GIS-Based Spatial Optimization Framework for Defense Industrial Planning and Logistics Accessibility in Indonesia

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Abstract
Global geopolitical developments, particularly in the Middle East, indicate a significant transformation in modern warfare, which is no longer dominated by conventional weaponry but by the integration of artificial intelligence, information warfare, and asymmetric weapon systems such as naval and aerial mines. In this context, the use of Geographic Information Systems (GIS) has become increasingly important to support strategic analysis and defense industrial policy formulation at both national and global levels. This study aims to analyze the impact of global geopolitical dynamics on the urgency of defense industrial independence in Indonesia using a geospatial approach, and to identify patterns of industrial distribution and strategic vulnerabilities based on GIS. This research employs a qualitative method with a descriptive case study design of the defense industry in Indonesia. Data analysis follows the Creswell model, integrated with geospatial analysis using Geographic Information Systems (GIS). Qualitative data were processed using NVivo to identify key policy themes, while spatial analysis was applied to map the distribution of defense industries, logistics networks, and regional disparities through location-allocation and spatial clustering approaches. Indonesia's defense industry remains dependent on imported spare parts and is concentrated on Java Island, resulting in spatial inequality and logistical vulnerabilities. GIS analysis reveals a mismatch between industrial locations and strategic operational areas, particularly in eastern Indonesia. This condition weakens national resilience due to limited logistics independence, high supply chain disruption risks, uneven industrial development, delayed defense responses, and limited regional economic impact. Indonesia's defense industrial independence remains insufficient in addressing global geopolitical dynamics and technology-driven warfare. Integrating geoinformatics into defense industrial policy is essential to enhance distribution efficiency, reduce regional disparities, and strengthen national resilience. Policymakers should promote geospatial-based strategies to achieve industrial independence, improve deterrence capability, and reinforce Indonesia's position in the global geopolitical landscape.

Keywords: Archipelagic Environment, Decision Support System, Geoinformatics, Geospatial Intelligence, Regional Vulnerability

1. Introduction

Global geopolitical developments, particularly in the Middle East, indicate a significant transformation in the nature of modern warfare, which is no longer dominated by conventional weaponry but by the integration of artificial intelligence (AI), information warfare, and the use of asymmetric weapon systems such as naval and aerial mines [1]. This pattern of conflict underscores the importance of information superiority, rapid decision-making, and control of geographic space as key determinants of military operational success [2]. In this context, the utilization of Geographic Information Systems (GIS) and Geospatial Intelligence (GEOINT) becomes crucial in supporting strategic analysis, threat mapping, and the formulation of defense industrial policies at both global and national levels. For Indonesia, the integration of geoinformatics into defense industrial policy, particularly through Defend ID, is increasingly relevant to strengthen national defense independence and resilience in responding to multidomain threats [3].

The urgency of this study lies in the increasing complexity of global threats that are multidomain and technology-driven, requiring the national defense industry to be prepared not only in terms of production capacity but also in terms of spatial distribution and logistical efficiency. As an archipelagic country, Indonesia faces significant geographical challenges; therefore, without a GIS-based approach, defense industrial policies may not effectively support operations in strategic areas, particularly in eastern regions and border areas. Hence, the integration of geoinformatics becomes essential to ensure that defense industrial development aligns with operational needs and national interests [4].

Previous studies on defense industrial independence have largely been dominated by policy, economic, and technological approaches that emphasize regulatory strengthening, investment, and production capacity. These studies generally position the defense industry as a strategic instrument for achieving military equipment independence and global competitiveness, yet they have not comprehensively integrated the spatial dimension into policy analysis. On the other hand, the development of geoinformatics and GIS has primarily been directed toward environmental, disaster, and health sectors, such as disaster risk mapping, satellite-based monitoring, and big data-driven spatial analysis. Meanwhile, the application of GEOINT in the defense context has tended to focus on military operational needs, intelligence cycles, and enhancing situational awareness through spatial data and remote sensing integration, without being directly linked to defense industrial policy development [1]. In the context of Indonesia as an archipelagic state with high geographical complexity, defense industrial policy through strategic entities such as Defend ID remains oriented toward industrial consolidation and strengthening production capacity, without systematically incorporating geospatial approaches into policy formulation. Therefore, a significant research gap exists in the lack of integration between Geospatial Intelligence and defense industrial policy within a comprehensive analytical framework, particularly to support strategic planning of the defense industry in archipelagic countries such as Indonesia [5].

Previous studies generally examine defense industrial independence from policy, economic, and technological perspectives, but remain limited in integrating geospatial approaches comprehensively. On the other hand, geoinformatics studies have largely focused on environmental, disaster, and regional planning aspects, without directly linking them to defense industrial policy. Therefore, a significant research gap exists in connecting Geospatial Intelligence with defense industrial policy, particularly in the context of archipelagic countries such as Indonesia and within the framework of Defend ID as a national strategic entity [6]. Based on this gap, the present study form ulates the research problem as a geoinformatics-based spatial decision problem rather than solely as a defense industrial policy issue. Specifically, the study examines how *Geographic Information Systems* and *Geospatial Intelligence* can be utilized to identify the spatial distribution patterns of Indonesia's defense industry, evaluate logistics accessibility, detect regional industrial disparities, and analyze geostrategic vulnerabilities within Indonesia's archipelagic context. Therefore, Indonesia's defense industrial policy is positioned as an application domain through which *geospatial intelligence* supports evidence-based spatial decision-making and optimization processes in a more effective and efficient manner [7].

The contribution of this study lies in expanding the application of Geographic Information Systems into the defense sector, which remains limited in geoinformatics literature. While GIS has been widely applied in environmental and disaster-related fields, the defense sector also possesses strong spatial dimensions, particularly in industrial distribution, logistics, and strategic regions. This study demonstrates that GIS can function as an analytical tool to identify spatial disparities, evaluate logistics networks, and support data-driven defense industrial policymaking. Thus, this research not only enriches the literature but also introduces defense geoinformatics as a relevant approach for strategic decision-making and strengthening national resilience [8]. In contrast to previous studies that primarily emphasized regulatory, economic, and industrial perspectives, this study positions GIS not merely as a supporting visualization tool but as a geospatial analytical framework capable of identifying spatial patterns, optimizing industrial locations, evaluating logistics distribution connectivity, and supporting strategic decision-making in Indonesia. Therefore, the primary contribution of this study lies in expanding the application of GIS into the field of defense geoinformatics through spatially driven industrial policy analysis [9].

This study aims to develop a GIS-based geospatial analytical framework for identifying industrial distribution patterns, evaluating logistics accessibility levels, assessing spatial vulnerabilities, and optimizing strategic locations within Indonesia's defense industrial system. The defense sector is utilized as an application case to demonstrate the contribution of geoinformatics toward the development of spatially informed decision-support systems [5].

