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OPTIMIZING HALAL ZONE LAYOUTS IN INDUSTRIAL ESTATES FOR WAREHOUSING AND DISTRIBUTION: A SPATIAL MODELING APPROACH UTILIZING QGIS

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Abstract

This study develops a comprehensive spatial modeling framework for optimizing halal zones dedicated to warehousing and distribution within industrial estates in Indonesia. Employing Geographic Information System (GIS) tools—particularly QGIS—the research integrates buffering, overlay, and zoning analyses to identify and evaluate potential halal-compliant industrial areas based on accessibility, land suitability, and contamination risk. Data from West Java's industrial corridors reveal four viable sites (KM42, KM62, KM71B, and KM72A), with KM72A demonstrating superior strategic positioning due to high connectivity, low contamination risk, and ample capacity. The proposed model conceptualizes halal zones as integrated spatial entities designed to ensure strict product segregation, traceability, and adherence to Islamic principles. The study bridges theoretical constructs of halal assurance with pragmatic spatial planning methodologies, offering a replicable GIS-based approach to halal industrial zoning. From a policy perspective, it provides actionable insights for governments and industry actors to strengthen halal logistics infrastructure, thus supporting Indonesia's ambition to become a global halal hub. The fusion of geospatial analytics and halal governance in this study represents a strategic advancement toward transparent, efficient, and sustainable halal industrial ecosystems.

Keywords: ***Halal Logistics; Industrial Estate; Spatial Modeling; QGIS; Halal Zone Planning.***

INTRODUCTION

The halal sector has evolved from a specialized niche into a significant global economic force, encompassing diverse industries such as food, pharmaceuticals, cosmetics, fashion, and logistics (Karudin et al., 2024). Reports indicate that Muslim consumer expenditure on halal products has exceeded USD 2.3 trillion, with an annual growth rate surpassing 6%. This expansion is driven not only by the increasing global Muslim population but also by a heightened awareness of halal lifestyle principles among both Muslim and non-Muslim consumers, consequently escalating the imperative for an integrated halal supply chain spanning production to distribution (Abbas et al., 2025). Indonesia, as the nation with the largest Muslim population globally, possesses substantial potential to emerge as a leader in the international halal economy. The government has designated the halal industry as a national priority within the Masterplan Ekonomi Syariah Indonesia, aiming to transform the country into a global halal hub (Christanti et al., 2023). However, despite governmental support, the infrastructure supporting the halal industry, particularly in logistics and warehousing, remains underdeveloped. Many existing industrial zones have yet to incorporate halal principles into their spatial planning and operational frameworks.

Halal logistics fundamentally diverges from conventional logistics by mandating the preservation of product integrity in accordance with Islamic law across all stages of movement and storage (Karıa & Deng, 2025). Core requirements include the stringent segregation of halal and non-halal materials, comprehensive contamination prevention measures, the establishment of dedicated logistics routes, and robust traceability mechanisms (Rizapoor, 2024). Without appropriate spatial and operational design, the integrity of halal products is compromised, especially within mixed industrial estates where both halal and non-halal goods are processed or stored (Andespa et al., 2024). In this context, the concept of a Halal Zone has gained prominence as a spatial intervention to ensure halal integrity within industrial estates. A halal zone constitutes a designated area engineered and managed to adhere to halal requirements, encompassing its infrastructure, layout, and management protocols. The development of such zones

necessitates a multidisciplinary approach, integrating considerations from logistics, industrial design, environmental planning, and Sharia compliance (Karudin et al., 2024; Shariff et al., 2024). Nevertheless, most industrial zones in Indonesia are developed primarily based on general economic and infrastructure criteria, with limited consideration for specific halal requirements. This often results in warehouses, logistics centers, and distribution hubs lacking adequate physical and systemic segregation between halal and non-halal operations (Husna et al., 2024). This spatial deficiency presents a substantial impediment to achieving a fully integrated halal ecosystem. To address this lacuna, the application of spatial modeling and geospatial analysis becomes essential for objectively identifying potential halal zones and effectively planning their layouts (Urus et al., 2025a).

Geographic Information Systems, particularly QGIS, have proven to be potent instruments for spatial-based decision-making in industrial development. Through advanced spatial analysis techniques, including buffering, overlay analysis, and proximity modeling, GIS can delineate optimal areas for specific functions, such as halal logistics zones. By integrating environmental and infrastructural data, GIS-driven analyses ensure that halal zone development aligns with logistical efficiency, land use planning objectives, and contamination risk mitigation strategies (Muslih et al., 2025). In West Java, one of Indonesia's most industrialized provinces, the rapid expansion of manufacturing zones and logistics infrastructure offers a strategic opportunity for developing halal zones (Andespa et al., 2024). The region benefits from an extensive network of toll roads, industrial parks, and rest areas, which serve as critical nodes within national supply chains. Despite these advantages, spatially integrated planning for halal logistics remains limited. Therefore, employing QGIS to map and evaluate potential halal zones can establish a scientific basis for selecting suitable sites for halal warehouses and distribution centers (Huda et al., 2024).

The establishment of halal-compliant warehousing and distribution systems is not merely a religious imperative but also a strategic economic maneuver. Robust halal logistics infrastructure enhances product trustworthiness, facilitates access to global halal markets, and supports Indonesia's aspiration to become a leading halal exporter (Basuki & Maulidizen, 2025). Furthermore, it safeguards consumer interests and reinforces industry credibility, aligning with the objectives of the Halal Product Assurance Agency and the national halal certification system (Ramadhan et al., 2024). A spatially informed methodology for halal zone planning offers numerous advantages, including the integration of logistical efficiency with halal assurance, optimized land utilization, and the promotion of sustainable industrial growth (Shariff et al., 2024). Moreover, spatial modeling empowers policymakers to visualize priority areas, assess environmental risks, and guide investment decisions effectively. This study, therefore, endeavors to bridge the gap between halal compliance requirements and spatial planning methodologies through the application of QGIS-based modeling (F. A. M. Zain et al., 2024).

Despite increasing awareness regarding halal logistics, there remains a notable absence of spatial-based models to guide policymakers and industrial planners in the identification and development of halal zones. Industrial estates frequently encounter spatial, infrastructural, and environmental challenges that impede the establishment of halal-compliant warehousing and distribution systems (N. F. M. Zain et al., 2022). Existing planning approaches often prioritize economic or infrastructural aspects over halal compliance and contamination control. Consequently, there is limited empirical evidence demonstrating how spatial data analysis—utilizing tools such as GIS and QGIS—can be systematically applied to model and visualize halal zones. This significant gap underscores the necessity for a geospatial framework that synthesizes technical, religious, and logistical perspectives to support the development of halal zones in industrial areas (Alourani & Khan, 2025).

The objectives of this study are: to identify and map industrial estates with the potential for development into halal zones for warehousing and distribution; to determine strategic locations for halal warehouses by analyzing halal contamination risks and logistical accessibility; to develop a spatial model using QGIS for visualizing potential halal zones within industrial estates; to design a comprehensive halal zone implementation concept encompassing facility standards, distribution flow systems, and halal supervision mechanisms; and finally, to provide strategic recommendations for local governments and industry stakeholders concerning the planning and development of halal-compliant warehouse infrastructure, thereby strengthening Indonesia's halal logistics ecosystem.

