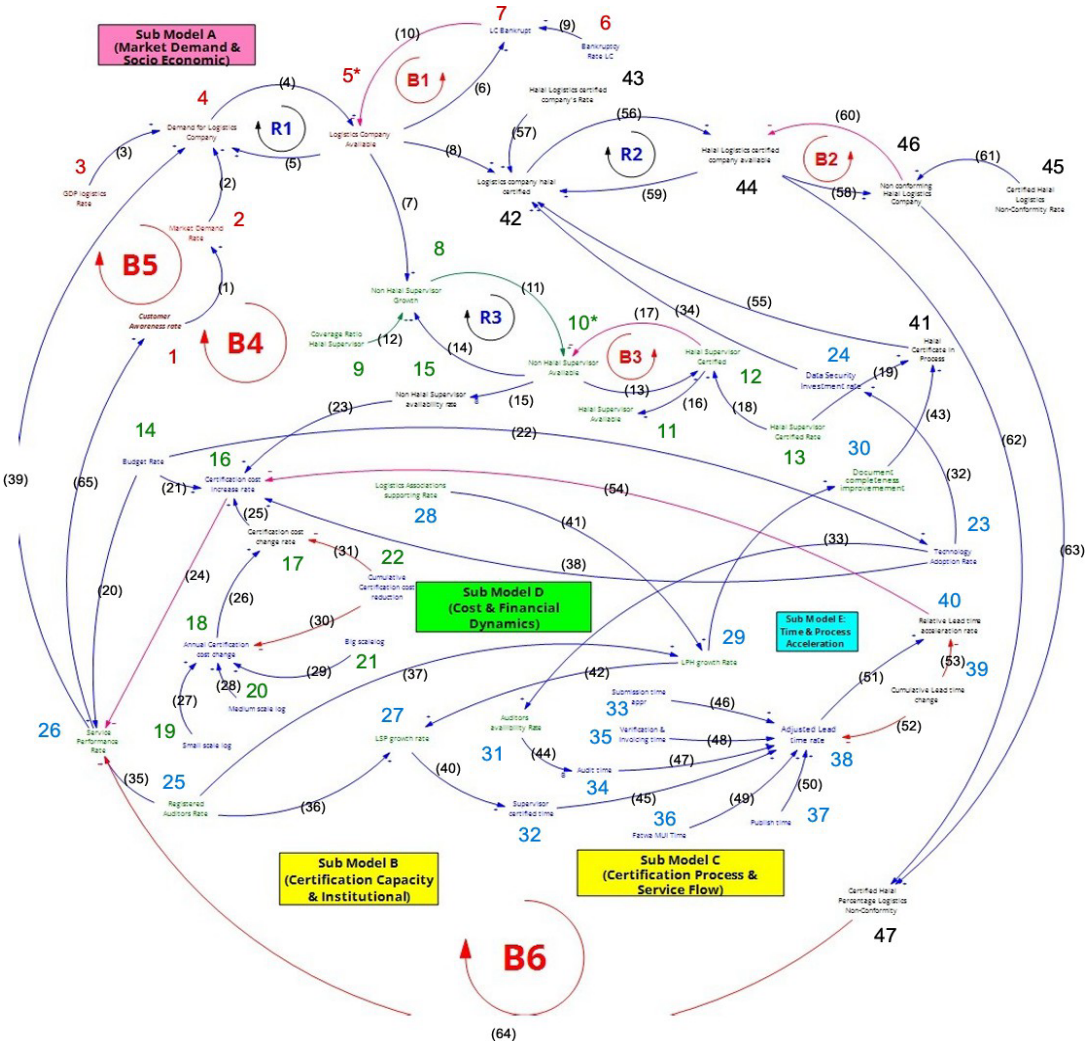


Source : Research results

Figure 3. Priority weighted gap score of SERVQUAL dimension with priority indicator that need improvement