2. Method*s*

2.1 Design

This study employs a *Geographic Information Systems* (GIS)-based geospatial analytical framework integrated with a qualitative case study approach. GIS serves as the principal analytical component for examining industrial distribution patterns, logistics accessibility levels, spatial disparities, and strategic vulnerabilities within Indonesia's defense industry. Geospatial analysis was conducted through the integration of *spatial clustering*, *location-allocation* modeling, and logistics network analysis to provide a more systematic understanding of spatial relationships among relevant variables. Meanwhile, qualitative approaches, including interviews and coding procedures using NVivo, were utilized as supporting information to provide contextual understanding and strengthen the interpretation of spatial patterns generated through GIS analysis [10].

2.2 Data Sources

Data consist of both primary and secondary sources. Primary data were obtained through in-depth interviews with stakeholders, including government officials, defense industry actors, and geospatial experts. Secondary data include policy documents, industry reports, and geospatial data such as transportation networks, regional accessibility, and the distribution of defense industrial facilities [11].

2.3 Data Analysis Techniques

The analytical sequence was structured by placing GIS-based procedures as the primary analytical engine of the study. Spatial clustering analysis was first applied to identify industrial concentration patterns, followed by location-allocation modeling to determine optimal industrial distribution scenarios, and network analysis to evaluate logistics accessibility and connectivity. Geospatial analysis was implemented using ArcGIS Pro 3.2 and QGIS 3.34 environments [12]. Spatial data were organized within a geodatabase structure consisting of vector and raster datasets [13]. Vector datasets included administrative boundaries, defense industrial facility locations, transportation networks, ports, airports, and strategic operational areas, while raster datasets consisted of accessibility surfaces and regional spatial characteristics [14]. The GIS workflow consisted of five sequential stages:

2.3.1 Spatial data acquisition and preprocessing

Spatial datasets were collected from publicly available national geospatial databases and standardized using the World Geodetic System (WGS 84 coordinate reference system). Data preprocessing included projection correction, topology validation, missing value identification, and attribute standardization.

2.3.2 Spatial clustering analysis

Industrial concentration patterns were analyzed through spatial clustering procedures using density-based spatial analysis and hotspot identification. Industrial density was calculated using Equation 1.

$$D_i = \frac{N_i}{A_i}$$

Equation 1

Where D_i denotes the industrial density within spatial unit i, n_i denotes the number of defense industrial facilities within spatial unit i, and A_i denotes the total area of spatial unit i expressed in square kilometres.

2.3.3 Location-allocation modelling

Location-allocation modelling was applied to identify facility-to-demand assignments that minimize total logistics travel impedance. The objective function combines the impedance between each demand location and candidate facility with the corresponding allocation decision variable. The optimization objective is expressed in Equation 2.

$$\min Z = \sum_{i=1}^{n} \sum_{j=1}^{m} d_{ij} x_{ij}$$

Equation 2

Where Z denotes the total travel impedance, d_{ij} denotes the distance, travel time, or other impedance between demand location i and facility location j, and x_{ij} denotes the allocation decision variable between demand location i and facility location j.

2.3.4 Network analysis

Network analysis was used to determine the least-cost logistics route between industrial facilities and strategic destinations. The shortest-path problem was formulated by minimizing the cumulative impedance of the edges forming a feasible path between an origin and a destination, following a weighted shortest-path formulation commonly applied in network analysis [15]. The objective function is expressed in Equation 3.

$$SP_{s,t} = \min_{P \in \mathcal{P}_{s,t}} \sum_{e \in P} w(e)$$

Equation 3

Where $SP_{s,t}$ denotes the minimum path cost between origin node s and destination node t, $P_{s,t}$ denotes the set of feasible paths from s to t, e denotes an edge belonging to path P, and $w(e)$ denotes the travel cost or impedance assigned to edge e.

2.3.5 Validation procedure

Spatial validation was conducted through cross-validation between multiple geospatial datasets and comparison of generated outputs with strategic operational areas and existing logistics infrastructure. The entire geospatial procedure was designed to ensure methodological transparency, reproducibility, and analytical consistency.

2.3.6 GIS Workflow

Figure 1 illustrates the complete GIS workflow used in this study, including spatial data acquisition, preprocessing, geoprocessing, spatial clustering, location-allocation analysis, network analysis, and validation procedures.

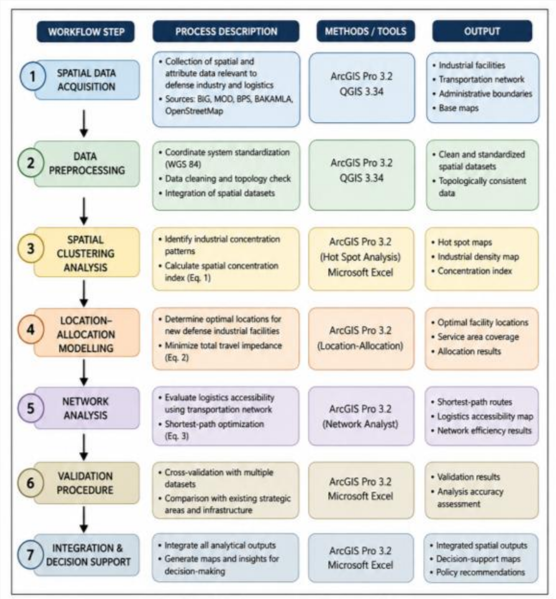

Figure 1. GIS-based analytical workflow

2.4 Geospatial Innovation and Analytical Contribution

The geospatial contribution of this study lies in developing a GIS-based analytical framework for defense industrial planning in archipelagic environments. Unlike conventional policy-centered studies, the proposed framework integrates spatial clustering analysis, location-allocation modeling, and network accessibility assessment into a geospatial decision-support system capable of identifying industrial concentration patterns, logistics inefficiencies, and strategic vulnerabilities. This framework extends GIS applications beyond traditional mapping functions toward analytical and optimization-oriented geoinformatics applications.

2.5 GIS Parameterization and Spatial Modeling Procedure

GIS-based analytical workflow integrating spatial clustering, location-allocation analysis, and transportation network modeling. The analysis utilized the following spatial datasets:

- Defense industrial facility locations (point vector data)
- Administrative boundaries (polygon data)
- Transportation networks including roads, ports, and airports (line vector data)
- Strategic operational areas and border regions (polygon data)
- Accessibility surface layers (raster data)

Travel impedance was measured using transportation distance and estimated travel time across multimodal logistics routes. Network topology was constructed using nodes representing industrial facilities and transportation hubs, while links represented transportation corridors connecting operational regions. Optimization constraints included:

- Logistics capacity limitations
- Transportation accessibility constraints
- Strategic operational coverage requirements
- Regional infrastructure availability

Sensitivity analysis was conducted by varying weighting parameters by approximately ±10–20% to assess the stability and reliability of the spatial model under different conditions. This procedure aimed to determine whether changes in parameter values significantly influenced the resulting outputs, including accessibility levels, industrial distribution patterns, and allocation scenarios. By comparing outputs across alternative weighting conditions, the analysis evaluated model robustness and ensured that the identified spatial patterns remained consistent and reliable for supporting geospatial decision-making.