This study significantly contributes to the evolving body of knowledge on spatial planning for halal supply chain management by proposing a reproducible GIS-based model for halal zone identification and design (Rochim et al., 2024). Academically, it introduces an integrative spatial methodology that interlinks halal logistics, industrial layout design, and environmental assessment. Practically, the research offers evidence-based insights for policymakers, industrial estate developers, and halal certification authorities to effectively design and manage halal-compliant infrastructure. The findings are anticipated to bolster Indonesia's competitiveness in the global halal market by fostering the creation of efficient, sustainable, and contamination-free halal logistics zones. Ultimately,

this research fortifies the foundation for Indonesia's transition towards a scientifically grounded halal industrial ecosystem, harmonizing spatial development policies with the broader national halal economy agenda.

LITERATURE REVIEW

1. The Concept of Halal Logistics and Warehousing

Halal logistics encompasses the comprehensive management of material, information, and financial flows within the supply chain, strictly adhering to Islamic principles to guarantee product purity and freedom from non-halal contamination (Putit et al., 2025). This includes meticulous handling from raw material sourcing to final delivery, ensuring every stage complies with Sharia law (Susanty et al., 2025). The complexity of the halal supply chain network and the potential for a lack of transparency necessitate robust management techniques to uphold the authenticity of halal products (Ismail et al., 2024). Crucially, this involves preventing cross-contamination, ensuring proper storage, and maintaining detailed records of material flow, all of which are essential for upholding halal integrity throughout the logistics process (Mahadi, 2023).

The primary objective and focus of the halal supply chain are to expand halal integration under Sharia law, from procurement to production and ultimately to the consumer's point of purchase (Aini & Safira, 2021). Therefore, implementing rigorous halal certification standards is paramount for shaping effective halal supply chain practices, focusing on traceability, compliance, and operational efficiency (Ali et al., 2021). This comprehensive approach is vital for ensuring the integrity and legitimacy of halal products, especially within the micro, small, and medium processing industries (Nugroho et al., 2024). Research into halal logistics and supply chain management has highlighted several key areas of development, including conceptual models, critical control points, and strategic approaches, yet a significant gap persists in integrating spatial planning with these considerations (Qurtubi & Kusrini, 2018).

For instance, while previous studies have underscored the importance of halal integrity from raw material sourcing to final delivery, especially within the food sector, they often overlook the geographical implications of establishing and managing compliant logistical infrastructures (Susanty et al., 2025). This oversight creates a void in understanding how spatial data analysis, particularly through GIS, can optimize the location and design of halal zones to mitigate contamination risks and enhance supply chain efficiency (Aini & Safira, 2021). Furthermore, the distinctive requirements of halal supply chain management, differing significantly from conventional approaches, necessitate specific design parameters across supply chain objectives, logistics control, and network structures, which inherently involve spatial considerations (Tieman et al., 2012). Thus, developing a comprehensive halal supply chain model requires not only an understanding of product characteristics and market requirements but also a geographical dimension to strategically place control activities and assurance measures.

This includes managing relevant information and certification standards throughout the operation and supply chain, aligned with the foundational principles of Sharia (Karıa & Deng, 2025). Differences in halal requirements across various markets, influenced by Islamic schools of thought, local fatwas, and customs, further complicate the establishment of standardized halal supply chains (Ratnasari et al., 2020). These variations highlight the necessity for unified certification frameworks and increased cross-border collaboration to streamline trade and enhance supply chain integrity globally (Ali et al., 2021). The imperative for a robust halal logistics standard has been widely acknowledged to support the international growth of the halal supply chain (Aini & Safira, 2021). However, despite the growing importance of the global halal market, many halal companies, particularly in Malaysia, often lack the requisite resources to identify and implement effective strategies for enhancing their performance and competitiveness while adhering to these stringent standards (Karudin et al., 2024).

A systematic literature review examining challenges in Malaysian halal logistics, for instance, identified high operational costs, a lack of knowledge, and inadequate management as primary hurdles, underscoring the complexities involved in maintaining halal integrity throughout supply chain processes (Husna et al., 2024). This situation is exacerbated by the general underrecognition of halal logistics within mainstream logistics and decision sciences, which risks undermining its future viability without concerted efforts toward global standardization and technological integration (Talib, 2024). Moreover, entrepreneurs often fail to fully grasp the significance of halal principles and their potential to attract consumers, despite organizations like MATRADE actively encouraging the adoption of technology to improve productivity and quality within the halal sector (Azmi et al., 2018).

2. Industrial Estates and the Halal Ecosystem

In this context, industrial estates offer a structured environment conducive to establishing dedicated halal zones, thereby mitigating contamination risks and streamlining the certification process for businesses. Such zones

can facilitate the implementation of stringent halal assurance systems, from raw material handling to final product distribution, ensuring compliance with Sharia principles at every stage (Zain et al., 2018). They also provide a centralized platform for improved coordination among governmental bodies, industry players, and academic institutions, which is essential for reinforcing adherence to halal standards and facilitating the export-oriented marketing strategies necessary for global competitiveness (Urus et al., 2025b). This integrated approach is crucial for fostering consumer trust, as product guarantees and country of origin significantly influence purchasing decisions for halal products, especially those from predominantly Muslim countries (Aini & Safira, 2021).

\Furthermore, the establishment of halal industrial estates can significantly boost the competitiveness of Micro, Small, and Medium Enterprises by providing them with the necessary infrastructure and support to obtain halal certification, thereby increasing their market access and consumer willingness to pay for their products (Salsabila et al., 2025). This is particularly critical in regions like Indonesia, where MSMEs form the backbone of the economy but often face challenges in achieving halal certification and competing with larger multinational companies (Pratikto et al., 2023). The proactive development of robust halal standards within these specialized industrial estates is therefore crucial, mirroring efforts seen in leading halal industry nations such as Malaysia, Indonesia, the Philippines, and Thailand (Rahman et al., 2020).

These standardized frameworks are essential for fostering consumer trust and supporting the growth of the industry by providing clear guidelines for halal integrity from production to distribution (Muharni et al., 2025). Despite Indonesia's historical prominence in halal food production and certification, its halal industry now faces intense competition and internal challenges, highlighting the urgent need for strategic infrastructure development to regain its leadership position. A critical aspect of this strategy involves leveraging enhanced access to Sharia-compliant financing and capital sources, which are pivotal for integrating MSMEs into the halal industry ecosystem and upholding Sharia principles in financial transactions (Ghoni et al., 2025). This financial integration is crucial for addressing the existing infrastructure and production constraints that hinder the development of the halal industry, especially given the fragmented regulatory landscape and inconsistencies in standards within Indonesia (Sahir et al., 2021).

