GIS APPLICATIONS FOR HALAL LOGISTICS COMPLIANCE MONITORING: A CRITICAL REVIEW OF SPATIAL GOVERNANCE FRAMEWORKS

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Abstract:

The rapid expansion of global halal markets has intensified the need for robust logistics systems to safeguard halal integrity across increasingly complex, spatially distributed supply chains. Within this context, Geographical Information Systems (GIS) have emerged as a promising digital enabler for compliance monitoring, traceability, and governance by embedding logistics operations within explicit spatial and temporal frameworks. However, despite growing scholarly interest, the application of GIS in halal logistics remains fragmented, technologically focused, and insufficiently integrated with broader halal governance and regulatory mechanisms. Existing halal logistics practices continue to rely heavily on periodic audits, document-based reporting, and siloed information systems, limiting real-time visibility and proactive risk management. The literature further reveals a lack of a coherent synthesis of how GIS capabilities, such as spatial traceability, geofencing, risk mapping, and decision-support, can be systematically aligned with halal compliance requirements across transportation, warehousing, and distribution stages. This fragmentation highlights a clear research gap at the intersection of geospatial technologies, halal standards, and supply chain governance. Accordingly, this review aims to critically synthesize and evaluate existing studies on GIS applications in halal logistics compliance and monitoring, with particular emphasis on transparency, traceability, and trust as core governance dimensions.

By integrating insights from logistics management, geospatial science, and halal studies, the review consolidates dispersed conceptual discussions into a structured understanding of GIS as a spatial governance enabler rather than a standalone technical tool. The review contributes to the literature by clarifying conceptual linkages, identifying gaps in governance and implementation, and outlining future research directions for spatially enabled halal logistics systems. It concludes that GIS holds significant potential to support evidence-based, continuous, and location-aware compliance monitoring when embedded within coherent institutional and regulatory frameworks. This review is timely and important as halal supply chains undergo digital transformation, offering scholars and policymakers a consolidated foundation for advancing resilient, transparent, and trusted halal logistics governance.

Introduction

Halal logistics plays a critical role in safeguarding the integrity of halal products, particularly food, pharmaceuticals, and cosmetics, by ensuring compliance with Islamic law (Shariah) throughout the entire supply chain, from sourcing and processing to storage, transportation, and final delivery. (Yuan et al., 2009). With the rapid expansion of the global halal market, valued at trillions of dollars annually, halal supply chains have become increasingly complex, involving multi-modal transportation networks, cross-border movements, and diverse regulatory environments. This complexity heightens the risk of non-compliance, cross-contamination, and loss of traceability, especially when halal and non-halal goods coexist within shared logistics infrastructures.

In parallel with these challenges, digital transformation has reshaped supply chain governance, leading to the adoption of data-driven monitoring, transparency, and risk management practices. (Yuan et al., 2009). Among the emerging digital enablers, Geographic Information Systems (GIS) have gained prominence as powerful spatial decision-support tools capable of integrating location-based data with operational, regulatory, and compliance information. GIS enables the real-time tracking of halal goods, spatial visualization of logistics networks, route optimization to minimize contamination risks, and geofencing of halal-certified facilities. Several systematic reviews have examined the applications and implications of GIS in halal logistics compliance and monitoring, particularly in supporting spatial traceability, regulatory oversight, and governance across complex halal supply chain networks **(Table 1).**

These capabilities offer significant potential to strengthen halal assurance systems, enhance regulatory enforcement, and support certification bodies in monitoring compliance beyond static audits. Despite growing interest in GIS-enabled logistics, existing halal logistics practices remain largely fragmented, paper-based, and reactive, with limited adoption of spatial intelligence for continuous compliance monitoring (Khairuddin et al., 2024). Current studies tend to focus on isolated technological applications such as traceability or cold-chain monitoring without systematically examining how GIS can be embedded within halal governance frameworks, regulatory standards, and institutional practices.

Moreover, the alignment between GIS applications and established halal logistics standards (e.g., transportation, warehousing, and retailing requirements) remains underexplored. Against this backdrop, this review paper aims to synthesize and critically examine the current state of GIS applications in halal logistics compliance and monitoring. Specifically, it reviews the existing literature on GIS-enabled tools, regulatory and certification frameworks, implementation challenges, and emerging trends that are shaping spatially enabled halal logistics governance.

Table 1. Summary of Previous Studies on GIS Applications in Halal Logistics Compliance and Monitoring

Study	Focus Area	Key Contributions	Limitations Identified
Arifa'illah Syaiful Huda et al. (Huda et al., 2024a)	GIS dashboard monitors halal certification compliance for Micro, Small, and Medium Enterprises (MSMEs)	GIS integrates halal certification data for real-time monitoring, hotspot analysis, and policy support.	Limited to regional scope; lacks end-to-end logistics coverage, advanced traceability, and standardized compliance frameworks.
Mohamad et al.(Mohamad et al., 2016)	Real-time halal product transportation monitoring using Global Positioning System (GPS) and geofencing.	Introduced Halaltracer for real-time tracking, route monitoring, and cross-contamination detection.	Limited to the transportation stage, with no integration into a complete GIS-based halal supply chain compliance framework.
Muslih et al.(Muslih, Gustian, Somantri, et al., 2025)	GIS-enabled digital halal supply chain management for MSMEs.	Integrated GIS and multivariate analysis to support halal Supply Chain Management (SCM) digitalization and traceability.	Limited to a regional case study; lacks real-time logistics monitoring and full halal compliance integration.
Madanchian et al.(Madanchian & Taherdoost, 2025)	Blockchain for supply chain transparency, traceability, and trust.	Reviewed blockchain roles, metrics, and sectoral applications in data-driven supply chains.	Narrative review with inconsistent metrics and limited long-term empirical evidence.

| Study	Focus Area	Key Contributions	Limitations Identified
Afnarius et al.(Afnarius et al., 2020).	GIS for halal tourism mosque information.	Enabled spatial search and routing via web and mobile GIS.	Limited to tourism use; not applicable to halal logistics or compliance monitoring.

By consolidating dispersed knowledge across logistics, geospatial science, and halal studies, this review seeks to identify research gaps, highlight best practices, and outline future research directions. Ultimately, the paper positions GIS beyond a technical tool, as a strategic enabler of robust, transparent, and resilient halal logistics systems in an increasingly globalized and digital supply chain landscape. (Wan-Chik et al., 2023).

Technological and Conceptual Foundations

GIS Capabilities for Halal Logistics Compliance Monitoring

GIS is a core spatial technology for managing, analyzing, and visualizing location-based data within complex supply chain environments. In halal logistics, where compliance requirements are closely tied to physical locations, movement routes, and segregation practices, GIS offers a structured platform for integrating spatial intelligence into governance and monitoring processes. Unlike conventional information systems that treat logistics data as purely transactional, GIS embeds compliance-relevant information within a spatial context, enabling stakeholders to understand *where*, *when*, and *under what conditions* halal requirements are fulfilled or violated. (L. Wang & Hsu, 2024).

One of the primary capabilities of GIS in halal logistics lies in its ability to enhance spatial traceability across logistics nodes. Transportation routes, warehouses, ports, distribution centers, and retail outlets can be spatially mapped and linked to halal certification status, operational controls, and risk attributes. This spatial integration enables regulators and logistics operators to monitor the movement of halal goods in real-time, thereby ensuring adherence to segregation requirements and minimizing the risk of cross-contamination. For instance, applications such as geofencing further enable automated compliance controls by defining halal-certified zones and triggering alerts when logistics activities deviate from approved spatial boundaries (Mohamad et al., 2016).
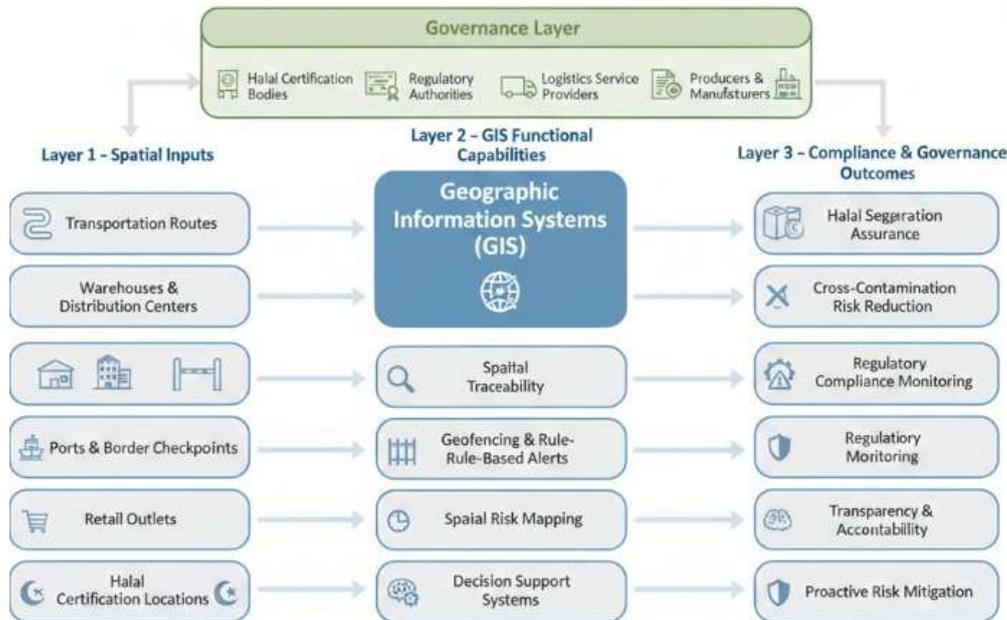
Figure 1: GIS-Based Spatial Governance Framework for Halal Logistics Compliance

Additionally, GIS supports compliance monitoring through spatial risk mapping and decision support. In particular, potential contamination risks, non-certified facilities, congestion points, and high-risk transit corridors can be identified and visualized using layered spatial data analysis. By overlaying halal standards with logistics infrastructure and operational data, GIS enables proactive risk mitigation rather than reactive enforcement. This capability is particularly critical in multi-modal and cross-border halal supply chains, where compliance risks vary across jurisdictions and logistics environments (Imam Arifa'Illah Syaiful Huda et al., 2024). From a governance perspective, GIS functions as a spatial data integration platform that facilitates coordination among multiple stakeholders, including halal certification bodies, regulatory agencies, logistics service providers, and producers. Centralized spatial databases enable standardized data sharing, enhancing transparency and reducing information asymmetry throughout the halal logistics ecosystem. Nevertheless, the effectiveness of GIS-based compliance monitoring depends heavily on data quality, interoperability, and institutional readiness factors that remain unevenly addressed in current halal logistics implementations (Haibo, 2010). **Figure 1** illustrates how GIS integrates spatial inputs, functional capabilities, and governance layers to support halal logistics compliance and risk mitigation.

