P-ISSN: 2798-1134 | E-ISSN: 2797-3549 | DOI: 10.52562/injoes.2024.845

Indonesian Journal of Earth Sciences

http://journal.moripublishing.com/index.php/injoes

| Research Article |

Check for updates

Evaluating Industrial Areas with Spatial Multicriteria Analysis (SMCA)

Marwah Noer [1,2]*, Adi Wibowo [1]

[1]Geography Department, University of Indonesia, Margonda Raya Street, 16424, Depok, Indonesia
[2]Ministry of Agrarian Affairs and Spatial Planning/National Land Agency, Sisingamangaraja Street No.2, 12014, Jakarta, Indonesia
** Correspondence: marwah.noer@ui.ac.id*

Received: 31 October 2023 / Accepted: 18 February 2024 / Published: 23 February 2024

Abstract: The assessment of industrial areas stands as a pivotal challenge, increasingly recognized for its urgency across various regions. The industrial sector is a cornerstone of national economic development, contributing significantly to growth and enhancing community welfare. Nonetheless, the establishment of industries also poses environmental and societal risks, primarily due to potential pollution. This study focuses on evaluating the suitability of industrial zones in East Cikarang District, Bekasi Regency, through spatial analysis, benchmarking findings against government-regulated industrial areas as outlined in the Bekasi Regency spatial plan for 2011-2031. Employing Spatial Multicriteria Analysis (SMCA) via ILWIS software, this research aims to deliver a comprehensive assessment of industrial locations by considering variables such as proximity to roads, rivers, settlements, land slope, and alignment with designated industrial zones in the regional spatial plan. The analysis reveals a nuanced classification of industrial suitability, with 48.55% of the area deemed highly suitable, indicating a substantial portion of East Cikarang District is favorable for industrial development. Conversely, a smaller segment falls into the less suitable or unsuitable categories. Overall, the study concludes that 55% of the region qualifies as suitable for industrial purposes based on the SMCA-derived spatial model, with 98.1% of the assessed area aligning with the criteria for designated industrial zones. These insights are intended to guide industrial planning and environmental management strategies, fostering sustainable development within the region.

Keywords: SMCA, ILWIS, Industrial Suitability Area, Industrial Designated Area

INTRODUCTION

The industrial sector's significance transcends mere economic metrics, embodying a critical conduit for a nation's overall prosperity. This sector is instrumental in elevating raw materials to finished goods, inherently increasing their value and societal benefit. Such transformational activities are central to economic growth, technological progress, resource enhancement, and the development of human capital. As articulated by Saputra et al.(2021), the sector is a pivotal element in the economic framework, fostering the transition of raw inputs into products of increased value. Echoing this sentiment, Azaria et al. (2020) highlight the industrial sector's role in augmenting goods' value, facilitating a tangible elevation in their utility and market worth. This sector's expansion has a profound impact on urbanization patterns, with Widiawaty (2019) noting a significant migration trend from rural locales to urban centers, attributed to the lure of industrial employment opportunities. However, this migration and industrial expansion bring to the fore considerable environmental challenges (Zaenuri, 2011). Zwolak et al. (2019) underscore the detrimental effects on agricultural lands and the exacerbation of pollution through industrial waste, emphasizing the urgent need for strategic delineation and management of industrial activities to harmonize economic aspirations with environmental stewardship and societal well-being.

The strategic establishment of industrial areas emerges as a critical solution to the challenges posed by the sector's expansion. These areas, serving as economic infrastructures, play a vital role in generating essential financial resources for communities, as outlined by Alder, et al.(2013), who studied the effect of place-based industrial policy on economic development, focusing on the establishment of Special Economic Zones (SEZ) in China. Their findings indicated that the establishment of SEZs is associated with a significant increase in the level of GDP, highlighting the economic benefits of industrial areas. Moreover, the research by Meyer (1986) on the evaluation of designated Industrial and Commercial Improvement Areas provided insights into the economic and environmental measures

adopted under the Urban Programme, further reinforcing the importance of industrial areas in community development.