2.6 Reproducible GIS Workflow and Validation Strategy

To improve reproducibility and methodological transparency, the geospatial analytical procedure was implemented using a structured workflow consisting of dataset preparation, preprocessing, spatial analysis, validation, and uncertainty assessment. The geospatial analysis was implemented using ArcGIS Pro 3.2 and QGIS 3.34 platforms under the World Geodetic System (WGS 84) coordinate reference system to ensure consistency and compatibility across spatial datasets. The criteria and corresponding weights used in the location suitability analysis are presented in Table 1. The spatial datasets, data types, resolutions, and analytical purposes used in this study are summarized in Table 2.

Table 1: Criteria weights for location suitability analysis

Variable	Weight (%)
Transportation accessibility	30
Distance to operational areas	25
Industrial concentration	20
Infrastructure availability	15
Strategic regional importance	10

Table 2: Spatial datasets included

Dataset	Type	Resolution/Scale	Purpose
Administrative boundaries	Vector polygon	1:50,000	Spatial reference
Defense industry facilities	Point vector	Facility level	Industrial distribution
Transportation network	Line vector	National scale	Network analysis
Ports and airports	Point vector	Facility level	Accessibility analysis
Strategic operational areas	Polygon vector	Regional scale	Allocation modeling
Accessibility surface	Raster	30 m spatial resolution	Accessibility assessment

Spatial clustering analysis was employed to identify industrial concentration patterns and spatial agglomeration across different regions, enabling the detection of geographic disparities in defense industrial distribution. Location-allocation analysis was selected because Indonesia's archipelagic characteristics require optimization of industrial locations and logistics facilities based on spatial accessibility and operational demand. Furthermore, network analysis was applied to evaluate logistics connectivity and transportation efficiency, considering that logistics movement across dispersed islands strongly depends on transportation topology and accessibility conditions [15]. To ensure analytical reliability, validation procedures were conducted through cross-validation among multiple spatial datasets, comparison with strategic operational regions, and consistency assessment across alternative allocation scenarios. In addition, uncertainty assessment was performed through sensitivity testing by varying weighting parameters by approximately ±10–20% and evaluating their effects on accessibility and allocation outputs. This procedure was intended to assess model robustness and improve confidence in the stability and reliability of the spatial analysis results [16].

2.6.1 Qualitative analysis

The qualitative analysis followed Creswell's data-analysis procedures, including data reduction, coding, categorization, and iterative interpretation. NVivo software was used to identify policy themes, relationships among actors, and strategic dynamics within the defense industry [17].

3. Results and Discussion

The revised analytical structure prioritizes GIS-based outputs as the principal findings of this study. Spatial analysis results provide the primary evidence supporting industrial distribution assessment, logistics network evaluation, and strategic vulnerability identification, while qualitative findings are utilized to strengthen contextual understanding and policy interpretation.

3.1 Results

The qualitative outputs generated through NVivo, including coding frequencies, text search analysis, and visualization outputs, were used only to provide contextual interpretation of policy and industrial themes. The principal analytical findings of this study are derived from GIS-based spatial analysis, including industrial clustering patterns, accessibility variations, logistics network performance, and spatial optimization scenarios. In the revised analytical structure, GIS-based outputs are treated as the principal scientific findings of the study, while qualitative outputs generated through NVivo are used only as supporting contextual information to interpret policy and industrial themes. Therefore, the primary contribution of this study lies in the spatial analytical framework and GIS-derived evidence rather than qualitative text-mining outputs. The Results section was reorganized to prioritize GIS-derived findings as the principal analytical outputs of the study. Spatial visualizations including industrial distribution maps, accessibility analysis, logistics connectivity, and optimization scenarios are presented as the main scientific evidence, whereas NVivo-based visualizations are retained only as supporting contextual information for interpreting policy and industrial themes.

3.1.1 Findings from interviews with defense experts in Indonesia

Interviews with defense experts indicate that Indonesia's dependence on imported spare parts in the defense industry is not merely a technical production issue, but is also related to the weak domestic supporting industrial ecosystem, suboptimal technology transfer, and limited investment in research and development. The concentration of defense industries in Java further reinforces disparities in production capacity and logistical support, causing regions outside Java to function primarily as consumers rather than producers. This condition results in slower logistical responses during emergencies or conflicts in border and archipelagic areas, which ultimately has the potential to reduce national defense operational readiness [18].

3.1.2 Literature review on regulatory framework

The literature review on regulations in this study refers to various laws and strategic national policies that form the basis for the development of defense industrial independence in Indonesia, including:

1) Law No. 16 of 2012 on the Defense Industry, which serves as the main foundation for developing the national defense industry, including strengthening domestic industry roles, mandatory use of local products, and technology transfer (ToT) mechanisms.
2) Law No. 3 of 2002 on National Defense, which emphasizes the importance of a total defense system, including defense industry support as an integral part of national strength.
3) Law No. 34 of 2004 on the Indonesian National Armed Forces, which regulates military equipment and logistical support requirements, directly related to strengthening the domestic defense industry.
4) Presidential Regulation No. 8 of 2021 on the General Policy of National Defense, which outlines defense development policies, including defense industry independence and reducing import dependence.
5) Presidential Regulation No. 74 of 2022 on National Industrial Policy, which includes the defense industry as a national strategic priority sector.
6) Presidential Regulation No. 42 of 2019 on the Defense Industry Policy Committee, which governs cross-ministerial coordination in formulating and overseeing defense industrial policies.
7) Minister of Defense Regulations concerning procurement of defense equipment and empowerment of domestic industries, prioritizing local products and regulating international cooperation mechanisms.
8) The Defense Industry Master Plan and Minimum Essential Force (MEF), which serve as strategic policy documents guiding defense industry capacity development and phased fulfilment of military equipment needs.

Overall, the literature review indicates that Indonesia has a comprehensive normative regulatory framework to support defense industrial independence. However, this study finds that the main challenge lies in policy implementation, particularly in inter-agency coordination, consistency of execution, and equitable spatial development of the defense industry beyond Java.

3.1.3 Previous studies

The current state of Indonesia's defense industrial independence remains at a developing stage, characterized by a dominance of assembling activities rather than core component manufacturing. Dependence on global supply chains remains high, particularly for strategic technologies and critical components. In addition, geographical disparities in industrial development persist, potentially weakening logistical resilience in the context of an archipelagic state.