Functional Linkages to Transparency, Traceability, and Trust

Transparency in halal logistics refers to stakeholders' ability to access accurate, timely, and verifiable information about logistics processes, locations, and compliance status. (Mahadi et al., 2023). In this regard, GIS enhances transparency by transforming complex logistics data into intuitive spatial visualizations, enabling regulators and industry stakeholders to monitor compliance conditions across the supply chain. Spatial dashboards, interactive maps, and real-time tracking interfaces enable decision-makers to identify non-compliance hotspots, remotely audit logistics activities, and communicate compliance status more effectively (Kourouthanassis et al., 2023). Traceability, a foundational requirement of halal logistics governance, is inherently spatial in nature. (Saad & Sri Nor Haslina 2020). Accordingly, GIS

enables end-to-end traceability by linking products to their geographic origins, transit routes, storage locations, and handling points throughout the supply chain. (Rahman & Ali 2024). Note that each logistics event can be recorded with spatial and temporal attributes, creating a continuous location-based audit trail.

This spatial traceability is particularly valuable in halal assurance, as it supports the verification of segregation practices, handling integrity, and compliance continuity across logistics stages (Mohamad et al., 2016). Consequently, trust emerges as an outcome of sustained transparency and traceability within halal logistics systems (Hassan & Osman 2025). GIS contributes to trust-building by reducing reliance on manual reporting and subjective assessments, instead offering evidence-based, spatially verifiable compliance records (Wibowo et al., 2020). Regulators gain greater confidence in their oversight mechanisms, logistics providers can demonstrate their compliance performance objectively, and consumers benefit indirectly from strengthened assurance of halal integrity (Rashid & Bojei 2020). In this sense, GIS functions as a technical tool and an enabler of institutional trust within (Raimi, 2025).

Despite these functional advantages, existing literature reveals several limitations. GIS applications in halal logistics are often implemented in isolation, lacking integration with certification systems, regulatory databases, and complementary digital technologies (Zrelli & Rejeb, 2024). Furthermore, empirical evaluations of GIS-enabled compliance outcomes remain scarce, with many studies focusing on conceptual potential rather than operational effectiveness (Vashishth et al., 2024). These gaps underscore the need for governance-oriented research that examines how GIS capabilities can be systematically integrated into halal logistics compliance frameworks (Saba et al., 2025). **Figure 2** depicts how GIS enhances transparency, end-to-end traceability, and institutional trust in halal logistics through the use of spatial analytics and integrated compliance records.

Figure 2: Integrating GIS for Evidence-Based Transparency and Traceability in Halal Logistics Operations

Theoretical Dimensions of Transparency, Traceability, and Trust

Transparency, traceability, and trust constitute a foundational triad in the governance of modern supply chains, particularly in systems that are highly regulated, value-sensitive, and geographically dispersed, such as halal logistics (Ghalih et al., 2025). These dimensions are not merely operational attributes. However, they represent interconnected governance principles that shape how compliance is monitored, verified, and legitimized across supply chain networks (Arshad et al., 2023). In the context of halal logistics, the integrity of logistics processes, rather than solely product attributes, necessitates governance mechanisms that can capture spatial, temporal, and procedural compliance in an integrated manner (Mahidin et al.m 2019). While digital technologies have enhanced these dimensions in various supply chain contexts, GIS offer a distinctive theoretical contribution by embedding transparency, traceability, and trust within a spatial framework (R. et al., 2013).

Unlike transactional systems that emphasize linear data flows, GIS conceptualizes supply chain governance as a spatially distributed system, where compliance is contingent upon locations, movements, and interactions across logistics nodes (Chen et al., 2023). Thus, understanding how these three dimensions function theoretically within a GIS-enabled halal logistics system is essential for designing effective compliance monitoring and governance frameworks (Nizar et al., 2023). Figure 3 illustrates how GIS functions as a unifying spatial framework that integrates transparency, traceability, and trust to strengthen governance and compliance in modern halal supply chains.

Figure 3. GIS as a Spatial Framework for Strengthening Governance and Trust in Modern Supply Chains

Transparency

Transparency in halal logistics refers to the extent to which stakeholders can access accurate, timely, and verifiable information regarding logistics activities, locations, and compliance status (Fernando et al., 2025). From a theoretical perspective, transparency is closely linked to visibility, the ability to observe logistics processes as they unfold across space and time. GIS enhances transparency by transforming abstract compliance data into spatial representations,

allowing stakeholders to visualize logistics flows, certified zones, and compliance conditions in real-time (Zhen et al., 2010). As a result, spatial transparency enabled by GIS reduces information asymmetry among regulators, logistics providers, certification bodies, and supply chain partners. Through spatial dashboards, interactive maps, and location-based monitoring tools, GIS makes previously opaque logistics operations observable and auditable.

This capability is particularly relevant in halal logistics, where compliance risks such as cross-contamination, improper routing, or unauthorized storage are often spatially contingent and invisible within traditional reporting systems (Khan et al., 2023). Nevertheless, transparency is not without its theoretical tensions. Increased spatial visibility may expose sensitive operational data, raising concerns related to commercial confidentiality, competitive advantage, and data ownership. Therefore, organizations may be reluctant to fully participate in transparent systems, especially when governance arrangements and data protection mechanisms are unclear or uncertain. These disincentives underscore that transparency is not solely a technological outcome, but a negotiated governance construct shaped by institutional trust, regulatory incentives, and organizational readiness (Rizki et al., 2023).

Traceability

Traceability is theoretically defined as the ability to reconstruct the history, application, and location of a product or process throughout its lifecycle within the supply chain. In halal logistics, traceability extends beyond product provenance to encompass the spatial integrity of logistics operations, including transportation routes, handling points, storage locations, and segregation practices (Jasman & Mohd Ariffin, 2021). This expanded notion of traceability aligns closely with GIS, which inherently links events and processes to geographic coordinates and temporal attributes. Consequently, GIS enables spatial traceability by integrating location-based data across multiple logistics stages, creating a continuous spatial audit trail. For example, each logistics event, such as loading, transit, storage, or transfer, can be recorded with spatial and temporal metadata, allowing regulators and auditors to verify compliance continuity across the supply chain. Notably, this spatially explicit traceability is particularly valuable in multi-modal and cross-border halal supply chains, where compliance risks vary across jurisdictions and logistics environments (Sunardi et al., 2024). From a theoretical standpoint, spatial traceability enhances governance by shifting compliance verification from retrospective documentation to proactive monitoring and enforcement. GIS-based traceability enables the early detection of potential non-compliance through spatial anomalies, route deviations, or unauthorized facility usage (Nazri et al., 2025). Nonetheless, the effectiveness of spatial traceability depends on data accuracy, system interoperability, and consistent data-capture practices. Fragmented data sources and inconsistent standards remain critical challenges that limit the realization of end-to-end halal logistics traceability (Alii et al., 2025).

Trust

Trust represents a higher-order outcome emerging from sustained transparency and traceability within supply chain systems. In halal logistics governance, trust operates across multiple dimensions, including trust in data, trust in actors, and trust in regulatory processes (N. Saad et al., 2016). Specifically, GIS contributes to trust-building by providing spatially verifiable evidence of compliance, reducing reliance on subjective assessments and manual reporting (W. et al., 2020). Trust in data is strengthened when compliance information is grounded in

objective spatial records rather than declarative statements. For instance, GIS-enabled monitoring systems allow stakeholders to validate claims regarding halal compliance through location-based evidence, enhancing confidence in the integrity of logistics operations (Sabar et al.,2025). Trust in actors such as logistics providers and certification bodies is similarly reinforced when compliance performance can be independently observed and audited within a shared spatial framework (Chen et al., 2004). However, trust is not purely a technological construct. Theoretical perspectives emphasize that trust is socially embedded and shaped by institutional arrangements, cultural contexts, and governance norms. While GIS can enhance calculative trust through data-driven verification, relational and institutional trust depend on how spatial systems are governed, who controls access to data, and how accountability mechanisms are enforced. Without clear governance frameworks, spatial technologies may inadvertently shift power imbalances or generate new forms of distrust (Jones, 2003).

Integrating Transparency, Traceability, and Trust through Spatial Governance

The theoretical integration of transparency, traceability, and trust underscores the importance of spatial governance in halal logistics systems. GIS serves as an enabling infrastructure that connects these dimensions by integrating, visualizing, and analyzing location-based data. Rather than treating transparency, traceability, and trust as isolated objectives, spatial governance frameworks conceptualize them as mutually reinforcing pillars of halal logistics compliance (Huda et al., 2024). In this regard, this perspective underscores the need to shift from technology-centric implementations to governance-oriented designs that align spatial data capabilities with regulatory requirements, institutional roles, and stakeholder expectations. By situating GIS within a broader halal governance framework, spatially enabled systems can support more robust, accountable, and trusted compliance monitoring mechanisms across halal logistics networks (Yakubu et al., 2025).