The Financial Services Authority's master plan for 2021-2025 aims to create a stable and inclusive financial sector that supports Indonesia's economic growth, which includes fostering the halal value chain by addressing the urgent need for a financial system free from usury and responsive regulations (Laksono, 2022). This strategic alignment emphasizes the importance of Islamic finance principles in underpinning the halal ecosystem's development, thereby attracting investments and facilitating sustainable growth across all sectors of the halal industry (Y. Hidayat et al., 2025). Such efforts are pivotal for fostering a harmonious system where industrial collaboration can thrive, allowing investors to channel long-term funds into the halal industry and ensuring that Muslim workers and producers possess a deep understanding of halal practices and ethical standards (Sahir et al., 2021).

This further necessitates integrated government policy support across investment, production, and export, alongside improvements in human resources, to fully realize Indonesia's potential as a global halal economy hub (Waluyo, 2020). Moreover, the challenges confronting Indonesia's halal industry, including external competition and the absence of internationally recognized halal certificates, necessitate robust governmental intervention and stakeholder support to strengthen its competitive edge and ensure global market acceptance (Trimulato, 2021). Addressing these challenges requires a comprehensive strategy that not only streamlines the halal certification process but also enhances consumer and producer awareness regarding its multifaceted benefits, thereby strengthening trust and market penetration (Pratikto et al., 2023). This strategic framework must encompass the legal aspects and governmental policies crucial for increasing the role of MSMEs within the halal ecosystem, recognizing that stronger governmental regulations and industry standards are essential for Indonesia to become a leader in the global halal industry (Ghoni et al., 2025).

3. Spatial Planning and GIS in Industrial Development

Integrating Geographic Information Systems with spatial planning offers a powerful methodological approach to strategically optimize the location and design of halal industrial estates, ensuring efficient resource allocation and adherence to Sharia-compliant logistical flows. This approach enables precise mapping of supply chains, identification of suitable sites that minimize contamination risks, and the establishment of robust infrastructure tailored to halal production requirements. Specifically, GIS can facilitate multi-criteria analysis to select optimal locations for halal industrial zones, considering factors such as proximity to raw material sources, transportation networks, and availability of skilled labor, while also accounting for environmental and social impacts (Yudha et al., 2020).

Moreover, GIS technology can also model the flow of goods and services within these estates, optimizing logistical efficiency and minimizing the potential for cross-contamination between halal and non-halal products, thereby strengthening the integrity of the halal certification process (Dewi & Sa'adah, 2024; Pratikto et al., 2023). The strategic integration of GIS with multivariate analysis can further enhance supply chain management digitalization within the halal industry, providing a sophisticated tool for solving complex logistical and operational challenges from production to consumption (Muslih et al., 2025). This digital integration is crucial for addressing the current fragmentation in Indonesia's halal supply chain and enhancing overall transparency and traceability (Anwar & Sarip, 2024). Furthermore, this advanced spatial analysis can aid in developing infrastructure that supports robust halal ecosystems by identifying optimal locations for supporting services such as halal certification bodies and research centers (Urus et al., 2025a).

Such integrated approaches, encompassing both spatial and analytical methodologies, are vital for transforming Indonesia's halal industry into a globally competitive and sustainable sector, ultimately driving economic growth and ensuring consumer confidence in halal products (Bakhri et al., 2021). The application of spatial analysis extends beyond industrial estate planning to include sustainable agro-industry logistics, optimizing the movement of halal-certified agricultural products by minimizing supply and demand imbalances (Hardjomidjojo et al., 2022). This is particularly relevant for the fisheries sector, where spatial analysis combined with data mining can mitigate supply chain uncertainties and enhance regional development through targeted agro-industrial placement (Teniwut et al., 2020).

Moreover, this robust integration of spatial analysis can extend to optimizing site selection for aquaculture, including marine fish cage, aquaculture management areas, mangrove oyster raft culture, and offshore marine fish farms, ensuring adherence to halal principles and environmental sustainability (Teniwut et al., 2018). Ultimately, the comprehensive implementation of these spatial and analytical tools offers a pathway to not only enhance the efficiency and integrity of the halal supply chain but also to foster sustainable practices across various sectors of the halal industry, including food, pharmaceuticals, and cosmetics (S. E. Hidayat & Musari, 2021). This holistic approach underpins the development of a resilient and competitive halal ecosystem, critical for Indonesia's ambition to become a global leader in the halal industry (Judijanto et al., 2025).

Specifically, the digitalization of halal certification services, such as through the SIHALAL application, is anticipated to bolster the halal ecosystem and elevate the global competitiveness of certified products (Ernawati et al., 2024). This digital framework not only streamlines the certification process but also enhances the overall integrity and global market acceptance of halal products by providing a transparent and traceable supply chain (Jannah & Al-Banna, 2021). Despite its potential, only a small fraction of certified products currently demonstrate global competitiveness. This highlights the critical need for further strategic interventions, including enhanced logistical frameworks and market penetration strategies, to fully leverage the advantages offered by digital certification and elevate Indonesia's stature in the global halal market (Purwanto et al., 2024).

4. Research Gap

Despite considerable advancements, a critical research gap persists in the comprehensive theoretical framework integrating the multifaceted elements of halal supply chain integrity with technological innovations and spatial analytics (Shariff et al., 2024). Specifically, there is a notable absence of studies exploring the synergistic application of Industry 4.0 technologies, such as Artificial Intelligence and blockchain, within the intricate context of halal certification processes and meat supply chain integrity (Ellahi et al., 2025; Ridho, 2025). While some research acknowledges the general benefits of information technology, blockchain, and artificial intelligence for halal ecosystems and traceability, a focused analysis on their practical implementation to resolve integrity challenges, particularly cross-contamination and fraud in halal meat supply chains, remains largely underexplored (Elbadiansyah et al., 2024).

This gap is particularly salient given the increasing complexity of global supply chains and the imperative to ensure end-to-end halal assurance, where AI can automate the identification of non-halal materials and blockchain can provide secure, transparent traceability (Alourani & Khan, 2025). Moreover, current literature often overlooks the specific challenges and opportunities presented by Indonesia's unique socio-economic and infrastructural landscape in adopting these advanced digital solutions for halal agricultural supply chains (Keefe et al., 2024). Furthermore, while the benefits of technologies such as IoT for enhancing traceability and efficiency in halal food supply chains have been identified, the integration of these with AI and blockchain to create a holistic and immutable record-keeping system for halal compliance is not yet fully conceptualized in the literature (Rejeb et al., 2021; Sunmola et al., 2025).

This omission prevents a complete understanding of how these technologies can collectively fortify halal integrity against sophisticated forms of fraud and contamination (Bux et al., 2022). Therefore, a robust system leveraging both AI and blockchain is crucial to establish trust and ensure the authenticity of halal food products by providing immutable traceability throughout the entire supply chain, from sourcing raw materials to final consumption (Maulidizen, 2019b). Such a system could overcome the current limitations of disparate halal certification standards and regional variations by offering a unified, transparent, and verifiable framework (Alourani & Khan, 2025). This comprehensive framework addresses critical challenges such as the lack of universally accepted halal certifications and variability in standards, which are often complicated by regional differences and divergent interpretations among Islamic schools of thought.