3.1.4 Findings based on comparison with other countries

The case of Brazil demonstrates that the integration of GIS in the defense sector has evolved into an operational geoinformation governance system supported by advanced technology. The development of a modular GIS framework, as presented in Procedia Computer Science, functions not merely as a mapping tool but as a data-driven decision support system capable of integrating spatial data with real-time military operational needs, such as route tracing and troop accessibility analysis. This indicates a strategic shift from traditional analytical use toward a system-based geospatial architecture that enhances planning and mobilization capabilities. From an analytical perspective, this success highlights that strengthening defense policy requires not only regulatory frameworks but also the development of integrated geospatial systems that enable fast, adaptive, and evidence-based decision-making in response to complex modern threats.

Croatia's approach, utilizing GIS combined with multi-criteria decision analysis (MCDA) for determining optimal Coast Guard homeport locations, illustrates the effective application of geoinformatics in geostrategic maritime defense planning. This model integrates key spatial variables such as distance, risk levels, accessibility, and strategic importance to identify optimal deployment locations. Analytically, this demonstrates that GIS integration enables systematic optimization of defense resource allocation, which cannot be effectively achieved through conventional approaches. In the context of maritime or archipelagic states, such as Indonesia, this approach is highly relevant as it enhances patrol efficiency, accelerates response time to threats, and strengthens maritime security through comprehensive, spatially informed planning [19].
The Egyptian case highlights the application of GIS through a spatial decision support system based on multi-criteria decision-making to determine optimal ammunition depot locations by considering factors such as security, accessibility, risk, and logistical efficiency. The resulting prioritized locations are not only technically feasible but also strategically aligned with defense operational needs. From an analytical standpoint, this demonstrates that GIS integration reduces subjectivity in decision-making by introducing quantitative, spatially driven analysis, thereby improving accuracy, transparency, and policy accountability. Furthermore, this approach underscores that defense infrastructure and logistics development must systematically incorporate spatial dimensions, as facility location directly affects supply chain resilience and overall military operational readiness.

3.1.5 Findings based on Geographic Information Systems (GIS)

GIS analysis generated quantitative spatial outputs revealing measurable patterns related to industrial concentration, accessibility disparities, and logistics efficiency across Indonesia. Spatial clustering analysis identified significant industrial agglomeration in western Indonesia, particularly on Java Island, with an industrial density index ranging from 0.73-0.85 facilities/km². In contrast, eastern regions such as Papua, Maluku, and Nusa Tenggara exhibited substantially lower density values, ranging between 0.12-0.26 facilities/km². These findings indicate that the distribution of the defense industry remains concentrated in specific regions and has not yet been evenly distributed across the country. Furthermore, accessibility analysis revealed considerable regional variation. The average accessibility score within industrial regions in western Indonesia ranged from 0.76-0.89, whereas eastern regions reached only 0.32-0.47. This difference indicates limited transportation connectivity, which consequently affects longer logistics distribution times. The results of the location-allocation modeling further demonstrated that the current industrial locations do not fully correspond with the requirements of strategic operational regions. Optimization scenarios indicated that the establishment of additional supporting facilities in strategic areas of eastern Indonesia could reduce logistics travel impedance by approximately 28-35%, thereby improving distribution efficiency and accelerating defense operational response times.

In addition, network analysis identified logistics bottlenecks across inter-island transportation corridors with limited connectivity. Route optimization simulations demonstrated that the integration of distribution networks could reduce estimated transportation costs and improve connectivity efficiency among strategic regions. To ensure model reliability, spatial outputs were evaluated through sensitivity testing and comparison across multiple allocation scenarios. The results demonstrated relatively stable patterns under varying weighting conditions, indicating that industrial concentration and accessibility levels remained consistent despite changes in model parameters. Validation procedures were also conducted through cross-comparison with strategic operational regions and multiple spatial datasets, which demonstrated consistency in the outputs and strengthened the robustness of the optimization model. These spatial distribution patterns, accessibility variations, and proposed optimization scenarios for defense industrial facilities are illustrated in Figure 2.

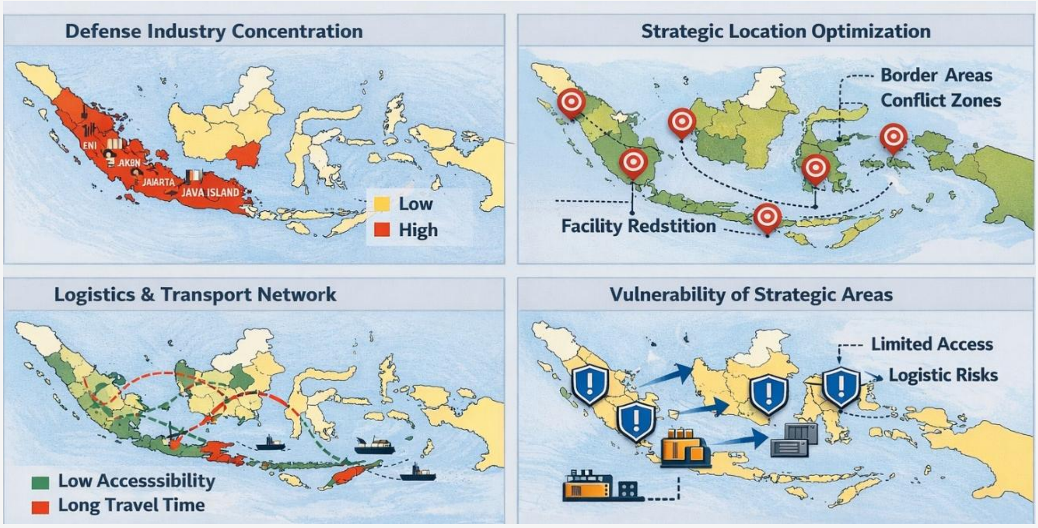

Figure 2: Illustrates the spatial distribution, accessibility patterns, and proposed optimization of defense industrial facilities

Table 3: GIS-based spatial outputs

Spatial Indicator	Western Indonesia	Eastern Indonesia
Industrial Density Index	0.73-0.85	0.12-0.26
Accessibility Score	0.76-0.89	0.32-0.47
Travel Impedance Reduction	-	28-35%
Connectivity Efficiency	High	Moderate-Low

A comparative summary of the GIS-based spatial outputs for western and eastern Indonesia is provided in Table 3. The table highlights differences in industrial density, accessibility levels, travel impedance reduction, and connectivity efficiency between the two regions. These comparative results demonstrate clear spatial disparities, particularly the lower accessibility and connectivity observed in eastern Indonesia, which indicate the need for more balanced defense industrial distribution and improved logistics infrastructure planning.