The weighted SERVQUAL score was used as the primary input for calculating the Customer Satisfaction Index (CSI), ensuring that overall satisfaction reflects both perceived service performance and the relative importance of each dimension based on normalized AHP weights. With five SERVQUAL dimensions, the weighted perception score reached 6.23. Referring to the attribute-based customer satisfaction model developed by (Johnson et al., 1995) and operationally explained by (Hill et al., 2007), this value was normalized against the maximum scale (7), resulting in a CSI of 89%, which indicates a high level of customer satisfaction. A CSI of 89% indicates that halal logistics certification services are perceived as highly satisfactory and institutionally credible, suggesting a stable system that requires targeted improvements in priority attributes to sustain performance under increasing regulatory and market pressures.

The causal loop diagram (CLD) of the halal logistics certification system is illustrated in Figure 4, consisting of five interconnected sub-models: (A) Market Demand & Socio-Economy, (B) Certification Capacity, (C) Certification Process & Service Flow, (D) Cost & Financial Dynamics, and (E) Time & Process Acceleration. The system is driven by reinforcing loops, namely R1 (market growth), R2 (capacity–throughput), and R3 (supervisor development), which collectively accelerate certification expansion. However, this growth is constrained by balancing loops including B1 (auditor capacity limits), B2 (non-conforming halal logistics company or compliance risk effects), B3 (supervisor limitations), B4 (cost–accessibility trade-off), B5 (macroeconomic pressure reducing demand), and B6 (service capacity saturation). Certification cost plays a central role in limiting accessibility, while improvements in technology adoption, data security, and document processes reduce lead time and enhance overall certification performance.



Source : Research Results

Figure 4. Causal loop diagram halal logistics acceleration certification

For quantitative Model validation of SFD, the key variables demonstrate strong behavioural consistency with historical certification data, achieving a Mean Absolute Percentage Error (MAPE) below 7%, confirming the reliability of the model for policy analysis (Bala et al., 2017; Sterman, 2000; Wang et al., 2024). The study conducted model testing using historical data from 2022-2024, which refers to two and three years simultaneously, and the reliability was evaluated using the MAPE based on the error between the actual data and the simulated data. When a MAPE of less than 10% indicates a highly accurate prediction, while a MAPE between 10% and 20% indicates a good prediction. The MAPE values were computed using Python-based numerical analysis to accurately evaluate the deviation between actual and simulated data, as recorded on Table 2

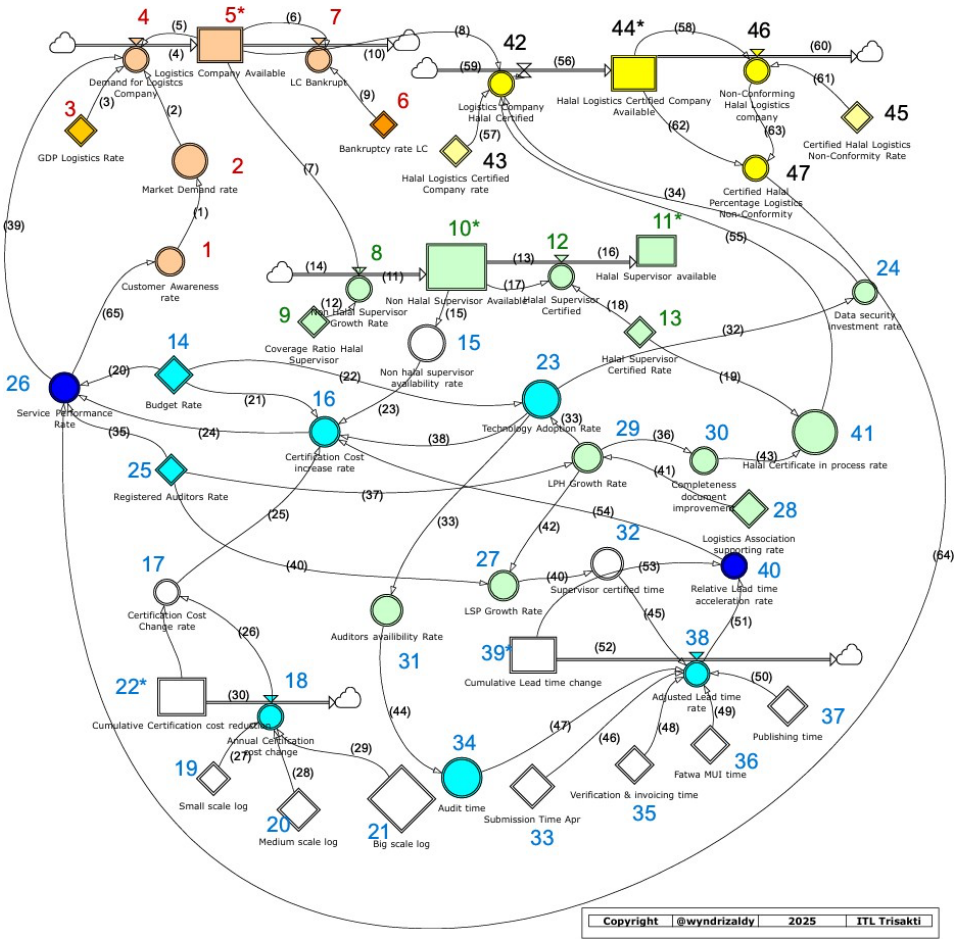
Table 2. Dynamic model validation for 7 key variables using MAPE.