By concentrating industrial activities within well-equipped zones, these areas not only streamline operations but also facilitate the efficient management of resources and environmental impacts. The selection and development of industrial area locations are paramount, necessitating a meticulous planning process that integrates social, economic, and environmental considerations. Ruiz et al. (2012) emphasize the importance of this coordination, asserting that effective site selection is pivotal for fostering sustainable development and ensuring the optimal utilization of these industrial zones. The objectives of industrial designated areas development in Indonesia have been explained in Government Regulation No. 142 of 2015, which, among other things, provides location certainty following spatial plans, accelerates the spread and even distribution of industrial development, increases environmentally sound industrial development efforts, and increases investment competitiveness and industrial competitiveness.

The literature on industrial area suitability has increasingly recognized the utility of multi-criteria analysis in navigating the complexities of site selection. This analytical method, favored for its comprehensive approach to decision-making, has been pivotal in addressing the multifaceted challenges inherent in determining suitable locations for industrial activities. Tirkolaee et al. (2021) presented an integrated decision-making approach for green supplier selection, utilizing MCDM techniques based on Analytic Hierarchy Process (AHP) and fuzzy TOPSIS. This methodology was applied to a green service food manufacturing company in Iran, demonstrating its applicability in selecting suppliers under uncertain conditions. Feng et al. (2021) developed a novel MCDM method integrating the linguistic entropy weight (LEW) method and fuzzy axiomatic design (FAD) for selecting suitable sites for electric-vehicle charging stations from a sustainable perspective. This method's stability and reliability were confirmed through sensitivity and comparative analyses. Akpinar et al. (2020) discussed the use of AHP for vehicle selection, highlighting the methodology's ability to compare tangible and intangible criteria and define their importance, showcasing its utility in subjective decision-making processes. Studies by Ravichandran et al. (2022), Astuty et al. (2023), Eldamaty et al. (2023), and Yildiz (2024), also have demonstrated the efficacy of integrating multi-criteria analysis with Geographic Information Systems (GIS) to produce nuanced suitability maps for industrial areas. This integration facilitates a more informed and nuanced assessment of potential sites, leveraging spatial data to enhance the accuracy and relevance of the selection process.

Despite significant advancements in the methodologies for assessing industrial area suitability, a notable research gap persists in the comprehensive evaluation of existing government-regulated industrial areas against spatial plans. The current literature, while rich in methodologies for site selection, lacks in-depth analysis of how these selected areas align with or diverge from government regulations and spatial planning objectives.

Pagone et al. (2020) emphasized the common feature of MCDA in evaluating sustainable manufacturing, noting the participation of decision-makers in defining the importance of each criterion, which could be complex and time-consuming. This highlights a need for methodologies that can simplify and streamline the decision-making process in evaluating industrial areas. Contreras-Massé et al. (2020) proposed a new methodology for selecting IIoT platforms for smart manufacturing, suggesting the use of multi-criteria analysis for a repeatable and justified decision-making process. This approach includes not only technical but also economic and social criteria, providing a comprehensive view of the problem analyzed. However, the adaptation of such methodologies to evaluate the suitability of industrial areas within government regulations remains underexplored.

This study seeks to bridge this gap by applying advanced spatial modeling techniques to assess the suitability of industrial areas within the regulatory and planning framework of Bekasi Regency. By doing so, it aims to contribute valuable insights into the efficacy of current planning practices and the potential for their optimization in alignment with broader development goals.

Bekasi Regency, recognized as Southeast Asia's largest industrial hub and a key support zone for Jakarta, hosts over 7,500 national and multinational industries (Iskandar, 2023). The region's industrial prominence attracts a significant number of immigrants, contributing to its demographic growth. This increase in population, while beneficial for economic development, necessitates careful management to ensure environmental sustainability. This research is driven by the objective to formulate and evaluate a spatial model for assessing the suitability of industrial areas in East Cikarang District, Bekasi Regency, with a particular focus on their compliance with the Bekasi Regency spatial plan for 2011-2031. The study's novelty lies in its application of multi-criteria analysis and GIS technologies to scrutinize existing industrial

zones within a government-regulated spatial context, offering a pioneering perspective on the assessment of industrial area suitability. Through this novel approach, the research aspires to furnish stakeholders in industrial planning and development with critical insights, facilitating more informed decision-making processes. Furthermore, by aligning its objectives with the Sustainable Development Goals, specifically Goal 9, the study underscores its commitment to fostering resilient infrastructure, inclusivity, sustainability, and innovation in industrial area development.