Overall, these findings indicate that regions with lower accessibility levels and limited transportation connectivity tend to exhibit higher logistics travel impedance and narrower operational coverage. Uneven industrial distribution may also reduce defense logistics responsiveness and increase supply chain vulnerability within strategic regions. Conversely, a more optimized distribution of facilities could expand operational coverage, reduce distribution costs, and strengthen the efficiency of defense logistics systems. These findings provide empirical geospatial evidence supporting interpretations related to Indonesia's defense readiness, logistics vulnerability, and strategic efficiency. The revised GIS visualization incorporates standard cartographic elements, including a north arrow, scale bar, coordinate reference system (WGS 84), legends, and geographic labels, to improve map readability and reproducibility. In addition, quantitative indicators such as industrial density indices, accessibility values, transportation connectivity indicators, and allocation optimization scenarios were included to strengthen analytical interpretation while enhancing the quality of spatial evidence presented in this study.

3.1.6 Supporting qualitative context from NVivo analysis

This section presents the findings derived from qualitative data analysis using NVivo 12, focusing on the integration of geospatial intelligence within Indonesia's defense industrial policy framework. The analysis systematically organizes data from interviews, policy documents, and secondary sources through coding, categorization, and thematic interpretation. NVivo facilitates the identification of dominant patterns, relationships, and emerging themes related to governance, technological capability, and institutional coordination. The results highlight how geospatial intelligence functions as a strategic enabler in strengthening decision-making processes, enhancing operational efficiency, and supporting the development of the national defense industry, particularly within the ecosystem of Defend ID Indonesia. Furthermore, the use of NVivo provides methodological rigor and transparency, enabling systematic data traceability and validation of findings. The practical benefit of this analysis lies in offering evidence-based insights for policymakers to design more integrated and adaptive defense industrial strategies. It also supports stakeholders in improving inter-agency coordination, optimizing resource allocation, and strengthening innovation capacity within the national defense sector.

Figure 3 presents the percentage distribution of the key themes generated through NVivo coding analysis within Indonesia's defense industrial policy. The regulatory framework shows the highest percentage, indicating that Indonesia's defense industrial policy is still dominated by a normative and regulatory approach. Meanwhile, themes related to domestic industrial capacity and supporting industries are also relatively prominent, suggesting that strengthening national production capabilities and the industrial ecosystem remains a primary focus. However, the aspects of spatial distribution and defense logistics have relatively lower proportions, despite their critical importance in an archipelagic country such as Indonesia. This indicates an imbalance between policy priorities and operational needs in the field.

Furthermore, the relatively weaker emphasis on policy implementation compared to the regulatory framework indicates a persistent gap between policy formulation and execution within Indonesia's defense industrial sector. While regulatory instruments and institutional frameworks have been established to support the development of the national defense industry, their translation into effective operational outcomes remains limited. This gap is reflected in suboptimal defense readiness, particularly in terms of logistics efficiency, industrial responsiveness, and the ability to support operations in strategic and remote regions. In the context of the present study, these findings demonstrate that current defense industrial policies have not yet fully incorporated a geospatial perspective.

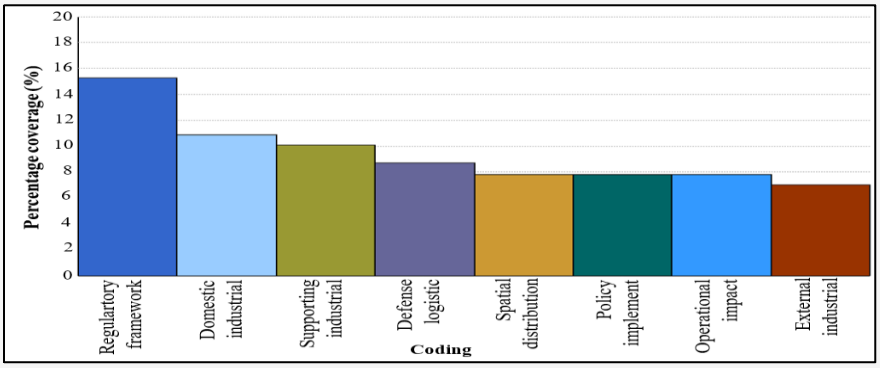

Figure 3: presents the percentage distribution of the themes generated through NVivo coding.

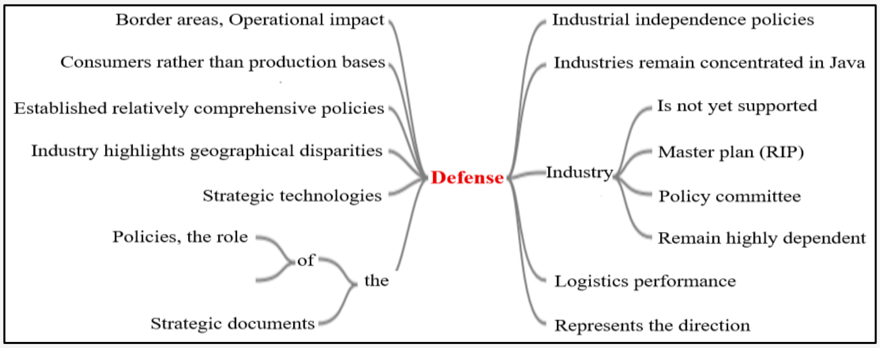

Figure 4: Shows the relationships between the keyword "defense" and the associated policy, industrial, and logistics themes

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The relationships between the keyword "defense" and the associated policy, industrial, and logistics themes are further illustrated in Figure 4. The visualization demonstrates that defense-related discourse is closely connected with regulatory frameworks, industrial capacity, logistics performance, policy implementation, and spatial distribution. These interconnections indicate that defense industrial development cannot be addressed through a single-sector perspective. Instead, it requires an integrated approach that combines institutional governance, industrial strengthening, logistics efficiency, and geospatial considerations. The findings therefore emphasize the importance of incorporating spatial information and coordinated policy mechanisms into strategic planning to support more effective, adaptive, and evidence-based defense industrial development in Indonesia.

As a result, industrial planning and development tend to overlook spatial disparities, including accessibility in eastern regions, and misalignment with strategic defense areas. Geographic Information Systems (GIS)-based analysis offers a critical solution by enabling spatial evaluation of industrial locations, logistics networks, and regional accessibility, thereby supporting more accurate and data-driven decision-making.

Therefore, the integration of Geospatial Intelligence is not merely complementary but essential, particularly in the context of a geographically complex country like Indonesia. GEOINT enables policymakers to incorporate spatial data, terrain analysis, and real-time geographic information into strategic planning processes. This capability transforms defense industrial policy from a predominantly regulation-oriented framework into a spatially informed and operationally driven system. Through the application of Geographic Information Systems (GIS), decision-makers can identify optimal locations for defense infrastructure, improve supply chain efficiency, and enhance coordination across regions. Moreover, GEOINT supports risk assessment, threat mapping, and resource allocation based on geographic priorities. Within the ecosystem of Defend ID Indonesia, this integration can strengthen industrial synergy and operational readiness. Ultimately, GEOINT enhances national resilience by ensuring that defense capabilities are aligned with spatial realities, thereby improving the effectiveness and responsiveness of Indonesia's overall defense posture [20].