GIS Capabilities in Halal Logistics Compliance and Monitoring

The increasing reliance on spatially distributed logistics networks has elevated the importance of location-based data operations in ensuring halal compliance. Unlike transactional technologies that primarily record events, GIS enables the integration, validation, and analysis of spatial data across halal logistics operations (Šidlauskas et al., 2009). By embedding compliance-relevant information within geographic and temporal contexts, GIS directly supports data-driven monitoring, regulatory oversight, and coordinated governance across halal supply chains. In this context, this section critically examines key GIS capabilities in halal logistics data operations, focusing on data integrity, access control, automation, system integration, and stakeholder collaboration (Muslih, Gustian, & Hasman, 2025). **Figure 4** illustrates how core GIS capabilities integrate spatial data, enable data-driven monitoring, and enhance coordinated governance across the halal logistics supply chain.

Spatial Data Integrity and Validation

Data integrity is a fundamental requirement for halal logistics compliance, as regulatory decisions and certification outcomes depend on the accuracy and reliability of logistics data (Ahmad et al.,2022). Traditional supply chain systems often suffer from fragmented data sources, manual data entry, and inconsistent reporting practices, which undermine confidence in compliance records. Therefore, GIS addresses these challenges by providing structured

mechanisms for spatial data validation and consistency checking across multiple data layers (Mr. Ajay Bhimrao Thorat, 2024).

Through spatial referencing and geocoding, GIS ensures that logistics events, such as transportation movements, storage activities, and handling operations, are accurately linked to verified locations (Yao, 2020). Spatial validation rules can be applied to detect anomalies, such as unauthorized route deviations, the use of non-certified facilities, or inconsistencies between declared and actual logistics locations (Metvaei et al., 2025). This capability is particularly critical in halal logistics, where compliance is location-sensitive, and violations often arise from spatial misalignments rather than product attributes alone (Khairuddin et al., 2018). Moreover, GIS enables cross-validation of data by integrating multiple spatial data sources, including logistics tracking systems, certification databases, and regulatory records (Wang et al., 2023). By serving as a spatial "single source of truth," GIS enhances the credibility of compliance data while reducing reliance on subjective reporting (Cota-Rivera, 2025). Nevertheless, the effectiveness of spatial data integrity mechanisms remains contingent upon data quality standards, institutional coordination, and continuous data updating, areas that are currently unevenly addressed in halal logistics systems (Shamsudin & Majid 2022).

Location-Based Identity and Access Control

Access to halal logistics data must strike a balance between transparency and confidentiality, particularly when sensitive commercial or regulatory information is involved. Specifically, GIS supports location-based identity and access control by regulating who can view, edit, or analyze spatial data based on user roles, institutional mandates, and geographic jurisdictions. (Bertino & Kirkpatrick 2011). Through role-based and location-aware access mechanisms, GIS platforms can restrict sensitive data, such as audit findings, non-compliant locations, or proprietary logistics routes, to authorized stakeholders (Hansen & Oleshchuk, 2006). For example, regulators may be granted complete spatial oversight, certification bodies may have limited access to verification, and logistics may have operational-level visibility for operators (Hebbar, 2023). This spatial differentiation of access enhances governance by aligning data availability with accountability responsibilities (Nai et al., 2025). From a conceptual perspective, location-based access control reinforces institutional trust by ensuring that compliance data is neither overexposed nor selectively concealed. Nonetheless, the literature highlights persistent challenges related to interoperability between GIS platforms and existing halal certification systems, as well as the lack of standardized data governance frameworks that define ownership, custodianship, and access rights to spatial halal logistics data (Nai et al., 2025)
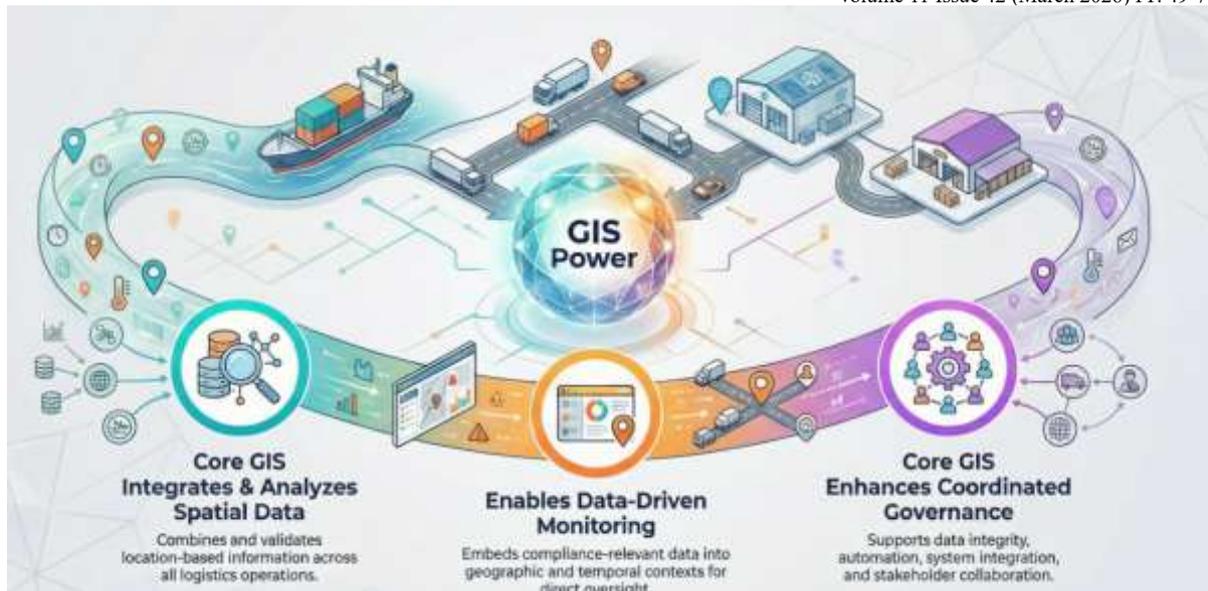
Figure 4: GIS-Centric Architecture for Halal Logistics Monitoring

Automated Spatial Monitoring and Decision Support

Automation in halal logistics compliance monitoring has traditionally focused on documentation workflows and reporting procedures (Rahman & Awal 2025). Additionally, GIS extends automation into the spatial domain through real-time monitoring, rule-based alerts, and decision-support tools (Pranjal & Soni, 2025). Technologies such as geofencing enable the automated detection of compliance breaches when logistics activities occur outside approved halal-certified zones or routes (Hussain et al., 2025). GIS-based automation supports proactive compliance management by enabling regulators and logistics operators to respond to emerging spatial risks rather than relying on post-hoc audits (Teodoro and Duarte, 2022). For instance, real-time spatial monitoring can identify prolonged dwell times at unauthorized facilities, route deviations through high-risk areas, or congestion points that increase the risk of contamination. These insights support evidence-based decision-making and resource allocation within halal governance systems (Chico et al., 2025). Despite these advantages, empirical studies evaluating the effectiveness of automated spatial monitoring in halal logistics remain limited. Most existing implementations are exploratory or conceptual, highlighting the need for longitudinal studies that evaluate performance outcomes, compliance improvements, and cost-benefit trade-offs of GIS-enabled automation (Hamid & Tan, 2022).

Interoperability and System Integration

Notably, interoperability remains a critical barrier to effective monitoring of halal logistics compliance. Halal supply chains encompass a range of systems, including transportation management systems, warehouse management systems, certification databases, and regulatory platforms (Rahman et al., 2022). GIS plays a pivotal role as an integrative layer that unifies heterogeneous data sources through a shared spatial framework (Teodoro & Duarte 2022). By integrating logistics, certification, and regulatory data within a shared geospatial environment, GIS enables holistic analysis and real-time situational awareness (Lorenzin, 2018). This integration enhances coordination across agencies and supply chain actors, supporting consistent interpretation of compliance conditions. Spatial interoperability is crucial in cross-

border halal logistics, where differences in regulatory standards and institutional arrangements complicate compliance verification (Hamdan et al., 2021). However, challenges persist due to incompatible data formats, varying spatial data standards, and limited institutional alignment. Without standardized spatial governance protocols, GIS integration risks reinforcing data silos rather than breaking them down. Thus, addressing these challenges requires technical solutions, policy harmonization, and inter-agency collaboration (Zhang et al., 2025).

Governance and Stakeholder Collaboration

Effective halal logistics compliance is inherently collaborative, requiring coordinated action among regulators, certification bodies, logistics providers, and industry stakeholders. GIS enhances stakeholder collaboration by providing shared spatial representations of compliance conditions, risks, and performance indicators, thereby facilitating informed decision-making. These shared visualizations facilitate communication, joint decision-making, and collective accountability (Morris-Jones & Carter 2008). From a governance perspective, GIS supports transparency and trust by enabling stakeholders to engage with the same spatial evidence base. This shared understanding reduces information asymmetry and supports more inclusive and participatory governance models. Furthermore, GIS aligns with emerging Environmental, Social, and Governance (ESG) expectations by enabling the spatial assessment of sustainability risks, ethical practices, and compliance performance (Wu & 2025). Nevertheless, collaboration through GIS is contingent upon institutional willingness to share data and align governance objectives. Power asymmetries, data ownership disputes, and differing regulatory priorities may constrain the collaborative potential of spatial technologies. These limitations underscore the need for governance frameworks that clearly define roles, responsibilities, and accountability mechanisms within GIS-enabled halal logistics systems (Mohamed et al., 2016).