METHOD

Study Area

East Cikarang District, sharing its eastern border with Karawang Regency, encompasses an expanse of 5,131 hectares and is home to a population of 96,326 residents across its eight villages. This district is distinguished as one of Bekasi Regency's most industrially concentrated areas, positioning it within one of Southeast Asia's premier industrial hubs. The prominence of East Cikarang in the industrial landscape is not only a testament to its strategic location but also highlights its role in the broader economic development trends observed across the region. Figure 1 illustrates the study area, providing a visual context to the geographical and industrial significance of East Cikarang District.

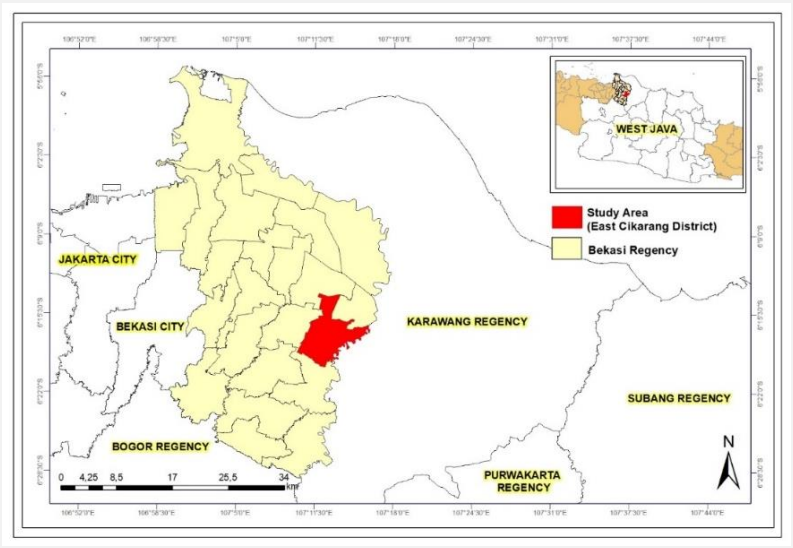


Figure 1. Study Area.

Research Methodology and Data Analysis

This study employs Spatial Multi-Criteria Analysis (SMCA) to address decision-making processes in public planning scenarios. SMCA integrates various variables that are normalized and weighted to reflect their relevance to the specific theme of suitability, facilitating comprehensive spatial decision-making across multiple domains such as regional development, risk management, and site selection (Ebrahimi et al., 2019; Colapinto et al., 2020; Foria et al., 2021). The methodological strength of SMCA lies in its robustness for spatial decision analysis, enabling prioritization, scenario forecasting, and elucidation of spatial alternatives for stakeholders, thereby enhancing informed decision-making (Aldiansyah & Wibowo, 2022). However, a notable limitation of SMCA is its dependence on expert knowledge, which risks subjectivity and potential inaccuracies in outcomes if the knowledge base is inadequate (Setiawan et al., 2021). To mitigate this limitation, this research incorporates a diverse array of scholarly sources and regulatory guidelines to define and refine the criteria for variables used.

The data for this study comprises digital information on roads, rivers, settlements, and topographical contours extracted from the 1:25,000 scale Indonesian Topographic Map. Additionally, data on industrial designated areas were digitized from the Bekasi Regency regional spatial plan for the period 2011-2031. The analysis utilizes ILWIS and ArcMap software tools. ILWIS, a free software licensed under the General Public License (GNU GPL), facilitates the creation of a spatial model for industrial area suitability using five variables in raster data format (Wibowo & Semedi, 2011). ArcMap software is employed for in-depth analysis of industrial suitability areas and comprehensive map generation. The application of Geographic Information Systems (GIS) through ArcMap aims to simplify the decision-

making process, particularly in spatial policy formulation (Nurhuda et al., 2020; Wibowo et al., 2015). The procedural flow of this research is detailed in Figure 2.