The word tree visualization from the NVivo Text Search Query shows that the keyword "defense" is strongly associated with themes such as industry, logistics performance, industrial independence policies, and geographical disparities. This indicates that Indonesia's defense industry is inherently multidimensional and cannot be separated from policy, spatial distribution, and logistics systems. In this context, "defense" extends beyond military capability and reflects a systemic relationship between production, distribution, and territory, requiring a comprehensive and integrated analytical approach[21]. These findings also highlight that Indonesia's defense industry continues to face structural challenges, including a strong dependence on normative policies, industrial concentration in Java, and suboptimal logistics performance. The emergence of phrases such as "industries remain concentrated in Java" and "consumers rather than production bases" reinforces the existence of spatial inequality, where regions outside Java have not yet developed as strategic production centers. Meanwhile, references to "RIIP" and "KKIP" indicate that a regulatory framework is already in place, but its implementation remains ineffective. This reflects a gap between policy formulation and real-world conditions, which ultimately limits industrial independence and logistics efficiency. Furthermore, the dominance of industrial and regulatory perspectives in defining "defense," without adequate integration of spatial considerations, highlights a significant limitation in current policy approaches. Existing policies tend to focus on Effective integration for multipurpose cadastre development requires formal institutional cooperation supported by an inter-agency data-sharing framework. Such cooperation should be established through a Memorandum of Understanding (MoU), supported by a technical cooperation agreement and a joint Standard Operating Procedure (SOP). The MoU should define the objectives and scope of cooperation, the integration and updating schedule, institutional rights and obligations, data custodianship, authorized data use, quality-control responsibilities, and procedures for maintaining the integrated database.

Technical interoperability requires agreement on coordinate reference systems, spatial data formats, metadata standards, common parcel identifiers, attribute structures, topology rules, version-control procedures, and data-exchange mechanisms. Institutional interoperability requires a clear allocation of responsibilities for data creation, verification, validation, updating, approval, and dissemination. In this arrangement, the Land Office is responsible for validating LRM parcel geometry and land-registration information, whereas BPKPAD is responsible for validating NOP and

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other taxation-related attributes originating from the LPTM.

The cooperation framework should also establish procedures for resolving discrepancies through document examination, joint spatial verification, and, where necessary, field validation. Provisions concerning authorized access, protection of sensitive information, data ownership, liability, accountability, and audit trails should be included. These institutional, technical, and governance arrangements are necessary to maintain the integrated cadastral database as a dynamic and reliable system supporting sustainable land administration and accurate property taxation. Therefore, technical integration must be complemented by formal institutional arrangements to achieve long-term interoperability and database synchronization.

Therefore, integrating Geospatial Intelligence is essential to ensure that defense industrial policy is aligned with real spatial conditions, particularly in a geographically diverse country such as Indonesia. By incorporating geospatial data into policy formulation, decision-makers are able to move beyond abstract planning toward more context-sensitive and location-specific strategies. This approach enables adaptive and evidence-based decision-making, as policies are grounded in accurate information regarding terrain, infrastructure, population distribution, and strategic vulnerabilities. Moreover, GEOINT enhances logistics efficiency by optimizing distribution routes, determining strategic locations for defense facilities, and improving supply chain coordination across islands and remote regions. It also plays a critical role in reducing regional imbalances by identifying underserved areas and guiding more equitable allocation of resources. In the long term, this integration strengthens national resilience by ensuring that defense capabilities are responsive, well-distributed, and aligned with Indonesia's unique geographic and strategic environment [22].

The NVivo word cloud visualization highlights the frequency of key terms in Indonesia's defense industrial policy discourse, with dominant words such as "defense," "industrial," "industry," and "policy." This indicates that the primary focus remains on the relationship between policy and industrial development. However, the presence of terms like "limited," "distribution," "capacity," "logistics," "java," and "imported" reveals core challenges, including limited domestic industrial capacity, spatial inequality, reliance on imports, and suboptimal logistics systems [23]. This suggests that the discourse is not only policy-driven but also reflects structural constraints that affect the overall performance of the defense industry. The prominence of the terms "limited" and "distribution" further emphasizes that the main issues extend beyond production to include geographical imbalances and uneven industrial distribution, particularly the concentration of industries on Java Island. At the same time, the appearance of terms such as "policy," "framework," and "coordination" indicates that regulatory attention is substantial, yet the inclusion of words like "weak," "inconsistent," and "constraints" points to deficiencies in policy implementation. Additionally, terms such as "technology transfer," "supporting industries," and "capacity" highlight ongoing challenges in strengthening the domestic defense industrial ecosystem, particularly in achieving sustainable technological and industrial independence [24].

Moreover, the overall pattern of keywords suggests that Indonesia's defense industrial policy remains largely dominated by normative and industrial perspectives, with only limited integration of the spatial dimension. Although terms such as "regions," "geographical," and "archipelagic" appear within the discourse, they have not yet been positioned as central elements in policy formulation. This indicates that spatial considerations are still treated as supplementary rather than strategic, despite Indonesia's unique geographical characteristics as a vast archipelagic state. As a result, policy development tends to emphasize regulatory frameworks and industrial capacity without fully addressing issues related to spatial distribution, accessibility, and regional disparities [25].

Integrating Geospatial Intelligence through Geographic Information Systems offers a strategic solution to bridge the gap between policy design, industrial distribution, and operational requirements, particularly in a complex archipelagic context such as Indonesia. By utilizing GIS-based analysis, policymakers can identify spatial patterns, assess regional strengths and vulnerabilities, and determine optimal locations for defense industrial facilities. This approach improves connectivity within logistics networks, ensuring more efficient distribution across islands and remote areas. Furthermore, it supports more adaptive and data-driven decision-making processes. Ultimately, the integration of GEOINT enhances logistics efficiency, reduces regional disparities, and contributes to strengthening national resilience and the overall effectiveness of Indonesia's defense system [26]. The proportional distribution of the dominant themes identified through NVivo treemap analysis is presented in Figure 5.