Synthesis of Quantitative Findings

Over the past decade, empirical research in logistics, supply chain management, and spatial analytics has increasingly employed quantitative metrics to assess transparency, traceability, and trust. While studies explicitly focusing on halal logistics remain limited, a growing body of quantitative evidence from logistics, food supply chains, and regulatory monitoring contexts provides valuable insights into how GIS-enabled systems contribute to compliance-related outcomes. This section synthesizes quantitative findings relevant to GIS applications, with a particular focus on measurement approaches, observed performance effects, and methodological limitations (Grant & Shaw 2021). GIS demonstrates significant potential as a monitoring and governance tool for halal logistics. Nonetheless, its current applications remain fragmented and require a more integrated framework for halal compliance **(Table 2)**.

Transparency Metrics in GIS-Enabled Logistics Systems

Quantitative assessments of transparency in GIS-enabled logistics systems often rely on composite indices or performance indicators that capture information visibility, data accessibility, and reporting timeliness. Standard measures include transparency scores, visibility indices, frequency of data updates, and audit disclosure metrics. In spatial logistics studies, transparency is frequently operationalized through indicators such as real-time tracking availability, spatial coverage of monitored assets, and the proportion of logistics events that are captured with geospatial attributes (Kant, 2025). Moreover, empirical findings consistently

indicate that higher levels of spatial visibility enabled through GIS dashboards and real-time mapping are associated with improved operational transparency and reduced information asymmetry.

Studies reported measurable improvements in reporting accuracy, faster access to compliance-relevant information, and enhanced regulatory responsiveness following the implementation of GIS-based monitoring systems. In regulated supply chains, such as those in the food and pharmaceutical industries, increased spatial transparency has been associated with reductions in reporting errors and improved audit outcomes (Schulz & Schäfer 2024). However, quantitative transparency metrics vary widely across studies, with differences in scale construction (e.g., binary indicators, Likert-based scores, or normalized indices) limiting cross-study comparability. Moreover, many studies relied on self-reported perceptions of transparency rather than objective spatial performance measures, which raises concerns regarding response bias and construct validity (Lazdauskas & McDevitt 2025).

Traceability Metrics and Spatial Performance Indicators

Traceability outcomes in GIS-enabled systems are commonly quantified using time-based and coverage-based metrics. Typical indicators include time-to-trace, percentage of supply chain nodes covered by spatial tracking, trace completeness scores, and reductions in trace delays following system deployment. In logistics contexts where GIS has been integrated with tracking technologies, empirical evidence demonstrates substantial improvements in traceability efficiency, with reported reductions in trace time and an enhanced ability to reconstruct logistics routes and handling histories (Wang & Hsu, 2024). In food supply chains, quantitative studies have shown that GIS-supported traceability systems reduce the time required to identify product origins and affected locations during recall events. Consequently, reductions in product loss often accompany these improvements, recall scope, and compliance-related disruptions (Gallo et al., 2021). Spatial traceability metrics also enable finer-grained analysis of compliance continuity, allowing researchers to quantify the proportion of logistics movements conducted within approved routes or certified zones (Gallo et al., 2021). Despite these positive findings, traceability metrics are often narrowly defined and context specific. Many studies focus on single-sector applications or pilot implementations, which limits their generalizability. In addition, the lack of standardized spatial traceability indicators hinders comparative evaluation across different halal logistics contexts, particularly in cross-border operations where regulatory requirements and spatial data availability differ significantly (Shamsudin & Majid, 2022).

Trust Metrics and Compliance Confidence

Trust-related outcomes are typically quantified through survey-based trust indices, confidence scores, or stakeholder perception scales. In logistics and supply chain research, trust is often measured at the consumer, organizational, or inter-organizational level, reflecting confidence in data accuracy, compliance assurance, and governance effectiveness (Lee & Ha 2024). Furthermore, empirical studies suggest that enhanced spatial visibility and traceability, facilitated by GIS, are positively correlated with higher trust scores among supply chain stakeholders (Modgil & Sakhuja 2022). In the food and agri-logistics contexts, quantitative evidence suggests that improved traceability and higher transparency lead to increased consumer trust and a higher perceived integrity of products (Lam et al., 2022). Organizational-

level studies also reported improvements in regulator and partner trust following the adoption of GIS-based monitoring tools, particularly when spatial data is used to support audit processes and compliance verification (Dong et al., 2025). Nevertheless, trust metrics remained highly subjective and sensitive to contextual factors. Many studies employed cross-sectional survey designs, making it difficult to establish causal relationships between GIS adoption and sustained trust outcomes. Additionally, initial research (Saeed et al., 2025) suggested the need for longitudinal quantitative research to assess trust dynamics in GIS-enabled halal logistics systems (Skarlatidou et al., 2013).

Methodological Patterns and Limitations

Across the reviewed quantitative studies, several methodological patterns emerge. Most studies combine system-generated performance metrics (e.g., trace time, coverage rates) with survey-based perceptual measures to assess transparency, traceability, and trust. Statistical techniques, such as regression analysis, structural equation modeling, and pre–post intervention comparisons, are commonly employed to validate hypothesized relationships (Khan et al., 2022). Nonetheless, significant limitations persist. Sample sizes are often small or localized, particularly in studies involving regulated or sensitive supply chains. Many analyses are cross-sectional, limiting causal inference. At the same time, definitions and measurement scales for transparency and traceability vary substantially across studies. Importantly, empirical research explicitly examining GIS in halal logistics compliance remains scarce, with most quantitative findings extrapolated from adjacent sectors (Chikumba, 2014).

Implications for GIS-Based Halal Logistics Research

The synthesis of quantitative findings suggests that GIS-enabled transparency and traceability are consistently associated with positive compliance and performance outcomes, including improved visibility, faster traceability, and higher trust levels (Muhamad Muslih et al., 2025). However, the lack of standardized metrics, limited halal-specific empirical evidence, and methodological constraints underscore the need for more rigorous, context-sensitive quantitative research (Nurhayati et al., 2025). Future studies should prioritize the development of standardized spatial compliance indicators, longitudinal research designs, and sector-specific validation within halal logistics environments. Such efforts would strengthen the empirical foundation for GIS-based halal governance frameworks, supporting evidence-based policymaking and industry adoption (Rahim, 2023).

Discussion

This critical review demonstrates that the applicability and effectiveness of GIS in halal logistics compliance and monitoring vary considerably across sectors, governance contexts, and institutional environments (Mohamad Muslih et al., 2025). While GIS offers substantial potential to enhance transparency, traceability, and trust through spatial intelligence, its actual impact remains highly contingent upon organizational readiness, regulatory alignment, inter-agency coordination, and the maturity of data governance frameworks. In this regard, GIS implementation outcomes are shaped not only by technological capabilities but also by institutional capacities and compliance cultures within halal logistics systems. Similar to other digital governance technologies, GIS should not be regarded as a universally applicable solution. Rather, it serves as a context-sensitive governance infrastructure whose value emerges

from its effective embedding, operationalization, and governance within specific halal logistics ecosystems. In highly regulated and location-sensitive sectors, such as food, pharmaceuticals, and cold-chain logistics, GIS applications demonstrate a more substantial alignment with compliance objectives. Spatial traceability, risk mapping, and geofencing directly address halal integrity concerns related to segregation, contamination risk, and route control (Huda et al., 2024b). Conversely, sectors characterized by complex stakeholder networks, fragmented operations, or low digital maturity may face greater challenges in realizing the benefits of GIS-enabled compliance monitoring. These findings underscore the importance of tailoring GIS adoption strategies to sector-specific logistics characteristics and governance requirements (Canada, 2013). **Table 3** outlines the sector-specific applicability of GIS in halal logistics compliance and monitoring.

Technical Challenges

From a technical perspective, several challenges constrain the effective deployment of GIS in halal logistics compliance. One of the most significant issues relates to system integration and interoperability. Many existing logistics and certification systems were not designed with spatial interoperability in mind, resulting in fragmented data architectures and integration challenges (El Azzouzy et al., 2025).Without seamless data exchange between GIS platforms, logistics management systems, and halal certification databases, spatial compliance monitoring remains partial and reactive (Afnarius et al., 2020). Scalability also presents a persistent challenge. As halal supply chains grow in scale and geographic scope, GIS systems must handle increasing volumes of spatial and temporal data.

Consequently, inadequate system architecture or insufficient computational capacity may lead to performance bottlenecks, thereby reducing the reliability of real-time monitoring and analytics (Luaces et al., 2005). Moreover, ensuring data accuracy and consistency across multiple data sources, particularly in cross-border operations, remains a critical technical concern (Saeed et al., 2025). Cybersecurity and data protection are additional technical considerations. GIS-based compliance systems aggregate sensitive operational and regulatory data, making them vulnerable to data breaches or misuse. Robust cybersecurity frameworks, encryption mechanisms, and secure access controls are therefore essential to maintain system integrity and stakeholder confidence (Górny, 2025).