METHOD

1. Research Approach

This study employs a mixed-methods research design, integrating both qualitative and quantitative analytical approaches, to construct a comprehensive spatial model for the implementation of halal zones within industrial estates (Mangestuti & Aziz, 2023). The qualitative dimension focuses on elucidating the operational, regulatory, and ethical facets of halal logistics through documentary analysis and expert interviews, while the quantitative component utilizes Geographic Information System tools for spatial mapping and geostatistical modeling (Maulidizen, 2019a). This combined methodological strategy facilitates a deeper comprehension of both the contextual realities and the quantifiable spatial parameters pertinent to developing halal-compliant warehousing and distribution systems (Das, 2025).

This dual approach is essential for developing a robust framework that not only addresses the integrity challenges in the halal supply chain but also accounts for the specificities required for global scalability and acceptance (Alourani & Khan, 2025). Specifically, the qualitative approach explores how integrating Maqasid Syariah principles with digital transformation can enhance governance and transparency in the halal industry (Zulkifli & Yusuf, 2023). Conversely, the quantitative phase utilizes advanced analytical techniques, such as surveying halal-certified companies, to assess risk management strategies and identify crucial partnerships for mitigating supply chain vulnerabilities (Johan et al., 2025). This mixed-methods design allows for a nuanced investigation into how digital transformation, encompassing AI and blockchain, can establish end-to-end transparency and accountability in the halal supply chain, thereby addressing issues like cross-contamination and fraud (Nashirudin et al., 2024).

2. Data Collection

Data collection encompassed a mixed-method approach, integrating both primary and secondary sources to ensure robust empirical accuracy and contextual relevance. Primary data were systematically acquired through direct field observations and semi-structured interviews with key stakeholders (Belina et al., 2025). These stakeholders included representatives from industrial estate management, halal certification bodies, local governmental authorities, and logistics operators. The interviews aimed to ascertain current operational practices, identify existing challenges, and uncover policy deficits pertinent to establishing halal-compliant logistics infrastructure. Complementary secondary data were obtained from authoritative documents, such as comprehensive spatial plans, industrial estate masterplans, national halal certification standards, and prior academic research (Amin et al., 2024).

Furthermore, an extensive array of geospatial datasets, including land use maps, transportation networks, topographic information, and environmental layers, was collected from governmental entities, notably Indonesia's Geospatial Information Agency and the Ministry of Industry. These datasets were critical for the subsequent spatial analysis and modeling phases, providing the foundational layers for evaluating potential halal zone locations and assessing logistical accessibility (Muslih et al., 2025). This multi-faceted data collection strategy ensured a comprehensive understanding of both the regulatory landscape and the physical attributes necessary for the development of effective halal logistics hubs. The systematic integration of these diverse datasets facilitated advanced multi-layered spatial analysis within the QGIS environment. For instance, transportation data offered crucial insights into logistical accessibility and supply chain efficiency, while environmental data were instrumental in evaluating potential contamination risks. This comprehensive integration of regulatory, infrastructural, and environmental datasets enabled a thorough assessment of each prospective site's suitability for halal zone development. The amalgamation of primary qualitative data with extensive secondary geospatial information allowed for a nuanced evaluation of sites, addressing both the tangible infrastructure and the intangible regulatory and social acceptance factors crucial for successful halal zone implementation (Droste & Gianoli, 2024).

To ensure the integrity of the findings, data validation was meticulously performed through triangulation. This involved cross-verifying information derived from interviews against spatial data and documentary evidence. This methodological rigor ensured that the research outcomes accurately reflected both spatial realities and institutional viewpoints. Additionally, validation meetings were conducted with esteemed experts in halal logistics and spatial planning to corroborate the precision of the defined zoning parameters and risk assessment criteria. Ultimately, this systematic and comprehensive data collection methodology established a robust empirical foundation for developing and validating a GIS-based halal zone model. This approach enhanced both analytical depth and policy relevance by seamlessly integrating qualitative insights with spatial data.

3. Data Analysis

The analytical process in this study consists of two main stages: qualitative thematic analysis and spatial analysis using QGIS. Thematic analysis was employed to identify recurring themes from interviews and documents related to halal compliance, logistics operations, and industrial estate management. These themes were then translated into spatial parameters such as contamination buffer zones, logistics access corridors, and facility zoning standards (Anggraini et al., 2024). Subsequently, the spatial analysis was conducted using QGIS, an open-source GIS platform that provides powerful tools for spatial data manipulation, mapping, and modeling. Key analytical techniques included buffering analysis (to determine safe distances between halal and non-halal operations), overlay analysis (to integrate multiple spatial layers such as land use, road networks, and industrial facilities), and proximity analysis (to measure accessibility to transport nodes like ports or highways). Each layer was weighted based on its relevance to halal compliance and logistics efficiency (Muslih et al., 2025).

A Multi-Criteria Decision Analysis (MCDA) approach was implemented within QGIS to evaluate and rank industrial sites according to their suitability for halal zone development. Criteria such as contamination risk, infrastructure readiness, and logistical accessibility were assigned specific weights derived from expert consultation. The weighted overlay output produced a spatial suitability map, identifying high-potential areas for halal warehouse placement. The results of the spatial analysis were interpreted in conjunction with qualitative findings to ensure contextual relevance. For instance, spatially suitable zones were further assessed for regulatory feasibility, community acceptance, and alignment with halal assurance requirements. This combined analytical process bridges technical precision and policy applicability, ensuring that the final model is not only data-driven but also socially and religiously compliant. Through this dual-layered analysis, the study produces a spatial decision-support framework that can guide policymakers, developers, and logistics firms in implementing halal-compliant industrial zoning strategies. The framework's adaptability allows for replication in various geographic contexts within Indonesia and beyond.

4. Model Development

The development of the Halal Zone Spatial Model involved transforming the analytical findings into a conceptual and visual representation of halal-compliant warehousing and distribution systems within industrial estates. This model integrates three key dimensions: (1) spatial zoning, (2) facility design standards, and (3) logistics flow management. Each dimension contributes to ensuring that industrial activities adhere to halal principles while maintaining operational efficiency. The spatial zoning dimension defines the allocation of halal, non-halal, and neutral zones within industrial estates. QGIS-generated maps identify optimal locations for halal warehouses and delineate buffer zones to prevent contamination. These spatial layers form the foundation for planning dedicated halal logistics corridors and controlled access points. The zoning model also incorporates environmental safety measures, such as drainage systems and waste management areas, that comply with halal assurance guidelines.