No	Variable	MAPE_% (2022-2024)	Category and Reference
1	Logistics Company Halal Certifiied	4.28	Highly valid/accurate
2	GDP Logistics Rate	1.65	Highly valid / accurate
3	LPH Growth Rate	5.25	Highly valid/ accurate
4	Registered Auditor Rate	0.4	Highly valid / accurate
5	Halal Supervisor Certified Rate	11.72	Acceptable valid/good

6	Cetification Cost Increase rate	0.03	Highly valid/ accurate
7	Lead time acceleration Rate	0.76	Highly valid// accurate
	average	3.44	Highly Valid(accurate

Source : Research results

Based on the MAPE validation requirement, a Stock–Flow Diagram (SFD) was formulated in figure 5 to represent the certification system as a dynamic process in which Logistics Companies Available (LCA) transition into Logistics Companies Certified Available (LCCA) through the certification rate, while attrition (e.g., non conforming halal logistics company/expiry) reduces the certified stock. Certification throughput is regulated by lead time (LT) and lead time acceleration rate (LTAr), which are influenced by certification cost rate (CCR), technology adoption rate (TAR), institutional capacity growth (LPHGr and LSPGr), halal supervisor availability (HSCA), service performance rate (SPr), and policy-mix scenarios (PMS). The simulated trajectory of LCCA from the SFD was then validated against observed certification data using MAPE to ensure that the model structure and parameters provide an empirically acceptable fit before running intervention scenarios.Further the computational structure of the model is represented in figure 5.



Source: Research Results

Figure 5. Stock Flow Diagram of halal logistics certification acceleration

Under existing regulatory and institutional conditions, the baseline simulation shown in figure 6, Comparative simulation results of certification performance across multiple policy scenarios (2024–2029). reveals persistent structural bottlenecks. Certification lead time remains

above 30 days, and cost volatility increases as certification demand grows. The baseline scenario confirms that current policy arrangements are insufficient to generate sustained improvements in certification performance, supporting previous findings on systemic weaknesses in Indonesian halal logistics governance (Abd Rahman et al., 2023; Hasibuan & Lubis, 2024). Simulation of alternative policy interventions yields several important insights. The auditor capacity expansion scenario, illustrated in figure 5, all scenarios are simulated over the period 2024–2029 using a system dynamics framework. Effects of auditor capacity expansion on certification related to lead time acceleration rate.