Table 2: Related Review Papers for Studies On GIS-Enabled Halal Logistics Compliance, Traceability, And Monitoring Outcomes

Study	GIS / Compliance Metric(s)	Data / Method	Outcome (Change / Impact)	Year	Halal Logistics Domain
Muslih et al.(Muslih, Gustian, Somantri, et al., 2025)	GIS for traceability, halal certification, and supply chain collaboration.	Case study of halal MSMEs in West Java using GIS with Analysis of Variance (ANOVA) and Pearson correlation	Collaboration, human resources, and halal certification are key drivers, while GIS enhances SCM efficiency and halal compliance	2025	Digital halal supply chain management for MSMEs
Zulfakar et al. (Talib et al., 2015)	Halal certification, halal standards, traceability, dedicated assets, trust, commitment, and government role.	Conceptual paper developing a framework for halal food supply chain integrity	Identifies key drivers of halal integrity in global supply chains and emphasizes the shared responsibility among all stakeholders	2014	Halal food supply chain integrity and governance
Ellahi et al. (Ellahi et al., 2026)	Spatial traceability & compliance visibility	Internet of Things (IoT)–Blockchain–Artificial Intelligence (AI) integrated monitoring framework	Real-time halal compliance, enhanced transparency, reduced fraud and contamination risk	2025	Halal meat supply chain
Yakubu *et al.* (Yakubu et al., 2025)	Traceability, data integrity & halal compliance assurance	Blockchain (PoA), smart contracts, IoT sensors & cryptographic verification	Tamper-proof records, real-time halal compliance, automated certification & reduced fraud risk	2025	Halal food supply chain
Yao.(Yao, 2020)	Spatial location accuracy & traceability	Georeferencing & geocoding methods	Accurate spatial identification enabling location-based tracking and analysis	2020	General GIS applications (logistics & supply chains)
Gallo *et al.*(Gallo et al., 2021)	Spatial traceability, safety & sustainability indicators	GIS-based traceability system integrating heterogeneous supply chain data	Improved monitoring of food safety, shelf-life decay, and environmental impact for decision support	2021	Food distribution supply chain (general / non-halal-specific)

Table 3. Sector-Specific Applicability of GIS In Halal Logistics Compliance and Monitoring

Halal Logistics Sector	Key Compliance Challenges	GIS Applications	Current Limitations / Gaps	Indicative References
Halal Transportation	Route deviation; cross-contamination risk; lack of real-time monitoring	GPS-GIS tracking; geofencing; route deviation alerts; real-time spatial dashboards	High implementation cost; limited enforcement integration; data reliability issues	[HalalTracer studies], [GIS logistics]
Halal Food Supply Chain	Traceability of origin; integrity assurance; fragmented data	Spatial traceability mapping; GIS-based halal status visualization; GIS + IoT integration	Interoperability challenges; low SME adoption; absence of halal-specific GIS standards	[Food traceability GIS]
Halal Warehousing	Zoning compliance (halal vs non-halal); storage contamination risks	Indoor GIS zoning; spatial layout compliance monitoring; hotspot analysis	Limited indoor spatial data; manual data input; lack of real-time sensors	[Warehouse GIS]
Halal Manufacturing	Process segregation; compliance auditing; monitoring critical control points	GIS-enabled facility mapping; spatial audit trails; GIS-based compliance dashboards	Resistance to digital audits; data sensitivity concerns	[Halal manufacturing GIS]
Halal Retail & Distribution	Visibility of halal certification; consumer trust; monitoring last-mile delivery	Location-based certification display; GIS consumer transparency platforms	Inconsistent certification databases; limited consumer awareness	[Retail halal GIS]
Halal Governance & Enforcement	Weak spatial oversight; reactive enforcement; limited risk prioritization	GIS hotspot analysis; risk-based inspection planning; spatial compliance intelligence	Fragmented institutional data; lack of integrated governance framework	[Halal governance GIS]

Organizational and Institutional Issues

Beyond technical constraints, organizational and institutional factors play a decisive role in shaping GIS adoption outcomes. Specifically, resistance to change is a recurring theme in the literature, particularly among organizations accustomed to manual or document-based compliance processes. The transition to spatially enabled monitoring systems often requires significant adjustments to workflows, skill sets, and organizational culture (Abdelrahman et al., 2025). Moreover, institutional fragmentation further complicates implementation. Halal logistics governance typically involves multiple authorities with overlapping mandates, leading to inconsistent requirements and limited coordination. In the absence of a centralized or harmonized governance framework, GIS platforms may be adopted in isolation, thereby reducing their effectiveness as tools for shared oversight and collaboration (Aydinoglu & Yomralioglu 2010). Capacity disparities among stakeholders also pose challenges. While large logistics providers and regulatory agencies may possess the resources to invest in GIS infrastructure and training, smaller operators, particularly SMEs, often lack the technical expertise and financial capacity to participate fully. As a result, these asymmetries risk excluding certain actors from spatial governance systems, potentially undermining compliance, inclusivity, and legitimacy (Pick et al., 2008).

Legal and Ethical Considerations

The deployment of GIS in halal logistics compliance raises important legal and ethical questions. Chief among these is data governance, including issues of data ownership, consent, accountability, and liability. Spatial data can reveal sensitive information about business operations, logistics routes, and enforcement activities, raising concerns about commercial confidentiality and misuse (Groothedde et al., 2008). Regulatory uncertainty also acts as a deterrent to adoption. In many jurisdictions, the legal frameworks governing the sharing of spatial data, digital monitoring, and cross-border data flows remain underdeveloped or ambiguous. Organizations may therefore hesitate to invest in GIS-based compliance systems due to concerns about legal exposure or regulatory non-compliance (Gryzunov & Gryzunova 2022). Ethically, the balance between transparency and privacy must be carefully managed. While increased spatial visibility supports compliance and trust, excessive surveillance may generate resistance or erode stakeholder confidence. These considerations highlight the necessity for clear legal frameworks and ethical guidelines to govern GIS-based halal logistics monitoring (Viola & Laidler 2021).

Limitations of the Review

This study adopts a narrative and critical review approach rather than a systematic review. Consequently, it does not aim to provide exhaustive coverage of all GIS-related literature. Source selection was guided by thematic relevance, conceptual contribution, and diversity of contexts rather than formal inclusion and exclusion criteria. As such, the findings should be interpreted as a conceptual synthesis and gap-identification exercise rather than statistically generalizable evidence. Additionally, the limited availability of halal-specific empirical studies necessitated the inclusion of evidence from adjacent domains such as food safety, logistics management, and regulatory monitoring. While this approach enriches theoretical understanding, it also highlights the need for more context-specific empirical research.

Research Gaps and Future Directions

The discussion reinforces several research gaps identified earlier. First, there is a need for empirical validation of GIS-enabled halal logistics compliance frameworks through case studies, pilot implementations, and quantitative performance assessments. Future research should examine not only operational improvements but also governance outcomes, such as regulatory effectiveness and stakeholder trust (Fernando et al., 2025). Second, longitudinal research designs are required to assess the sustainability of GIS adoption and its long-term impact on compliance culture and trust dynamics. Transparency and trust are not static constructs. Understanding how they evolve is essential for effective governance design (Alzahrani et al., 2024).

Furthermore, future studies should explore hybrid digital infrastructures that integrate GIS with complementary technologies, such as certification databases, tracking systems, and decision-support tools. Such integration may enhance automation, scalability, and analytical depth while preserving governance oversight (Singh & Patra 2025). Ultimately, comparative cross-border research is crucial in supporting the international harmonization of halal logistics governance. GIS-based approaches offer a promising foundation for aligning compliance monitoring across jurisdictions. However, this potential can only be realized through coordinated policy development and collaborative research initiatives (Bari et al., 2023).

Concluding Remarks on the Discussion

This narrative review aims to synthesize and critically examine conceptual discussions on the application of GIS in halal logistics compliance. Overall, this discussion highlights that the value of GIS in halal logistics compliance lies not solely in its technical capabilities, but in its capacity to support spatially enabled governance and management. Effective implementation requires alignment between technology, institutions, and regulatory frameworks. When embedded within coherent governance structures, GIS can play a transformative role in enhancing transparency, traceability, and trust across halal logistics supply chains ((Huda et al., 2024a)Mohammad Muslih et al. 2025; Prathama et al 2023).

Conclusions

This narrative review synthesizes and critically examines conceptual discussions on the application of Geographic Information Systems (GIS) in halal logistics compliance and monitoring. The primary aim is to consolidate fragmented literature from logistics management, geospatial technologies, and halal governance to clarify how GIS has been conceptualized as a mechanism for enhancing compliance, transparency, traceability, and institutional trust within halal supply chain systems. Rather than focusing on quantitative performance outcomes, the review is guided by themes of spatial governance, digital monitoring, and institutional oversight. The synthesis reveals several key conceptual insights. First, GIS is consistently framed as a spatial intelligence platform that embeds compliance information within geographic and temporal contexts, enabling visibility of locations, transport routes, and segregation practices essential to halal integrity. This spatial capability distinguishes GIS from conventional transactional systems. Second, transparency, traceability, and trust are conceptualized as interconnected governance dimensions. Transparency is understood as spatial visibility, traceability as the continuity of compliance across logistics

stages and locations, and trust as an institutional outcome supported by verifiable spatial evidence. Third, the literature reflects a gradual shift from audit-based, document-driven compliance toward continuous, location-aware monitoring, although this transition remains largely conceptual and uneven across contexts.

This review contributes to knowledge by integrating dispersed discussions into a coherent conceptual framework that positions GIS as an enabling infrastructure for halal logistics governance rather than merely a technical tool. By bridging perspectives from logistics, geospatial science, and halal studies, the review clarifies conceptual overlaps and resolves ambiguities surrounding governance-related outcomes. The findings carry important implications for policy and practice, particularly in promoting spatially enabled risk awareness, coordinated oversight, and evidence-based decision-making. However, these implications remain largely conceptual. The review also acknowledges limitations in narrative synthesis and in the availability of halal-specific empirical studies, highlighting the need for future empirical validation, standardized spatial indicators, and refined spatial governance models.