The facility design standards dimension focuses on the physical and operational aspects of warehouse management. Drawing upon MS 2400:2019 and Indonesia's Halal Product Assurance Law, this component specifies requirements for material handling, storage layout, and hygiene facilities. For example, unidirectional flow patterns are recommended to minimize contact between halal and non-halal goods, and cleaning protocols are standardized to maintain product purity. The logistics flow management dimension governs the movement of goods and information across the halal supply chain. It includes the design of halal-only transport routes, documentation processes for traceability, and supervision mechanisms by halal auditors. By integrating these three dimensions, the proposed model serves as both a spatial planning tool and an operational guideline for halal industrial development. The model was validated through expert review sessions and iterative feedback. Stakeholders from academia, government, and industry assessed the model's feasibility and alignment with real-world operational constraints. The

validated model not only visualizes spatial arrangements but also provides actionable policy insights for implementing halal-compliant infrastructure in industrial estates.

5. Research Validity and Ethical Considerations

Ensuring the validity and reliability of the research outcomes required rigorous methodological controls and ethical compliance. Internal validity was maintained through triangulation—cross-referencing interview data, regulatory documents, and spatial analyses. External validity was reinforced by selecting diverse industrial sites representing varying geographic, infrastructural, and regulatory contexts. This diversity increases the model's generalizability to other industrial estates across Indonesia. Reliability was ensured through the use of standardized GIS procedures and transparent documentation of analytical parameters. Each step of the spatial analysis—data preparation, weighting, buffering, and overlay—was recorded and reproducible, allowing future researchers to replicate or modify the model based on new data inputs. The use of open-source QGIS software also promotes methodological transparency and accessibility.

Ethical considerations were observed throughout the research process. Informed consent was obtained from all interview participants, and sensitive information related to industrial operations was anonymized. The study strictly adhered to ethical guidelines concerning data privacy, integrity, and respect for cultural and religious sensitivities in halal-related research. Furthermore, the research upholds Shariah compliance not only as an object of study but as an ethical foundation guiding data interpretation and model formulation. This alignment between methodology and moral principles strengthens the credibility of the study within both academic and Islamic governance frameworks. By maintaining high standards of validity, reliability, and ethical integrity, this research ensures that the resulting halal zone spatial model is both scientifically robust and socially responsible. It stands as a replicable reference for policymakers, planners, and industry leaders committed to advancing halal logistics through data-driven and ethically grounded spatial design.

RESULTS AND DISCUSSION

1. Overview of the Study Area

West Java's geographical and infrastructural configuration positions it as a pivotal node within Indonesia's national logistics network. The province's dense manufacturing clusters, interconnected toll road corridors such as Cikampek, Cipali, and Purbaleunyi, and its extensive distribution grid linking Jakarta, Bandung, and Central Java make it an ideal testing ground for halal logistics spatial planning. This configuration amplifies the urgency of structured spatial governance for halal compliance, since the massive volume of commodity movement inherently increases the likelihood of cross-contamination if not properly managed. The selection of West Java as a case study thus provides strong practical relevance for national-level policy formulation.

Dependence on toll corridors as logistical arteries produces a distinctive spatial pattern: warehouse and distribution centers cluster densely along toll access points. While this pattern enhances distribution efficiency, it also generates spatial risks when non-halal facilities operate within overlapping logistical spheres. Projecting all datasets to EPSG:32748 (UTM Zone 48S) allowed for precise metric-based spatial analysis, capturing location-specific details often missed by macro-scale planning. This spatial precision ensures that recommendations are grounded in real operational geography rather than abstract zoning concepts.

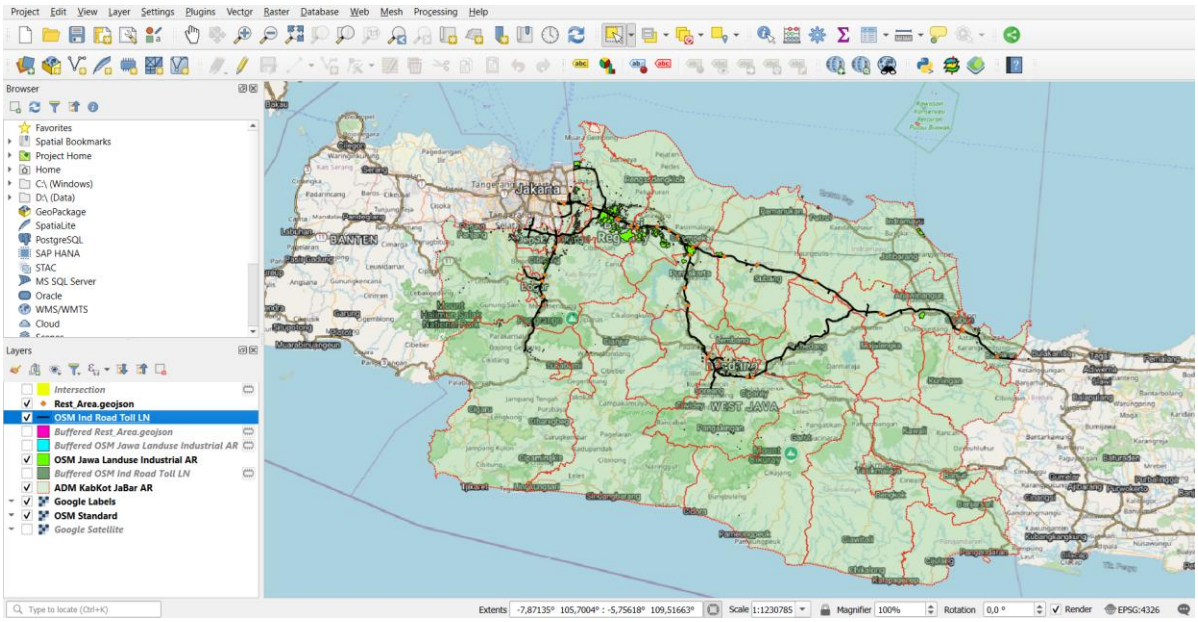

Figure 1 Research Area : West Java

The industrial composition of West Java—dominated by automotive, chemical, food-processing, and logistics industries—creates a dual challenge: the demand for large-scale facilities and diverse contamination risks. For example, chemical factories may emit airborne or liquid pollutants that degrade the surrounding environmental quality of halal storage sites, while non-halal food processors pose a risk of direct physical contamination. Such a mixed industrial environment confirms that identifying halal-compatible zones cannot rely solely on land availability or road access; environmental and industrial risk assessments must play an integral role in site evaluation. The base map generated in QGIS (Figure 1) illustrates the overlapping distribution of industrial clusters and toll corridors. The visualization reveals a fragmented yet interconnected industrial landscape, forming logistical "chains" that require flexible, multi-level zoning strategies. This spatial representation is crucial because it allows planners to pinpoint frontline risk zones and logistical nodes that can potentially be transformed into halal nodes, provided other compliance criteria are met. It bridges spatial theory with practical site identification.

From a spatial planning perspective, a fundamental tension emerges between economic imperatives—land optimization for industrial growth—and halal requirements, which emphasize segregation and environmental hygiene. West Java exemplifies this conflict: escalating land conversion pressures and high warehouse demand leave halal zoning options vulnerable to compromise. Therefore, the implementation of halal industrial estates must be supported by policy instruments beyond technical recommendations, including zoning incentives, buffer-based land-use restrictions, and integration into regional spatial plans (RTRW). Field surveys and stakeholder interviews integrated with spatial data further contextualized the analysis. Empirical findings confirm that some corridors possess robust supporting infrastructure—electricity, water supply, skilled labor—while others face operational constraints. These differences are decisive: environmentally "clean" sites may be economically unviable without basic infrastructure, and conversely, well-connected sites may suffer from environmental degradation (Maulidizen et al., 2024). The QGIS-based spatial framework visually and quantitatively highlights this trade-off, enabling evidence-based site prioritization.