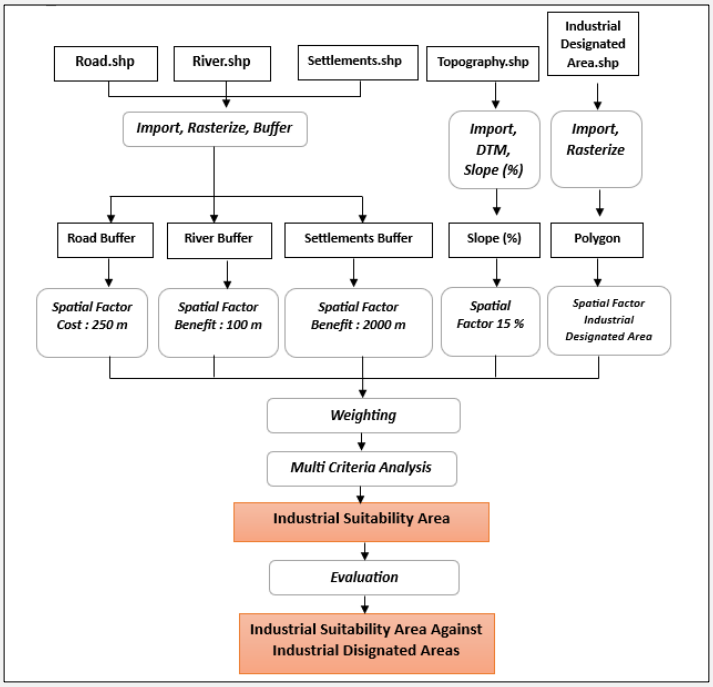


Figure 2. Research Flow Diagram.

Table 1. Variables and Criteria for Industrial Area Suitability

No	Variable	Criteria	Information
1	Distance from Road	≤ 250 m	(Nurhuda et al., 2020)
2	Distance from Settlements	≤ 2 km	Regulation of the Minister of Industry of the Republic of Indonesia Number 40/M-IND/PER/6/2016 concerning Technical Guidelines for Industrial Area Development
3	Distance from River	≤ 100 m	Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 28/PRT/M/2015 concerning the Determination of River Boundary Lines and Lake Boundary Lines
4	Topography/Slope	≤ 15%	Regulation of the Minister of Industry of the Republic of Indonesia Number 30 of 2020 concerning Criteria for Industrial Designated Areas
5	Industrial Designated Area	As per regional spatial plan	Bekasi Regency Regional Regulation Number 12 of 2011 concerning Bekasi Regency Regional Spatial Plan for 2011-2031

The research methodology incorporates five key variables to construct a model for assessing the suitability of industrial zones. These variables include proximity to rivers, roads, and settlements, land slope, and alignment with the regional spatial plan for industrial areas. The selection of these variables is grounded in comprehensive criteria derived from a range of authoritative sources. Each variable is assigned an equal weight of 20%, reflecting the assumption that all variables equally influence the determination of industrial area suitability. This weighting strategy is predicated on the hypothesis that the specified variables collectively play a pivotal role in assessing the appropriateness of locations for industrial development. The culmination of this analysis is a conformity map that aligns with the study's primary objectives, providing a spatial representation of suitable industrial areas within the Bekasi Regency (Yang et al., 2011). The variables, their corresponding criteria, and the legal frameworks guiding these determinations are summarized in Table 1.