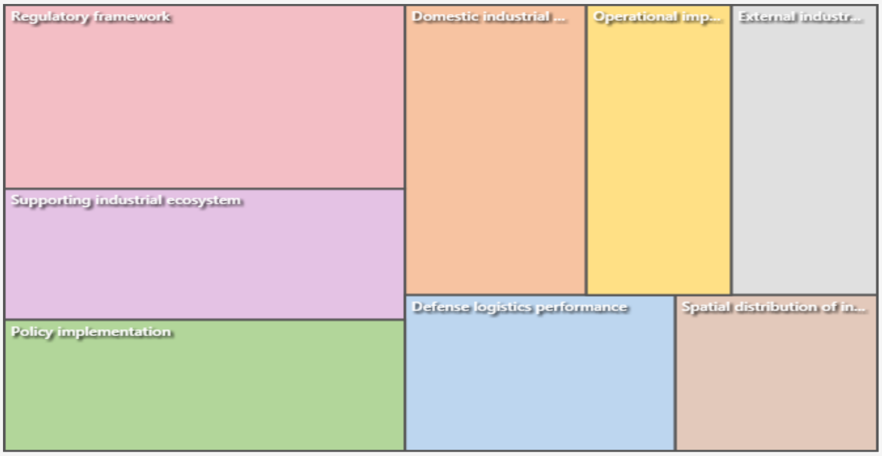

Figure 5: Tree map analysis Nvivo

The visualization illustrates the relative prominence of regulatory frameworks, supporting industrial ecosystems, policy implementation, domestic industrial capacity, defense logistics performance, and spatial distribution. These patterns provide clearer understanding of thematic priorities and gaps within Indonesia's defense industrial policy. The NVivo treemap visualization presents the proportional dominance of key themes in Indonesia's defense industrial policy based on their relative area size, where larger blocks indicate higher frequency and analytical significance. The most dominant theme is the "Regulatory framework," which reflects that policy discourse is still heavily centered on normative aspects, rule-making, and formal regulatory structures. This dominance indicates that Indonesia's defense industrial development, including within the Defend ID framework, is primarily guided by policy formulation rather than operational considerations [27]. However, the strong presence of the regulatory theme also reveals a critical limitation. Although regulations and policy instruments are extensive, their implementation remains constrained by various challenges. This suggests that the issue is not the absence of policy, but rather the effectiveness of execution. The gap between regulatory design and real-world application highlights systemic weaknesses, particularly in coordination, consistency, and enforcement mechanisms [28].

Meanwhile, the themes of "Supporting industrial ecosystem" and "Policy implementation" also appear with relatively large proportions, indicating that these areas are recognized as important within the broader discourse. The emphasis on the industrial ecosystem reflects awareness of the need to strengthen supporting industries, technology transfer, and production linkages. At the same time, the significant presence of policy implementation highlights persistent operational challenges, such as weak coordination among institutions and limited effectiveness in translating policy into practice. In contrast, themes such as "Domestic industrial capacity," "Defense logistics performance," and "Spatial distribution of industry," although still relevant, occupy smaller areas in the treemap. This suggests that critical operational aspects particularly those related to production capability, logistics efficiency, and spatial distribution have not yet become primary priorities in policy formulation. The imbalance between regulatory dominance and limited attention to spatial and logistical dimensions indicates a structural weakness in current policy approaches.

The relatively small representation of "Spatial distribution of industry" is particularly significant, as it demonstrates that the geospatial dimension has not been fully integrated into defense industrial policy. This is a major concern for an archipelagic country like Indonesia, where efficiency in distribution, connectivity, and territorial coverage is essential to ensure national defense readiness.

The absence of a strong spatial approach may lead to logistical inefficiencies, unequal industrial development, and limited responsiveness to strategic threats across regions. Therefore, the integration of Geospatial Intelligence through Geographic Information Systems (GIS) is crucial to address this gap. By incorporating spatial analysis into policymaking, Defend ID Indonesia can evolve from a regulation-driven framework into a more operational, data-driven system. This transformation enables improved logistics planning, optimized infrastructure placement, reduced regional disparities, and more adaptive decision-making processes. Ultimately, it strengthens national resilience by aligning defense industrial capabilities with Indonesia's unique geographic and strategic landscape [29].

3.2 Discussion

3.2.1 Main research findings

The research findings reveal measurable spatial patterns in terms of industrial concentration, accessibility variations, logistics bottlenecks, and industrial distribution optimization scenarios. These findings indicate that Indonesia's defense industry remains concentrated in specific regions with varying levels of accessibility across different areas, consequently affecting logistics distribution and operational efficiency. Accessibility measurements further demonstrate that eastern Indonesia has lower logistics connectivity compared to western regions, suggesting that the spatial distribution of industries and transportation networks directly influences operational response speed and the effectiveness of logistics systems. This condition indicates that differences in spatial characteristics are not merely geographical variations but also have strategic implications for defense operational readiness and supply chain resilience. Therefore, optimizing the spatial arrangement of industrial facilities and distribution networks becomes an essential factor in reducing transportation constraints within an archipelagic environment. The primary contribution of this study lies in the development of a GIS-based spatial analytical framework that supports decision-making through measurable outputs, including industrial concentration patterns, accessibility levels, distribution bottlenecks, and industrial optimization scenarios. Meanwhile, qualitative findings were utilized as supporting information to provide contextual understanding of the modeling results and strengthen the interpretation of patterns generated through GIS analysis.

3.2.2 The role of GIS as a decision support system in defense industrial policy

The role of Geographic Information Systems (GIS) as a decision support system in defense industrial policy is highly strategic, particularly through the integration of spatial clustering, location-allocation, and network analysis, which enable objective and data-driven decision-making. The findings of this study indicate that spatial inequality in Indonesia's defense industry is not merely a normative policy issue, but a structural problem that can be quantitatively analyzed and optimized through geospatial approaches [30]. In the context of global challenges such as supply chain disruptions due to geopolitical conflicts, technology-driven warfare, and increasing multidomain threats the need for an adaptive and resilient defense industrial system becomes more urgent. Through spatial clustering, patterns of industrial concentration can be identified; through location-allocation, optimal locations for industry and logistics facilities can be determined; and through network analysis, the efficiency of logistics connectivity across archipelagic regions can be evaluated. Thus, GIS evolves from a mapping tool into a model-based analytical system capable of simulating policy scenarios, supporting more adaptive, efficient, and geographically aligned defense industrial policymaking [31].

3.2.3 The role of location-allocation modeling in enhancing efficiency and resilience of the defense industry

The geoinformatics approach, particularly location-allocation modeling, provides a strong analytical foundation for designing an efficient and resilient defense industrial system, especially in the context of an archipelagic country like Indonesia. This model enables the identification of optimal locations for industrial and logistics facilities by considering key spatial variables such as distance, accessibility, travel time, density of strategic areas, and transportation network connectivity. Indonesia's dispersed and complex geography presents distribution challenges that cannot be effectively addressed through conventional, non-spatial policy approaches, often resulting in spatial inequality and logistical inefficiency [32]. Through location-allocation modeling, various industrial distribution scenarios can be systematically simulated to optimize costs, reduce response times, and minimize supply chain risks [33]. Furthermore, this approach enhances logistics mobility to border and conflict-prone areas, contributing to national resilience by aligning production locations with operational needs in a spatially adaptive defense system [34].