Topography and drainage analysis, though not the central focus, emerged as critical determinants of halal zone reliability. Flood risk or polluted runoff can undermine the sustainability of halal facilities. In West Java, elevated sites such as those near KM72A demonstrate a clear advantage: reduced flood risk and cleaner surroundings strengthen their suitability for halal warehousing beyond simple accessibility metrics. This dimension underscores the value of integrating geophysical parameters into halal spatial modeling. In summary, West Java represents both strategic opportunity and structural complexity for halal zone development. High-precision spatial mapping through QGIS and EPSG:32748 provides a robust analytical tool to reconcile logistical priorities, halal assurance, and environmental constraints. The findings affirm that halal site selection must be grounded in spatial evidence that integrates multidimensional factors—economic, technical, environmental, and religious—to ensure sustainable and compliant implementation.

2. Spatial Buffering and Overlay Analysis

Buffering served as a central analytical technique in this research, transforming points and lines into measurable zones of spatial influence. The chosen radii—0.00135° (≈150 m) for industrial estates, 0.009° (≈1 km) for toll roads, and 0.0045° (≈500 m) for rest areas—were not arbitrary but derived from WGS84 geodetic conversions to ensure contextual geographic accuracy. These calibrated distances allowed the model to represent real-world operational conditions relevant to logistics, accessibility, and contamination risk. The 150-meter industrial buffer facilitated a micro-level spatial lens, identifying warehouses and production facilities that lie in immediate proximity. This micro-scale is essential for assessing potential physical contact, local airflow patterns, and waste pathways that could trigger cross-contamination. The analysis also evaluated residual land availability for halal-designated facilities within already congested industrial centers, providing a critical insight into spatial efficiency versus compliance.

The 1-kilometer buffer around toll roads functioned as a proxy for logistical accessibility. Sites within this range generally enjoy direct access to toll gates or feeder roads, an advantage for efficient goods distribution. Yet this accessibility also entails risk: higher transport intensity near toll corridors increases the probability of cross-supply contamination if separate halal transport lanes or procedures are not established. Thus, the analysis reframes proximity as both an advantage and a liability, contingent on infrastructural segregation. The 500-meter rest-area buffer identified potential zones for small-scale halal-supporting facilities such as inspection points, micro-warehouses, or certified halal outlets. Given that rest areas often function as informal transshipment hubs, mapping these as buffers enables the identification of feasible intervention nodes for halal monitoring and certification at key transit points. This aligns micro-scale compliance with macro-level logistics flows. Overlaying (intersecting) these buffer layers produced a technically strategic output: areas that overlap among industrial, toll, and rest-area buffers represent zones with both high accessibility and potential environmental cleanliness. However, intersection alone is insufficient. Follow-up analyses on land availability, infrastructure readiness, and RTRW compliance are necessary to avoid false positives—overlaps that look ideal spatially but fail environmentally or legally.

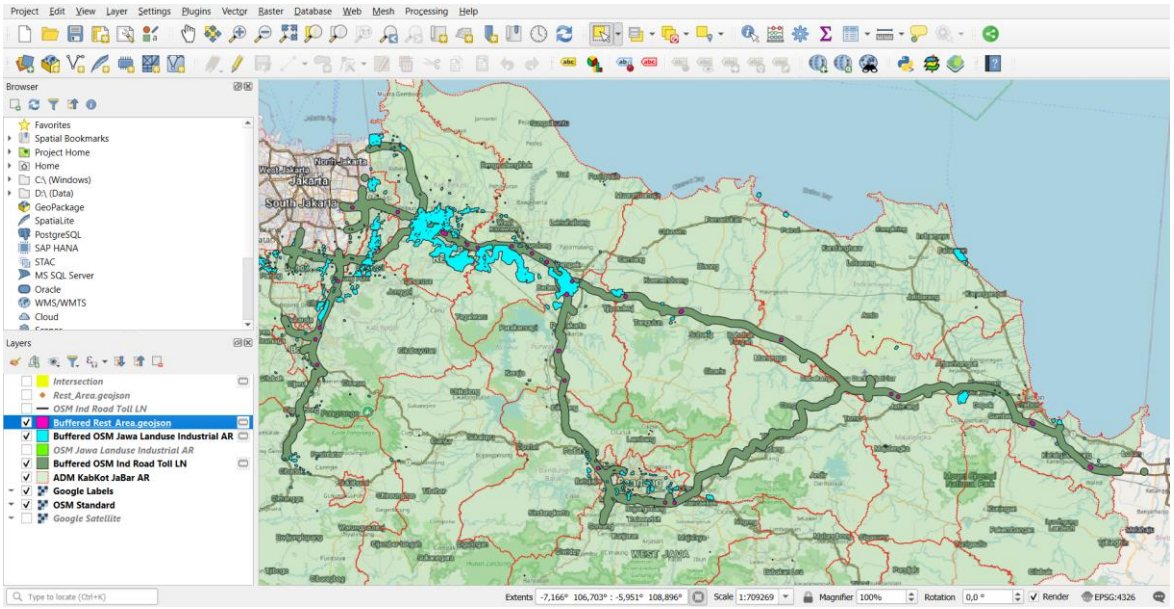

Figure 2 Buffered Area

The visualization of buffered areas (Figure 2) illustrates concentrated overlaps along the Cikampek–Subang corridor. These maps vividly reveal the classic trade-off: high-overlap areas promise logistical efficiency yet are frequently adjacent to non-halal activities. Consequently, buffer-overlay results must be interpreted alongside a risk matrix accounting for neighboring industrial types and environmental conditions.