References

Ab Rashid, N., & Bojei, J. (2020). The relationship between halal traceability system adoption and environmental factors on halal food supply chain integrity in Malaysia. *Journal of Islamic Marketing*, *11*(1), 117–142. https://doi.org/10.1108/JIMA-01-2018-0016

Abdelrahman, M., Papamichail, K. N., Hammady, R., Kurt, Y., Abdallah, W., Shixiong Liu, L., & Kapser, S. (2025). Organisational Culture and Knowledge Management Systems Adoption: Examining Employee Usage in Multinational Corporations. *Global Journal of Flexible Systems Management*, *26*(3), 439–467. https://doi.org/10.1007/s40171-025-00448-w

Afnarius, S., Akbar, F., & Yuliani, F. (2020). Developing web-based and mobile-based GIS for places of worship information to support halal tourism: A case study in Bukittinggi, Indonesia. *ISPRS International Journal of Geo-Information*, *9*(1), 1–18. https://doi.org/10.3390/ijgi9010052

Ahmad, F. B., Shah, M. Z., & Hamid, Z. J. B. I. M. H. (2022). Exploring the Halal meat cartel case: A legal framework and insight from the regulator. In *Halal Logistics and Supply Chain Management: Recent Trends and Issues* (pp. 122–131). Taylor and Francis. https://doi.org/10.4324/9781003223719-13

Alii, H. M., Ugli, A. A. G., Mannonov, A., & Lalnunthari, L. (2025). Artificial Intelligence and IoT in Logistics management for the Intelligent Supply chain Management For The Future era. *2025 International Conference on Computational Innovations and Engineering Sustainability, ICCIES 2025*. https://doi.org/10.1109/ICCIES63851.2025.11032715

Alzahrani, N. A., Sheikh Abdullah, S. N. H., Adnan, N., Zainol Ariffin, K. A., Mukred, M., Mohamed, I., & Wahab, S. (2024). Geographic information systems adoption model: A partial least square-structural equation modeling analysis approach. *Heliyon*, *10*(15). https://doi.org/10.1016/j.heliyon.2024.e35039

Arshad, M. S., Aslam, N., & Zafar, K. ul W. (2023). Current and Future Usage of RFID-Based Technology in Halal Food Validation System. In *Technologies and Trends in the Halal Industry* (pp. 161–171). Taylor and Francis. https://doi.org/10.4324/9781003368519-15

Aydinoglu, A. C., & Yomralioglu, T. (2010). A harmonised GI model for urban governance. *Proceedings of the Institution of Civil Engineers: Municipal Engineer*, *163*(2), 65–76. https://doi.org/10.1680/muen.2010.163.2.65

Bari, J. B. A., Tiwari, S. P., Mitra, B., Elhaj, A. I., Siddiqui, A., Reshi, O. R., & Rahman, S. M. (2023). GIS-Based Modelling for Estimation of Water Quality Parameters: A Review. In *Geospatial Analytics for Environmental Pollution Modeling: Analysis, Control and Management* (pp. 57–89). Springer Nature. https://doi.org/10.1007/978-3-031-45300-7_3

Bertino, E., & Kirkpatrick, M. S. (2011). Location-based access control systems for mobile users: concepts and research directions. *International Workshop on Security and Privacy in GIS and LBS*, 49–52. https://doi.org/10.1145/2071880.2071890

Canada, E. (2013). Canfor leverages data management to streamline forest management. *Pulp and Paper Canada*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/84878443779?origin=document-preview-flyout

Chen, X.-Q., Chi, Z.-X., & Xu, S.-H. (2004). Research on a spatial data warehouse framework for efficient spatial OLAP. *Dalian Ligong Daxue Xuebao/Journal of Dalian University*

of   *Technology*.   https://www-scopus-com.ezaccess.remotexs.co/pages/publications/12444315985?origin=scopusAI

Chen, Z., Cong, G., & Aref, W. G. (2023). STAR: A Cache-based Stream Warehouse System for Spatial Data. *ACM Transactions on Spatial Algorithms and Systems*, *9*(4). https://doi.org/10.1145/3605944

Chico, C., Cordel, M. O., Mariasingham, M. J., & Tan, E. S. (2025). Analyzing anomalous events in passageways with high-frequency ship signals. *PLoS ONE*, *20*(4 April). https://doi.org/10.1371/journal.pone.0320129

Chikumba, P. A. (2014). Geographic Information System as a Tool for Enriching Drug Logistics Information at District Level in Malawi: Challenges on Data Quality. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST, 135 LNICST*, 209–218. https://doi.org/10.1007/978-3-319-08368-1_25

Cota-Rivera, E. I. (2025). Advancing geographic information systems with machine learning: Innovations in spatial analysis and environmental management. In *Exploring Psychology, Social Innovation and Advanced Applications of Machine Learning* (pp. 253–270). IGI Global. https://doi.org/10.4018/979-8-3693-6910-4.ch013

Dong, J., Liang, X., Du, B., Ju, Y., Wang, Y., & Guo, H. (2025). Applications of Geographic Information Systems in Ecological Impact Assessment: A Methods Landscape, Practical Bottlenecks, and Future Pathways. *Sustainability (Switzerland)*, *17*(22). https://doi.org/10.3390/su172210358

El Azzouzy, O., Chanyour, T., & Andaloussi, S. J. (2025). Prescriptive Analytics for Logistics: Bridging Predictive Models and Actionable Decisions Through Advanced Optimization Techniques. *2025 5th International Conference on Innovative Research in Applied Science, Engineering and Technology, IRASET 2025*. https://doi.org/10.1109/IRASET64571.2025.11008321

Ellahi, R. M., Wood, L. C., & Bekhit, A. E.-D. A. (2026). A multi-layer Industry 4.0 framework for ensuring halal integrity in NZ meat supply chains. *Food Control*, *182*. https://doi.org/10.1016/j.foodcont.2025.111880

Fernando, Y., Hendayani, R., Jawo, M., Rahamaddulla, S. R., Abdul Aziz, K., & Maimunah, N. (2025). Discovering Islamic marketing potential in shaping blockchain--based halal logistic services: a bibliometric analysis. *Journal of Islamic Marketing*, *16*(3), 870–905. https://doi.org/10.1108/JIMA-06-2024-0258

Gallo, A., Accorsi, R., Goh, A., Hsiao, H., & Manzini, R. (2021). A traceability-support system to control safety and sustainability indicators in food distribution. *Food Control*, *124*. https://doi.org/10.1016/j.foodcont.2021.107866

Ghalih, M., Chang, C. H., Safitri, Y. D., & Wijayati, T. (2025). Integrating Sustainability in Halal Supply Chain Management: Strategies, Challenges, and Opportunities. In *Shaping Green and Inclusive Economies Through Innovative Entrepreneurship* (pp. 257–299). IGI Global. https://doi.org/10.4018/979-8-3373-1097-8.ch009

Górny, P. (2025). METHODS FOR IDENTIFYING CYBER THREATS IN GIS SYSTEMS. COMPARATIVE ANALYSIS. *Geographic Information Systems Odyssey Journal*, *5*(2), 121–134. https://doi.org/10.57599/gisoj.202025.5.2.121

Grant, D. B., & Shaw, S. (2021). Logistics and Supply Chain Management Performance Measures. In *International Encyclopedia of Transportation: Volume 1-7* (Vol. 3, pp. 16–23). Elsevier. https://doi.org/10.1016/B978-0-08-102671-7.10210-6

Groothedde, A., Lemmen, C., van der Molen, P., & van Oosterom, P. (2008). A standardized land administration domain model as part of the (Spatial) information infrastructure. In

Creating Spatial Information Infrastructures: Towards the Spatial Semantic Web. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/84978631107?origin=scopusAI

Gryzunov, V., & Gryzunova, D. (2022). Problems of Providing Access to a Geographic Information System Processing Data of Different Degrees of Secrecy. In *Lecture Notes on Data Engineering and Communications Technologies* (Vol. 73, pp. 191–198). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-16-3961-6_17

Haibo, C. S. (2010). Research and design of logistic information system based on GIS technology. *2010 2nd International Conference on E-Business and Information System Security, EBISS2010*, 611–614. https://doi.org/10.1109/EBISS.2010.5473739

Hamdan, F. A., Sarbani, N. B., Jaafar, H. S., & Nasir, S. (2021). Influencing determinants of halal land cross-border clearance operation in Malaysia. *Proceedings of the International Conference on Industrial Engineering and Operations Management.* https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85114216366?origin=scopusAI

Hansen, F., & Oleshchuk, V. (2006). Location-based security framework for use of handheld devices in medical information systems. *Proceedings - Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops, PerCom Workshops 2006*, *2006*, 565–569. https://doi.org/10.1109/PERCOMW.2006.76

Hassan, M. H. C., & Osman, L. H. (2025). Systematic Literature Review on Impact Integration Servitisation in Halal Supply Chain. *Paper Asia*, *41*(3), 203–217. https://doi.org/10.59953/paperasia.v41i3b.518

Hebbar, A. A. (2023). International quality management standard settings in the maritime sector: The role of international organizations and the emerging global regulatory framework. In *Maritime Law Perspectives Old and New*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85172814386?origin=scopusAI

Huda, I. A. S., Saadah, M., Sugiarto, A., Bin Ibrahim, M. H., Prasad, R. R., Putra, A. K., & Budianto, A. (2024a). Revealing Halal Certification Oversight Gaps for MSEs through ArcGIS Dashboard Integration. *Indonesian Journal of Halal Research*, *6*(2), 58–69. https://doi.org/10.15575/ijhar.v6i2.33308

Huda, I. A. S., Saadah, M., Sugiarto, A., Bin Ibrahim, M. H., Prasad, R. R., Putra, A. K., & Budianto, A. (2024b). Revealing Halal Certification Oversight Gaps for MSEs through ArcGIS Dashboard Integration. *Indonesian Journal of Halal Research*, *6*(2), 58–69. https://doi.org/10.15575/ijhar.v6i2.33308

Hussain, E. M., Zainuddin, S. A., Shamshudeen, R. I., Kandasamy, S. S., Maraya, R., Razali, A., & Aziz, R. C. (2025). Mapping the Landscape of Halal Logistics Research: A Bibliometric Analysis. In *Studies in Systems, Decision and Control* (Vol. 598, pp. 813–824). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-91424-9_70

Jasman, N. A. B., & Mohd Ariffin, N. H. B. (2021). A Proposed of Halal Food Supply Chain Traceability Model. *International Journal of Academic Research in Economics and Management Sciences*, *10*(3). https://doi.org/10.6007/IJAREMS/V10-I3/11167