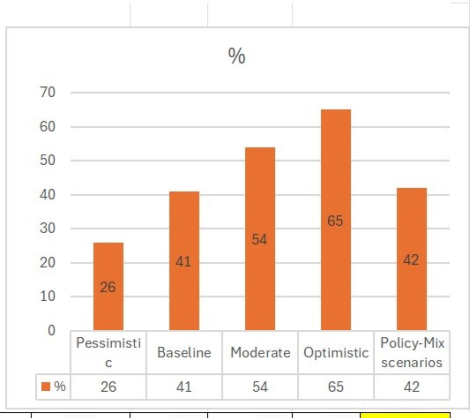
Lead time acceleration rate is introduced to represent process inefficiencies, where lower values indicate improved system performance. Lead time acceleration rate represents the degree of system inefficiency caused by variability in process times, delays, or other operational hindrances. Lower lead time acceleration rates imply greater inefficiency and slower system response, while higher lead time acceleration rates reflect improved efficiency. This concept is supported by studies on lead time variability and its impact on supply chain performance (Mohammed & Mandal, 2024). These results confirm the central role of human capital in regulatory performance (Bala et al., 2017; North, 1990). Among the tested configurations, the hybrid policy-mix scenario emerges as the best-performing and most feasible policy option.

With a baseline lead time of approximately 180 calendar days, smaller firms tend to complete certification slightly faster, while medium and large firms face longer processing times due to greater organizational and audit complexity. Given this heterogeneity, a 30-day target is unrealistic at the system level; thus, 50 days is adopted as a more feasible optimistic benchmark aligned with regulatory and operational constraints. Sensitivity analysis confirms an inverse relationship between the Lead Time acceleration Rate and cumulative lead time reduction, with simulations showing moderate reductions from approximately 103 to 129 days, indicating meaningful but not yet transformative efficiency gains toward the 30-day target.

This consistent pattern of change proves that the model is highly responsive to policy interventions yet remains stable and does not exhibit extreme behaviour. Thus, sensitivity analysis confirms that the model is valid, robust, and reliable as the basis for evaluating halal logistics certification policies. Digitalization and cost efficiency dynamics, produces moderate efficiency gains but limited system stabilisation when implemented independently, corroborating earlier studies that digital tools must be complemented by institutional reform (Rejeb, Rejeb, Simske, et al., 2021; Tseng et al., 2022)

The figure 6. compares incremental acceleration effects and changes in key operational and institutional variables across pessimistic, baseline, moderate, and optimistic scenarios.

Note:
LCA = Logistic company available
LCCA = Logistics company certified available
LTfr = Lead time Acceleration rate
CLTR = Cumulative Lead time Reduction
CCr = Certification cost rate
TAr = Technology adoption rate
LPHGr= Halal inspection body Growth Rate
LSPGr = Professional certification body Growth Rate
HSCA = Halal supervisor certified available
SPr = Service Performance Rate
CDIr = Completeness Document Improvement Rate
DSIr = Data Security Investment rate
% certification = calculate total LCCA: LCA
PMS = Policy-mix scenarios



1	Percent certification from LCA to HLCCA	26%	41%	54%	65%	42%
2	Percent change in LTAr	85%	88%	90%	92%	93%
3	Cumulative Lead time reduction CLTR (day)	103	114	122	129	136
4	Percent change CCC	0,11%	0,30%	0,43%	0,53%	0,30%
3	Percent change in TAr	14,88%	19,83%	24,78%	29,73%	74,83%
6	Ratio change of HSCA: LCCA	12:1	6:1	3:1	2:1	4:1
7	Percent change in SPr	14,77%	19,80%	24,82%	29,83%	24,83%
8	Percent change in CDIr	2,48%	2,48%	2,48%	2,48%	3,73%
9	Percent change in DSIr	1,93%	2,58%	3,22%	3,86%	9,73%

Source: Research Results

Figure 6. Effects of policy mix scenarios on the acceleration of halal logistics certification.