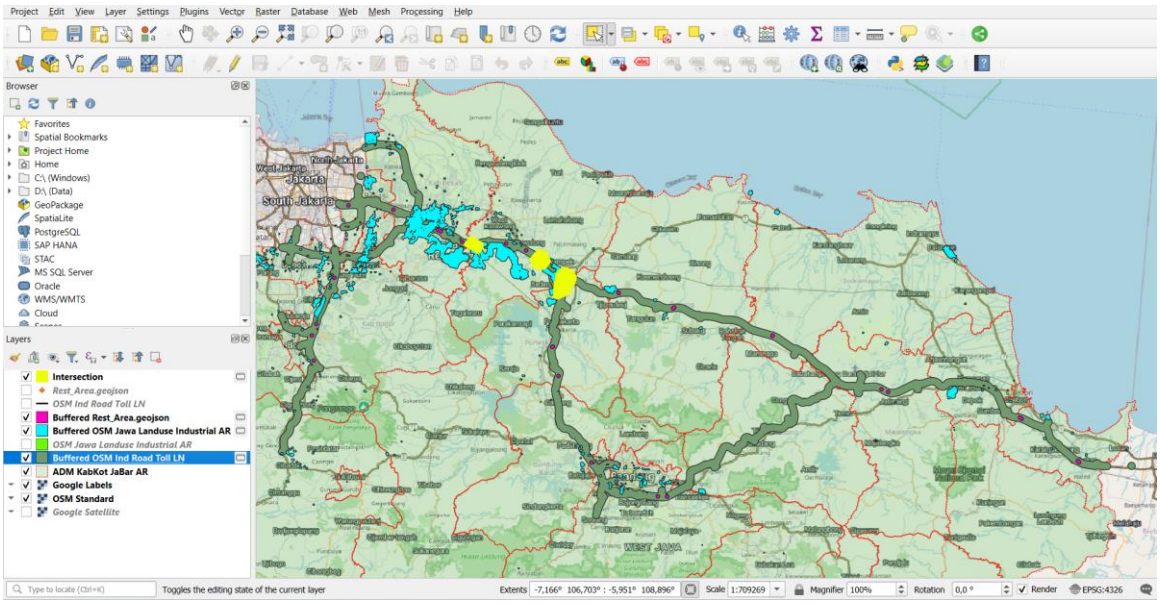

Figure 3 Intersection

Overlay analysis also serves as a communicative instrument for policymakers. The intersection map (Figure 3) provides spatial evidence easily understood by decision-makers when prioritizing halal zone sites. Nevertheless, these maps also signal where structural interventions—such as sanitation facilities or exclusive halal transport corridors—must precede halal designation. Thus, spatial evidence becomes both diagnostic and prescriptive. Critically, while the buffering–overlay method offers a powerful preliminary screening tool, it must be complemented with multi-criteria decision analysis (MCDA) and field verification. Buffering provides the quantitative foundation; final decisions require integrating legal, economic, and social dimensions to ensure sustainable halal zone implementation that is not merely spatially feasible but institutionally grounded.

3. Identification of Potential Halal Zones

The intersection results from the buffer and overlay analyses identified several spatial clusters across West Java that demonstrate both logistical viability and environmental compatibility for halal warehousing. Among these, the corridor spanning Cikampek–Subang–Purwakarta emerged as the most strategically advantageous. This corridor's dominance stems from its robust infrastructure, proximity to toll exits, and existing industrial ecosystem. However, the very intensity of industrial activity in this region necessitates strict spatial segregation protocols to prevent contamination from adjacent non-halal sectors. The analytical results therefore point toward a "controlled co-location" model—allowing halal and non-halal industries to coexist spatially but with infrastructural, operational, and regulatory boundaries clearly enforced.

Further analysis of spatial overlays revealed three primary concentration patterns of potential halal zones: (1) clustered formations near major toll corridors, (2) linear formations following arterial logistics routes, and (3) dispersed formations in peri-urban industrial zones. Clustered formations, such as those near Cikampek, offer immediate access to integrated logistics infrastructure but face land scarcity. Linear formations, like those observed along Cipali, offer scalability and reduced contamination risk due to spatial continuity and lower density. Dispersed formations in Purwakarta's peri-urban belt represent the cleanest spatial environment but face infrastructural deficits. Each typology presents a trade-off between accessibility, risk, and cost—an essential consideration in the final zoning recommendations.

An important dimension in the identification process lies in the risk-based spatial classification applied through QGIS raster reclassification. By assigning contamination risk scores based on proximity to non-halal industries, drainage flows, and air pollutant dispersion, the study integrates environmental health parameters into the spatial logic of halal designation. This approach departs from conventional industrial zoning, which rarely considers religious-compliance risks as quantifiable spatial variables. The result is a new methodological synthesis—Halal Spatial Risk Zoning (HSRZ)—which could serve as a replicable model for other provinces. Environmental sensitivity analysis further supports this risk-based classification. Areas with low air pollution index values and stable groundwater quality within a 1 km radius scored high on halal compatibility. Conversely, zones near high-emission

factories or waste treatment plants scored significantly lower (Maulidizen, 2019c). The combination of these variables demonstrates that halal zone suitability is not merely a logistical calculation but an environmental-ethical imperative, linking the spiritual concept of halal with the ecological principle of *tayyib* (purity and goodness) (Winanto et al., 2022). Socioeconomic factors also influence the spatial suitability of halal zones. Regions with high workforce availability, stable electricity grids, and established logistics service providers (e.g., Subang Industrial Estate) offer a foundation for sustainable halal operations. However, the study reveals that these advantages must be balanced with spatial justice concerns. For example, densely populated regions face displacement pressures if halal zones expand without community-inclusive planning. Therefore, potential halal zones must integrate participatory governance frameworks that involve local communities in decision-making to ensure that halal industrialization aligns with broader goals of sustainable development.

The analysis also highlights a policy misalignment between halal logistics aspirations and current regional spatial plans (RTRW). In several cases, potential halal-compatible areas are zoned for mixed industrial use without specific clauses for halal segregation. This regulatory gap underscores the need for regenerative spatial governance, in which halal industrial zoning is embedded not as an isolated policy but as a structural component of regional economic planning. The inclusion of halal parameters in RTRW revisions would thus transform halal logistics from a niche concept into a mainstream planning agenda. From a technological standpoint, the integration of QGIS spatial analysis with multi-criteria evaluation enhances decision transparency (Abdussalam & Auladi, 2024). The visualization outputs—layered maps indicating accessibility, contamination risk, and industrial compatibility—serve as tangible decision-support tools for policymakers (Purwanto & Hanif, 2024). This methodological framework transforms spatial data into actionable insight, facilitating cross-sector coordination between halal certification authorities, industrial estate managers, and local governments. Finally, the identification of potential halal zones reveals that while West Java's logistical corridors offer unparalleled connectivity, the sustainability of halal infrastructure depends on institutional discipline and environmental ethics. Spatial evidence confirms that halal compliance must extend beyond product certification to encompass the entire operational ecosystem—land use, infrastructure, waste management, and labor welfare (Azzaky et al., 2024). The spatial model thus becomes both a diagnostic and normative framework for advancing an integrated halal economy.

4. Spatial Model Interpretation and Conceptual Design

The spatial model developed through QGIS serves as both an analytical and conceptual framework for visualizing the potential implementation of halal zones within industrial estates. The model integrates multiple geospatial layers—industrial distribution, toll road networks, contamination risk zones, and accessibility hierarchies—into a single composite visualization. This synthesis enables a three-dimensional understanding of halal logistics geography, where each layer contributes to a multidimensional representation of spatial suitability. The resultant model is not merely descriptive but prescriptive: it provides an operational basis for land-use planning and policy intervention. At its core, the model demonstrates how halal logistics infrastructure must adhere to a graded zoning system. The inner core (radius ≤150 m) represents the operational halal zone—strictly segregated, certified, and monitored. The intermediate belt (150–500 m) acts as a controlled interface area accommodating support functions such as halal inspection, cold chain facilities, and transportation hubs. The outer buffer (500–1000 m) constitutes a transition zone that ensures environmental protection and minimizes cross-contamination. This concentric model translates religious principles into spatial logic, embedding halal ethics directly into the built environment.