3.2.4 Challenges in the development of geoinformatics in defense industrial policy

The effectiveness of GIS utilization depends not only on technological advancement but also on data availability, system interoperability, and integration with public policy. Limited availability of accurate, up-to-date, and standardized geospatial data remains a major constraint in producing reliable spatial analysis for strategic decision-making. In addition, low interoperability among systems and institutions leads to data fragmentation, hindering rapid and effective information exchange, especially in emergency or military operations. Moreover, the integration of GIS into public policy remains suboptimal due to the absence of adaptive and coordinated cross-sector data governance

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frameworks. Therefore, GIS innovation in the defense sector should not be viewed solely as a technical issue, but as part of a broader system requiring strong governance and policy support. The development of integrated, interoperable, and standardized geospatial data infrastructure is essential to ensure that spatial data can be effectively utilized in evidence-based defense industrial policymaking, thereby enhancing efficiency, accuracy, and national defense resilience in the face of global threats [35].

3.2.5 Expansion of GIS applications into defense geoinformatics.

This study demonstrates that the application of Geographic Information Systems is no longer limited to traditional fields such as environment, disaster management, or regional planning, but has significant potential in the domain of defense geoinformatics, particularly in supporting strategic industrial and logistics planning [36]. This is important to discuss because the defense sector especially in terms of industrial distribution and logistics remains underexplored in geoinformatics literature compared to other sectors[37]. By integrating spatial analyses such as spatial clustering, location-allocation, and network analysis, this study shows that GIS can be used to identify industrial distribution disparities, optimize the location of strategic facilities, and improve the efficiency of defense logistics networks. Thus, the main contribution of this research lies in expanding the application of GIS into the defense sector, enriching geoinformatics studies with a more interdisciplinary and strategically oriented approach, and opening opportunities for future research in spatially driven defense systems [38].

3.2.6 Research implications for geoinformatics development in system and policy design

The implications of this study lie in its contribution to the development of geoinformatics, particularly in methodological innovation and system design. This research demonstrates that the integration of qualitative analysis with GIS-based spatial analysis through spatial clustering, location-allocation, and network analysis can be developed into a geospatial decision support system for defense industrial policy [39]. This contribution is both scientific and technical, as it introduces a novel analytical model that not only maps phenomena but also optimizes industrial distribution and logistics using spatial data. Furthermore, the study expands the application of GIS into the defense sector, highlighting its potential as a strategic planning tool in complex systems such as archipelagic states. From a system perspective, it also emphasizes the importance of developing integrated and interoperable geospatial data infrastructure to support evidence-based policymaking. Therefore, the implications extend beyond practical applications, contributing to the advancement of theory, methodology, and system design in geoinformatics [40].

3.2.7 Comparison of research findings with previous studies

The findings of this study indicate a shift from fragmented approaches toward a more integrated geospatial analytical approach. Previous studies generally focused on policy perspectives and operational aspects of the defense industry, resulting in analyses that tended to be sectoral and were unable to comprehensively explain spatial relationships. In contrast to earlier studies, this research contributes to the field of geoinformatics through the integration of *spatial clustering*, *location-allocation* modeling, and logistics network analysis into a unified GIS-based analytical framework, thereby enabling a more measurable and systematic identification of industrial distribution patterns, accessibility levels, and logistics bottlenecks [41].

3.2.8 Geoinformatics contribution and spatial analytical framework

The primary contribution of this study lies in the development of a geoinformatics approach through the integration of *spatial clustering*, *location-allocation* modeling, and logistics network analysis into a unified GIS-based analytical framework. This integration provides additional value compared to conventional approaches that generally position GIS only as a spatial visualization tool or a supporting instrument for policy formulation. Through this framework, the analysis is not limited to describing the spatial distribution of defense industries but also explains the relationships among spatial variables that influence the effectiveness of logistics systems and operational performance. The application of *spatial clustering* enables the identification of industrial concentration patterns and regional disparities, while *location-allocation* modeling provides an analytical basis for determining more optimal facility locations according to operational requirements and accessibility conditions. Furthermore, logistics network analysis contributes to identifying distribution bottlenecks and evaluating connectivity efficiency across regions. Therefore, this study extends geospatial applications beyond descriptive mapping toward a more measurable, systematic, and spatial optimization-based decision-support system for defense industrial planning in an archipelagic environment.

3.2.9 Strengths and limitations of the study

This study's primary strength lies in its interdisciplinary approach, integrating qualitative analysis with Geographic Information Systems based spatial analysis, thereby generating more comprehensive evidence-based spatial insights into defense industrial issues. The use of methods such as spatial clustering, location-allocation, and network analysis also provides a strong methodological contribution in developing a geospatial decision support system relevant to an archipelagic context[42]. However, this study has several limitations, particularly regarding the availability and quality of geospatial data, which may affect the accuracy of the analysis. In addition, the approach remains largely conceptual and simulation-based, requiring further validation through empirical implementation at policy and operational levels. Another limitation concerns the suboptimal integration of cross-sectoral data and the dynamic nature of policy environments, which may affect the long-term sustainability of the proposed model [43].

4. Conclusion

This study demonstrates that Indonesia's defense industrial system continues to face spatial disparities related to industrial concentration, accessibility levels, logistics connectivity, and operational efficiency. Geographic Information Systems (GIS)-based analysis identified that defense industries remain concentrated in western Indonesia, particularly on Java Island, while eastern regions exhibit lower accessibility levels and relatively limited logistics connectivity. These conditions contribute to the emergence of logistics bottlenecks, higher travel impedance, uneven industrial development, and limitations in response speed during sudden threats as well as in supporting the effectiveness of humanitarian operations. These findings indicate that spatial dimensions are not merely geographical characteristics but also represent strategic factors influencing national defense readiness and the resilience of logistics supply chains.

The integration of *spatial clustering*, *location-allocation* modeling, and logistics network analysis into a GIS-based analytical framework provides a more systematic understanding of industrial distribution patterns and regional vulnerabilities. This approach enables the identification of industrial concentration patterns, the measurement of accessibility levels, the detection of regional disparities, and the evaluation of optimization scenarios for industrial and logistics facility locations. The findings suggest that a more balanced industrial distribution and strengthened logistics networks can improve operational coverage, reduce distribution costs, and enhance the efficiency of logistics systems within an archipelagic environment such as Indonesia. The principal contribution of this study lies in expanding the role of GIS beyond its conventional function as a descriptive mapping tool into a decision-support and spatial optimization framework within the field of defense geoinformatics. Unlike previous studies that primarily emphasized policy and operational aspects, this study demonstrates that geospatial analysis can function as an *analytical engine* supporting *evidence-based decision-making*, particularly in planning defense industrial locations in Indonesia. Future studies are recommended to integrate real-time geospatial data, remote sensing technologies, and empirical implementation at the operational level to further improve the validity, accuracy, and applicability.

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