The integrated policy scenario, combining capacity development, service quality enhancement in compleness document through registered auditor and halal supervisor certified rate, the data security investment rate from digitalization or technology adoption rate delivers the strongest performance improvements across all indicators. The multi-scenario comparison of certification outcomes, demonstrating the necessity of coordinated governance strategies. Beyond the numerical improvements observed across scenarios, these results reveal important policy insights. The superior performance of the policy-mix scenario indicates that certification acceleration is driven less by individual policy instruments and more by the interaction between registered auditor rate, halal supervisor certified rate, and technology adoption rate need regulatory coordination. Although the moderate and optimistic scenarios cumulative reduce lead time from baseline 180 days , can be reduced from 103–129 days, the magnitude of reduction remains modest, indicating incremental rather than transformative improvement in certification efficiency, particularly when compared to the formal standard of BPJPH, which generally issues halal certificates within 30–50 working days from initial registration to issuance, depending on document completeness, LPH audit results, and MUI fatwa approval.

The diminishing marginal gains between the moderate and optimistic scenarios further suggest the presence of structural saturation effects, where additional investments yield progressively smaller acceleration benefits. This finding highlights the importance of balanced and coordinated policy design to achieve sustainable improvements in halal logistics certification governance.

The results highlight three central conclusions. First, halal logistics certification performance is fundamentally constrained by institutional capacity rather than procedural design alone. Second, service quality particularly assurance and reliability functions as a strategic governance lever that strengthens trust and voluntary compliance. Third, fragmented policy interventions yield limited impact, whereas integrated strategies generate self-reinforcing improvement trajectories. These findings reinforce sustainability governance theory, which emphasises systemic coordination among regulatory, institutional and market mechanisms as the foundation of long-term transformation. In the context of halal logistics,

certification must therefore be managed not merely as regulatory enforcement, but as a service-based institutional system supporting sustainable transport and logistics development.

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CONCLUSION

This study shows that accelerating halal logistics certification performance in Indonesia requires a system-based governance approach rather than a narrow focus on regulatory compliance. By integrating SERVQUAL, Analytic Hierarchy Process (AHP), and system dynamics modelling, the findings reveal that certification outcomes emerge from dynamic interactions among institutional capacity, service quality, operational processes, and policy coordination. Persistent constraints such as limited auditor capacity, administrative delays, uneven service quality, and fragmented governance cannot be effectively addressed through isolated interventions.

Simulation results indicate that certification acceleration is driven primarily by coordinated policy-mix strategies. Improvements the document completeness through auditor capacity and halal supervisor certified, and data security investment through technology adoption rate generate reinforcing feedback effects that lead time acceleration rate become higher in %, reduce certification costs increase rate, and improve overall system performance. Scenario analysis further demonstrates non-linear dynamics, where integrated interventions outperform baseline and single-policy scenarios, while showing diminishing marginal returns at higher intervention levels. Policy mix-scenarios addresses the excessive lead time by simultaneously strengthening auditor capacity, enhancing digital process efficiency, improving halal supervisor certificate rate , and stabilizing certification costs, thereby structurally cumulative reduction lead time through coordinated policy integration rather than isolated interventions. The cumulative reduction of lead time from simulation is 136 days represents a significant improvement in certification efficiency; however, the magnitude of change remains incremental and has not yet reached a transformative threshold aligned with the 30-day benchmark.

From a governance perspective, halal logistics certification functions as a strategic institutional mechanism linking regulatory enforcement with sustainable logistics development. The proposed framework advances the literature by offering a dynamic, transferable analytical model for certification systems in emerging economies and provides policymakers with an evidence-based tool to support more coordinated and effective halal logistics governance.

This study contributes theoretically by advancing halal logistics research from fragmented governance and operational perspectives toward a dynamic system-based model integrating SERVQUAL, AHP, and system dynamics to explain how certification performance emerges from interacting institutional, service, and policy feedback mechanisms. Practically, the model offers policymakers an evidence-based simulation tool for integrated halal logistics governance.. However, the study is limited by its data scope, which is confined to certified logistics firms in the JABODETABEK area, and by modelling assumptions and parameter calibrations that may simplify broader institutional complexities and constrain the generalizability of simulated lead time reductions to wider national or cross-institutional certification contexts.

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