The model's interpretive strength lies in its ability to reveal hidden conflicts between economic and ethical geographies. For instance, QGIS spatial overlays reveal instances where highly accessible sites overlap with pollution-prone industrial belts. While these locations are economically ideal, they are spiritually and environmentally incompatible with halal warehousing. This dichotomy forces a paradigm shift in spatial decision-making—from efficiency-centered planning to integrity-centered planning—where spatial integrity and ethical compliance become the ultimate measures of suitability. The incorporation of visual symbology within QGIS (e.g., color-coded risk layers and vectorized halal corridors) further enhances interpretability for non-specialist stakeholders. By visualizing contamination risk as graduated color intensities, the model conveys complex spatial data intuitively. Such visualization democratizes technical analysis, allowing policymakers, religious authorities, and industrial planners to engage in evidence-based dialogue. The resulting transparency fosters trust and facilitates multi-stakeholder consensus—a critical requirement for halal ecosystem governance.

The conceptual design of halal zones also integrates facility and operational standards. Each designated area must adhere to standards for physical segregation, waste management, water supply, and logistics routing. These standards are visualized as spatial polygons within the model, enabling planners to simulate different configurations and assess their implications (Mulyana et al., 2024). This approach effectively bridges the technical domain of spatial engineering with the normative domain of Islamic jurisprudence (fiqh al-sinah), ensuring that physical planning aligns with halal legal norms. The QGIS-based spatial model also supports scenario analysis, allowing simulation of future development trajectories. By adjusting parameters such as land conversion rates or toll expansions, planners can forecast how the halal spatial network will evolve under different policy conditions. This predictive capacity is invaluable for strategic planning, enabling proactive interventions before spatial conflicts arise. The model thus transforms halal zoning from a static designation into a dynamic spatial process.

From a methodological perspective, this model represents an innovation in the field of halal logistics research. Unlike prior studies focusing on certification systems or supply chain management, this study introduces a geo-spatial epistemology of halal—treating halal compliance as a spatially embedded phenomenon (Aufi et al., 2024). This shift redefines halal not merely as a legal status of goods but as a geographical system governed by ethical flows, material boundaries, and spatial accountability. Ultimately, the spatial model translates abstract principles of halal assurance into concrete planning instruments. It equips policymakers with visual and quantitative tools to institutionalize halal zones through spatial regulations, land use incentives, and infrastructure planning. The model's replicability further enhances its policy relevance, offering a template adaptable to other provinces with similar industrial topographies.

5. Discussion and Implications

The findings of this study have far-reaching implications for both regional policy formulation and industrial competitiveness. At the policy level, the spatial evidence calls for integrating halal logistics zoning within regional spatial plans (RTRW) and national industrial policies. Current frameworks often treat halal certification as a downstream concern—focused on products rather than infrastructure. This research, by contrast, demonstrates that halal compliance begins upstream, within the very geography of logistics systems. Integrating halal zoning into RTRW would institutionalize spatial segregation principles and provide a legal foundation for halal industrial estate governance. For local governments, the spatial model offers a blueprint for targeted investment. Rather than dispersing resources evenly, governments can prioritize infrastructure upgrades—roads, drainage, utilities—in areas already demonstrating high halal compatibility. This evidence-based approach ensures efficient resource allocation and aligns infrastructure development with ethical-economic goals. Moreover, halal zoning could serve as a competitive branding strategy for regions seeking to attract foreign investment, particularly from Muslim-majority countries demanding traceable halal supply chains.

From the perspective of industry stakeholders, the implications are equally transformative. The model empowers logistics operators, warehousing companies, and industrial developers to internalize halal assurance within their spatial planning decisions. Establishing certified halal warehouses in identified zones could enhance market credibility and open access to high-value export markets. Furthermore, the integration of halal compliance into logistics infrastructure aligns with emerging global standards in ethical supply chain governance, strengthening Indonesia's positioning in the international halal economy. Institutionally, the research underscores the need for a multi-agency coordination mechanism that bridges religious authorities (e.g., MUI), spatial planners, and industrial regulators. Halal zoning requires not only spatial control but also regulatory synchronization. A national guideline on halal industrial zoning—grounded in geospatial analysis—would harmonize standards and prevent overlapping jurisdictions. This alignment is particularly critical for ensuring consistency between halal certification criteria and land-use permits.

In the broader socio-economic context, the establishment of halal zones could generate inclusive development benefits. The creation of halal-certified logistics clusters promotes employment in high-value sectors, stimulates SME participation in halal value chains, and catalyzes technology transfer in cold-chain management and traceability systems. However, to avoid enclave-based development, the policy must incorporate community engagement frameworks, ensuring that halal industrialization empowers rather than displaces local populations. At a conceptual level, this study contributes to the discourse on Islamic spatial ethics, bridging the gap between urban planning and Islamic economic jurisprudence. It demonstrates that halal, when treated as a spatial category, embodies a form of moral geography—where purity, safety, and sustainability converge as guiding principles for human-environment interaction. This epistemological contribution expands the scope of halal studies beyond legalistic interpretation, positioning it within the interdisciplinary dialogue of geography, ethics, and development studies.

Nevertheless, the research acknowledges its methodological limitations. While spatial modeling provides high analytical precision, it cannot fully capture socio-political dynamics such as policy inertia, industrial lobbying, or public perception. Therefore, future studies should integrate participatory GIS (PGIS) methods and institutional mapping to enrich the model with qualitative insights. This multidimensional approach would produce a more holistic halal spatial governance framework. In conclusion, the implications of this research extend beyond the technical realm of spatial planning. They offer a new vision for integrated halal development—a vision where spiritual compliance, environmental stewardship, and industrial efficiency coexist within a unified spatial system. Through this synthesis, halal zoning becomes not merely a regulatory requirement but a transformative framework for ethical, sustainable, and globally competitive industrial growth.

CONCLUSION

This research concludes that spatially planned halal zones within industrial estates are not only crucial for logistical efficiency but also fundamental for ethical and sustainable economic governance in the halal sector. By employing QGIS-based spatial modeling, the study demonstrates that halal compliance must be institutionalized spatially through dedicated zoning, contamination control, and environmental safeguards. The West Java case study confirms that ideal halal sites are determined by a balanced integration of accessibility, environmental hygiene, and land-use compatibility. The incorporation of halal parameters into regional and national spatial planning (RTRW) is essential to align industrial growth with Sharia-compliant logistics systems. Strategically, the study recommends the establishment of a National Halal Industrial Zoning Guideline supported by GIS-driven analytics to regulate land use, facility design, and traceability systems. Collaboration among government agencies, certification authorities, and private sectors is vital for the successful implementation of halal-compliant infrastructure. Ultimately, this research redefines halal logistics as a spatial-ethical system that unites moral geography, environmental integrity, and industrial efficiency, contributing to Indonesia's vision of becoming a leading global halal economy.

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