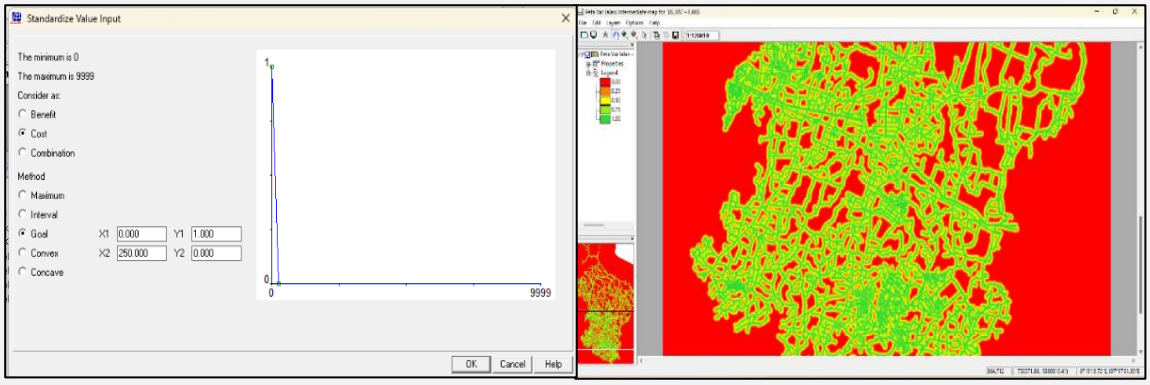
RESULT AND DISCUSSION

Industrial Suitability Based on Key Variables

Road Access and Industrial Suitability

Road access emerges as a pivotal variable in determining industrial area suitability due to its direct influence on transportation costs. Our analysis, illustrated in Figure 3, employs a binary coding system where green areas, marked with a value of 1 or "True", denote locations in East Cikarang District proximal to roads and thus presumed more suitable for industrial purposes. Conversely, red areas, coded as 0 or "False", represent locations deemed less suitable due to their distance from roads, surpassing the 250-meter threshold associated with increased transportation expenditures (Wibowo & Semedi, 2011; Nurhuda et al., 2020). This criterion underscores the critical role of road proximity in enhancing industrial area accessibility and minimizing operational costs.

Negi & Jain (2008) emphasized the importance of environmental and economic factors in siting industries through spatial multi-criteria analysis, similar to the current study's emphasis on road access to minimize transportation costs. However, our research extends this by integrating a binary coding system for a more nuanced assessment of road proximity, offering a practical tool for decision-makers.

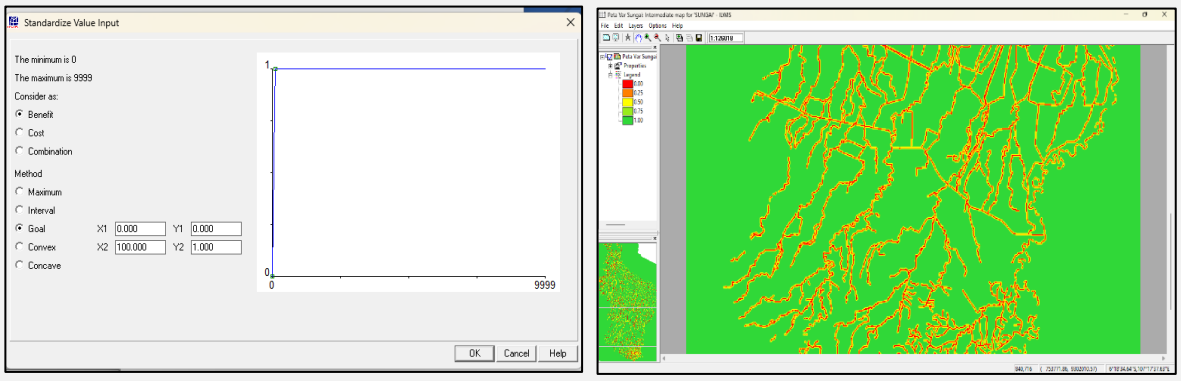


(a) (b)

Figure 3. (a) standardization of road variable values, and (b) suitability results of road variables for East Cikarang District.

Proximity to Rivers: Assessing Pollution Risks

The second critical variable, distance from rivers, addresses environmental considerations by assuming that areas closer to rivers, and thus at higher risk of pollution, are less suitable for industrial development. Figure 4 highlights the spatial distribution of suitability based on this criterion, with green zones (value 1 "True") situated beyond the 100-meter safe distance from rivers, as mandated by environmental regulations (Regulation of the Minister of Public Works and Public Housing Number 28/PRT/M/2015). This spatial analysis serves as a precautionary measure to mitigate potential environmental impacts associated with industrial activities.



(a) (b)

Figure 4. (a) standardization of river variable values, and (b) suitability results of river variables for East Cikarang District.

Baghel's (2022) GIS-based analysis for locating industrial parks highlights the integration of AHP with GIS, akin to our methodology for assessing river proximity to mitigate pollution risks. The current research adds value by specifically quantifying safe distances from rivers, thereby enhancing environmental sustainability practices.