Jones, B. A. (2003). Bullding a Pipeline GIS for Integrity Management, HCA Determination, and Incident Planning. *Proceedings of the ASCE International Conference on Pipeline Engineering and Construction: New Pipeline Technologies, Security, and Safety.* https://www-scopus-

com.ezaccess.remotexs.co/pages/publications/0344898361?origin=document-preview-flyout

Kant, S. (2025). Real-Time Tracking Technologies' Effect on Supply Chain Transparency by Mediation of Smart Logistics Technologies in the Horn of Africa. In *Emerging Trends in Smart Logistics Technologies* (pp. 105–132). IGI Global. https://doi.org/10.4018/979-8-3373-2434-0.ch004

Khairuddin, M. M., Amanshah, T. N. T., & Norman, M. R. (2024). Technology Adoption in Halal Logistics in Malaysia: Exploring Types, Benefits and Challenges for Halal Warehouse and Transportation. In *Emerging Technology and Crisis Management in The Halal Industry: Issues and Recent Developments* (pp. 35–48). Springer Nature. https://doi.org/10.1007/978-981-97-1375-2_3

Khairuddin, M. M., Rahman, N. A. A., Mohammad, M. F., Majid, Z. A., & Ahmad, M. F. (2018). Regulator perspective on halal air cargo warehouse compliance. *International Journal of Supply Chain Management*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85049172937?origin=scopusAI

Khan, M., Parvaiz, G. S., Dedahanov, A. T., Abdurazzakov, O. S., & Rakhmonov, D. A. (2022). The Impact of Technologies of Traceability and Transparency in Supply Chains. *Sustainability (Switzerland)*, *14*(24). https://doi.org/10.3390/su142416336

Khan, S., Haleem, A., Ngah, A. H., & Khan, M. I. (2023). Exploration of risks with halal logistics: a case of emerging economy. *Journal of Global Operations and Strategic Sourcing*, *16*(3), 745–772. https://doi.org/10.1108/JGOSS-01-2022-0001

Kourouthanassis, P., Bardaki, C., Sourvinos, A., Karyotis, V., & Mylonas, P. (2023). Platform Architecture and Functionality for Efficient and Intelligent Logistics. *2023 18th International Workshop on Semantic and Social Media Adaptation and Personalization, SMAP 2023*. https://doi.org/10.1109/SMAP59435.2023.10255183

Lam, T., Heales, J., & Hartley, N. (2022). Perceived Risk Triggers the Effects of Trace-Back Information on Consumer Trust. *28th Americas Conference on Information Systems, AMCIS 2022*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85192525254?origin=scopusAI

Lazdauskas, T., & McDevitt, S. C. (2025). Careless Responding May Reduce Data Quality in Self-Report Questionnaire Research: Evidence From Adult Temperament Samples From Two Cultures. *Psychological Reports*. https://doi.org/10.1177/00332941251390460

Lee, C., & Ha, B. C. (2024). Relationship between trust, the investment model and logistics performance in supply chain management. *Business Process Management Journal*, *30*(2), 485–504. https://doi.org/10.1108/BPMJ-02-2023-0073

Lorenzin, G. (2018). Developing a common guideline for geospatial support during a marine emergency response in the Australian context. *41st AMOP Technical Seminar on Environmental Contamination and Response, AMOP 2018*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85058809331?origin=scopusAI

Luaces, M. R., Brisaboa, N. R., Paramá, J. R., & Viqueira, J. R. (2005). A generic framework for GIS applications. *Lecture Notes in Computer Science*, *3428*, 94–109. https://doi.org/10.1007/11427865_8

Madanchian, M., & Taherdoost, H. (2025). A Narrative Review and Gap Analysis of Blockchain for Transparency, Traceability, and Trust in Data-Driven Supply Chains. *Applied Sciences (Switzerland)*, *15*(17), 1–22. https://doi.org/10.3390/app15179571

Mahadi, F., Syazwan, M., & Talib, A. (2023). LOGISTICS AND SUPPLY CHAIN MANAGEMENT IN HALAL PHARMACEUTICAL RESEARCH: A SYSTEMATIC

LITERATURE REVIEW USING PRISMA. *Journal of Halal Science and Technology*, *2*(1), 54–67. https://doi.org/10.59202/JHST.V2I1.668

Mahidin, N., Mustafar, M., Elias, E. M., & Abu Bakar, S. Z. (2019). Applying the theory of the planned behavior on halal logistics services adoption among food & beverages small and medium enterprises. *International Journal of Supply Chain Management*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85071546730?origin=scopusAI

Metvaei, S., Rahimi, A., Cao, H., Ahn, S. J., & Lei, Z. (2025). A GPS-Integrated IoT Framework for Real-Time Monitoring of Prefabricated Building Modules During Transportation. *Buildings*, *15*(23), 4242. https://doi.org/10.3390/buildings15234242

Modgil, A., & Sakhuja, S. (2022). The Role of Smart Technologies in Enhancement of Supply Chain Visibility. *ECS Transactions*, *107*(1), 8113–8120. https://doi.org/10.1149/10701.8113ecst

Mohamad, M. A., Mansor, S., Ahmad, N., Adnan, W. A. W., & Muhammad Wali, I. (2016). The reliability of halal product transportation using gps tracking system. *Journal of Theoretical and Applied Information Technology*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/84984876917?origin=scopusAI

Mohamed, M. I. K. P. H. P., Rasi, R. Z. R. M., Mohamad, M. F. bin A., & Wan Yusoff, W. F. (2016). Towards an integrated and streamlined halal supply chain in Malaysia-challenges, best practices and framework. *Social Sciences (Pakistan)*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/84988372471?origin=scopusAI

Morris-Jones, D. R., & Carter, D. A. (2008). Geospatial Information Systems and Enterprise Collaboration. In *Encyclopedia of Information Science and Technology: Second Edition* (pp. 1646–1651). IGI Global. https://doi.org/10.4018/978-1-60566-026-4.ch259

Mr. Ajay Bhimrao Thorat. (2024). Consistency in Spatial Databases. *International Journal of Advanced Research in Science, Communication and Technology*, 677–682. https://doi.org/10.48175/ijarsct-18978

Muslih, M., Gustian, D., & Hasman, D. (2025). GIS Combined with Multivariate Analysis in Supporting Digitalization Supply Chain Management of Halal Products: The Case Study of MSMEs in West Java Indonesia. *Engineering, Technology and Applied Science Research*, *15*(2), 21152–21158. https://doi.org/10.48084/etasr.9991

Muslih, M., Gustian, D., Somantri, & Hasman, D. (2025). GIS Combined with Multivariate Analysis in Supporting Digitalization Supply Chain Management of Halal Products: The Case Study of MSMEs in West Java Indonesia. *Engineering, Technology and Applied Science Research*, *15*(2), 21152–21158. https://doi.org/10.48084/etasr.9991

Nai, S., Rifai, A., & Sadiq, A. (2025). Data governance in education: Enhancing predictions and decision-making for performance monitoring. In *Data Governance, DevSecOps, and Advancements in Modern Software* (pp. 99–111). IGI Global. https://doi.org/10.4018/979-8-3373-0365-9.ch005

Nazri, M. Z., Kamal, A. J., Rashid, S. N. A. A., Mustafa, R. R., & Karim, H. A. A. (2025). Preliminary analysis of standard animal gelatines through FTIR-ATR spectroscopy coupled with multivariate data analysis and pattern recognition for halal verification. *Malaysian Journal of Analytical Sciences*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/105017994258?origin=scopusAI

Nizar, N. N. A., Abidin, S. A. S. Z., & Taib, M. N. (2023). Smart Data for Sustainable Halal Supply Chain in Kuala Lumpur: A Proposal. *2023 19th IEEE International Colloquium on Signal Processing and Its Applications, CSPA 2023 - Conference Proceedings*, 174–178. https://doi.org/10.1109/CSPA57446.2023.10087506

Nurhayati, N., Chelbi, A., Mabrouk, A. Ben, & Young, F. C. (2025). UNLEASHING HALAL POTENTIAL: EXPLORING THE DYNAMICS OF HALAL LOGISTICS IN TANGERANG CITY, INDONESIA. *Agrociencia*, *59*(3). https://doi.org/10.47163/agrociencia.v59i3.3272

Pick, J. B., Gollakota, K., Falatoon, H., & Greene, R. (2008). Readiness of small enterprises for GIS: The question of strategy. *14th Americas Conference on Information Systems, AMCIS 2008*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/84870367497?origin=scopusAI

Pranjal, P., & Soni, A. (2025). Next-Generation Geographical Information SystemsIntegrating Artificial Intelligence, Geographic Information Systems, and Satellite Imagery for Mapping and Surveying. In *Global Land-Ocean Geospatial Applications : Mapping and Surveying with Remote Sensing and GIS* (pp. 216–233). CRC Press. https://doi.org/10.1201/9781003422877-10

Prathama, M., Baihaqi, I., & Rakhmawati, N. A. (2023). Halal Traceability Systems in the Supply Chain for the Cosmetics Industry: Literature Review and Research Agenda. *2023 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies, 3ICT 2023*, 209–214. https://doi.org/10.1109/3ICT60104.2023.10391540

R., A., R., M., C., M., A., C., & S., P. (2013). Life cycle modelling for sustainable food supply chain. *22nd International Conference on Production Research, ICPR 2013*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/84929359685?origin=document-preview-flyout

Rahim, N. F. (2023). Rapid scoping review of blockchain adoption in halal industry supply chain. *AIP Conference Proceedings*, *2827*(1). https://doi.org/10.1063/5.0166546

Rahman, M. M., & Awal, M. R. (2025). 6G-Enabled smart Halal industry: enhancing compliance sustainability and efficiency. In *Human-Centric Integration of 6G-Enabled Technologies for Modern Society: Fundamentals, Applications, Analysis and Challenges* (pp. 345–358). Elsevier. https://doi.org/10.1016/B978-0-443-27434-3.00023-4

Rahman, N. A. A., Mahroof, K., Hassan, A., & Sujchaphong, N. (2022). The new age of Halal logistics and supply chain standards in Asia, the Middle East and the West: IHIAS, SMIIC and MS. In *Halal Logistics and Supply Chain Management: Recent Trends and Issues* (pp. 17–31). Taylor and Francis. https://doi.org/10.4324/9781003223719-4

Raimi, L. (2025). Development of Shari'ah Framework for Halal Policy and Standards for Integrating Blue Economy for Halal Industry Sustainability. In *Green and Blue Economy Frameworks for Halal Industry Sustainability* (pp. 151–170). Springer Nature. https://doi.org/10.1007/978-981-96-1729-6_9

Rizki, M., Zarory, H., & Luthfi, A. N. (2023). Development of Warehouse Management System Using IoT for Halal Supply Chain. *International Journal of Science and Society*, *5*(5), 507–514. https://doi.org/10.54783/IJSOC.V5I5.912

Saad, H., & SRI NOR HASLINA BINTI SAAD. (2020). Developing a Shariah Governance Framework (SGF) for Halal Logistics Industry: A Comparative Study of the SGF in Islamic Finance Industry. *Tesis Master, Universiti Teknologi MARA ((UiTM)*.

Saad, N., Rahman, F. A., & Muhammad, A. (2016). *An Overview of the Shariah Governance of the Halal Industry in Malaysia: With Special Reference to the Halal Logistics*.

Saba, A. O., Salisu, M. A., & Sule, H. A. (2025). Strategies for Maritime Excellence and Environmental Impact Mitigation Through Halal Practices. In *Green and Blue Economy*

Frameworks for Halal Industry Sustainability (pp. 101–116). Springer Nature. https://doi.org/10.1007/978-981-96-1729-6_6

Sabar, R., Anuar, N. K., & Hashom, H. (2025). The Development of the Halal-Logistics Value Creation (HLVC) Concept for Women's Social-Entrepreneurship in the Aviation Business. In *Women in Logistics and Transport: Trends, Challenges, and Future Research* (pp. 253–272). Taylor and Francis. https://doi.org/10.4324/9781032709550_19

Saeed, N., Ashour, M., & Mashaly, M. (2025). Comprehensive review of federated learning challenges: a data preparation viewpoint. *Journal of Big Data*, *12*(1). https://doi.org/10.1186/s40537-025-01195-6

Schulz, S., & Schäfer, S. (2024). The Relevance of the New EU Supply Chain Requirements for Combating Food Fraud. *European Food and Feed Law Review*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85202944072?origin=scopusAI

Shamsudin, M. F., & Majid, H. Z. A. (2022). Technology and traceability in Halal logistics: Critical success factors. In *Halal Logistics and Supply Chain Management: Recent Trends and Issues* (pp. 78–88). Taylor and Francis. https://doi.org/10.4324/9781003223719-9

Šidlauskas, D., Šaltenis, S., Christiansen, C. W., Johansen, J. M., & Šaulys, D. (2009). Trees or grids? Indexing moving objects in main memory. *GIS: Proceedings of the ACM International Symposium on Advances in Geographic Information Systems*, 236–245. https://doi.org/10.1145/1653771.1653805

Singh, A. K., & Patra, A. K. (2025). Pathways for Sustainable Development and Multi-Criteria Decision-Making Using AI and GIS. In *Artificial Intelligence, Geographic Information Systems, and Multi-Criteria Decision-Making for Improving Sustainable Development* (pp. 1–17). CRC Press. https://doi.org/10.1201/9781032683928-1

Skarlatidou, A., Cheng, T., & Haklay, M. (2013). Guidelines for trust interface design for public engagement Web GIS. *International Journal of Geographical Information Science*, *27*(8), 1668–1687. https://doi.org/10.1080/13658816.2013.766336

Sunardi, D., Bhari, A., & Wakil, M. N. B. A. (2024). Legal Awareness of Micro and Small Enterprise Operators Regarding Halal Certification: A Maslaha Perspective. *Ijtihad: Jurnal Wacana Hukum Islam Dan Kemanusiaan*, *24*(1), 23–45. https://doi.org/10.18326/ijtihad.v24i1.23-45

Talib, M. S. A., Hamid, A. B. A., Zulfakar, M. H., & Chin, T. A. (2015). Barriers to Halal logistics operation: Views from Malaysian logistics experts. *International Journal of Logistics Systems and Management*, *22*(2), 193–209. https://doi.org/10.1504/IJLSM.2015.071545

Tech-Driven Halal Logistics: A Gateway to Efficient Service Quality and Cross-Border Trade, Emerging Technology and Crisis Management in The Halal Industry: Issues and Recent Developments 273 (2024). https://doi.org/10.1007/978-981-97-1375-2_18

Teodoro, A. C., & Duarte, L. (2022). The synergy of remote sensing and geographical information systems in the management of natural disasters. In *Nanotechnology-Based Smart Remote Sensing Networks for Disaster Prevention* (pp. 217–230). Elsevier. https://doi.org/10.1016/B978-0-323-91166-5.00023-9

Traceability Technology in Halal Logistics and Supply Chain: Critical Success Factors, Halal Logistics and Supply Chain Management: Recent Trends and Issues 67 (2022). https://doi.org/10.4324/9781003223719-8/TRACEABILITY-TECHNOLOGY-HALAL-LOGISTICS-SUPPLY-CHAIN-ZUHRA-JUNAIDA-BINTI-IR-MOHAMAD-HUSNY-HAMID-MOHD-ISKANDAR-BIN-ILLYAS-TAN

Vashishth, T. K., Sharma, V., Sharma, K. K., Kumar, B., Chaudhary, S., & Panwar, R. (2024). Digital twins solutions for smart logistics and transportation. In *Digital Twins for Smart Cities and Villages* (pp. 353–376). Elsevier. https://doi.org/10.1016/B978-0-443-28884-5.00016-6

Viola, L. A., & Laidler, P. (2021). Trust and Transparency in an Age of Surveillance. In *Trust and Transparency in an Age of Surveillance*. Taylor and Francis. https://doi.org/10.4324/9781003120827

W., S., A., G., & H., H. (2020). Total ergonomics intervention perfecting has-23000 implementation in the cake processing industry; case study in the "gipang tiga bunda" cake industry of cilegon city. *International Journal of Advanced Science and Technology*. https://www-scopus-com.ezaccess.remotexs.co/pages/publications/85081188664?origin=scopusAI

Wan-Chik, R. Z., Khairuddin, M. M. bin, & Rahman, N. A. A. (2023). Technology Application in Halal Logistics: Transport and Warehouse Perspective. In *Technologies and Trends in the Halal Industry* (pp. 206–220). Taylor and Francis. https://doi.org/10.4324/9781003368519-18

Wang, L., & Hsu, H. H. (2024). The Utilization of Geographic Information System in Logistics Distribution. *Proceedings of 2024 2nd International Conference on Internet of Things and Cloud Computing Technology, IoTCCT 2024*, 131–135. https://doi.org/10.1145/3702879.3702902

Wang, Y., Khodadadzadeh, M., & Zurita-Milla, R. (2023). Spatial+: A new cross-validation method to evaluate geospatial machine learning models. *International Journal of Applied Earth Observation and Geoinformation*, *121*. https://doi.org/10.1016/j.jag.2023.103364

Wibowo, A. T., Hariadi, M., Sulistyono, M. T., Khusnu Milad, M., Rhofita, E. I., & Bimo Gumelar, A. (2020). Mapping of tourism destinations by GIS-Blockchain RPCA based on PNPOLY Algorithm. *Proceedings - 2020 International Seminar on Application for Technology of Information and Communication: IT Challenges for Sustainability, Scalability, and Security in the Age of Digital Disruption, ISemantic 2020*, 412–416. https://doi.org/10.1109/iSemantic50169.2020.9234191

Wu, Z., Islam, S., & Tang, L. (2025). Visualizing ESG Performance in an Integrated GIS–BIM–IoT Platform for Strategic Urban Planning. *Buildings*, *15*(18). https://doi.org/10.3390/buildings15183394

Yakubu, M. M., Hassan, M. F. B., Danyaro, K. U., Yakubu, B. M., Alabdulatif, A. A., Beevi, S. Z., & Garba, A. (2025). HalalChain: A decentralized blockchain model for enhanced data integrity, real-time compliance, and automated verification in halal food supply chain. *Results in Engineering*, *27*. https://doi.org/10.1016/j.rineng.2025.106591

Yao, X. A. (2020). Georeferencing and Geocoding. *International Encyclopedia of Human Geography*, 111–117. https://doi.org/10.1016/B978-0-08-102295-5.10548-7

Yuan, Z. J., Chux, Y. M., & Shen, Y. J. (2009). The application of 3S technologies in modern logistics information system. *Proceedings of the 2009 International Conference on Machine Learning and Cybernetics*, *5*, 2719–2723. https://doi.org/10.1109/ICMLC.2009.5212637

Zhang, Q. yu, Zhang, Y. Y., Liu, J. S., Li, X. C., Zhu, Z. L., Feng, X. Y., Han, L. F., Zhu, C. Di, Tun, H. M., Zong, L., & Zhang, X. (2025). Integrating One Health governance in China: Assessing structural implementation and operational entry points. *One Health*, *21*. https://doi.org/10.1016/j.onehlt.2025.101209

Zhen, T., Ge, H., Jiang, Y., & Che, Y. (2010). GIS-based spatial decision support system for grain logistics management. *Proceedings of SPIE - The International Society for Optical Engineering*, *7749*, 77491T. https://doi.org/10.1117/12.871031

Zrelli, I., & Rejeb, A. (2024). A bibliometric analysis of IoT applications in logistics and supply chain management. *Heliyon*, *10*(16). https://doi.org/10.1016/j.heliyon.2024.e36578