Residential Proximity and Industrial Compatibility

The third analysis dimension focuses on the proximity to residential areas, operating under the premise that closer proximity equates to lower suitability due to potential nuisances such as noise and pollution. Figure 5 delineates this relationship, where areas distanced more than 2 kilometers from settlements, depicted in green (value 1 "True"), are deemed more appropriate for industrial activities. This criterion reflects the necessity to balance industrial development with residential well-being, as outlined in the Regulation of the Minister of Industry of the Republic of Indonesia Number 40/MIND/PER/6/2016.

Jensen et al. (2012) discussed the use of a habitat suitability index for industrial symbiosis, focusing on mature industrial systems. Our study builds on this by examining residential proximity to industrial areas, thereby addressing potential social impacts such as noise and pollution, and suggesting a more harmonized industrial-residential coexistence.

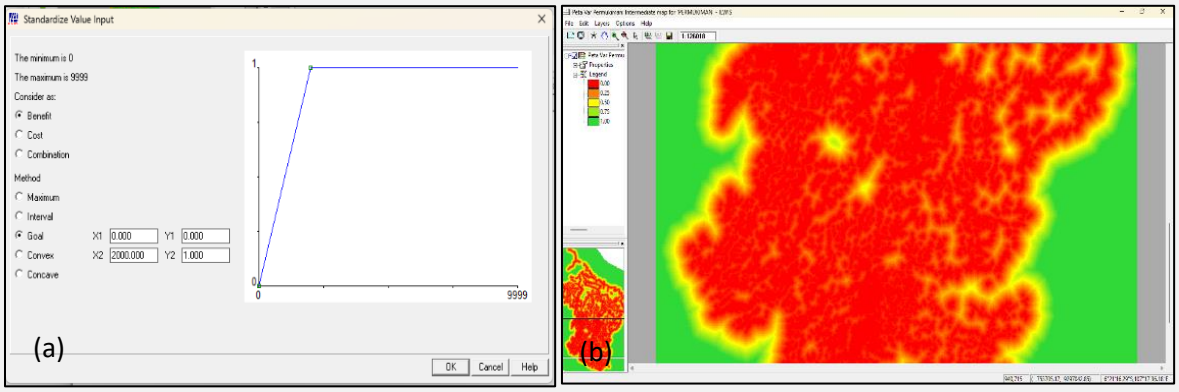


Figure 5. (a) standardization of settlement variable values, and (b) suitability results of settlement variables for East Cikarang District.

Topography and Industrial Development

The suitability analysis also considers topography, with a preference for flatter terrains deemed more conducive to industrial development. Figure 6 reveals that the majority of East Cikarang District is characterized by suitable slopes, aligning with the technical criteria for industrial areas stipulated by the Regulation of the Minister of Industry of the Republic of Indonesia Number 30 of 2020. The predominance of green in the figure suggests a favorable topographical condition for industrial expansion within the district.

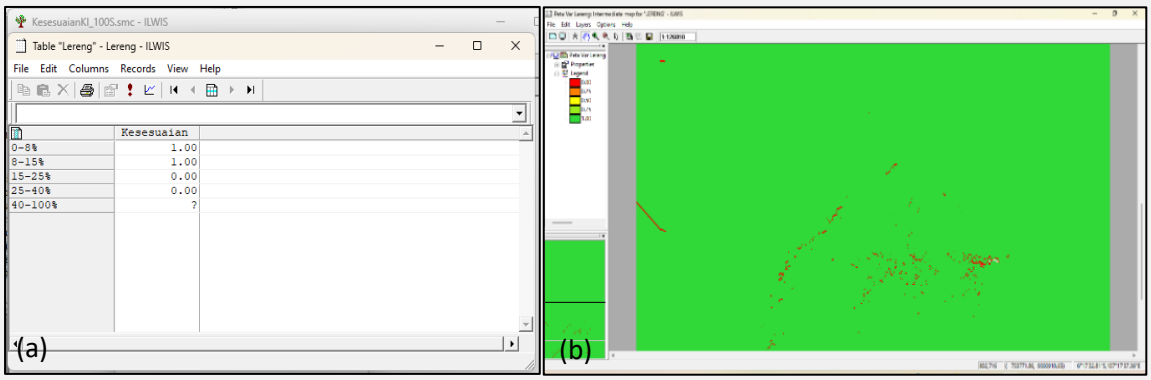


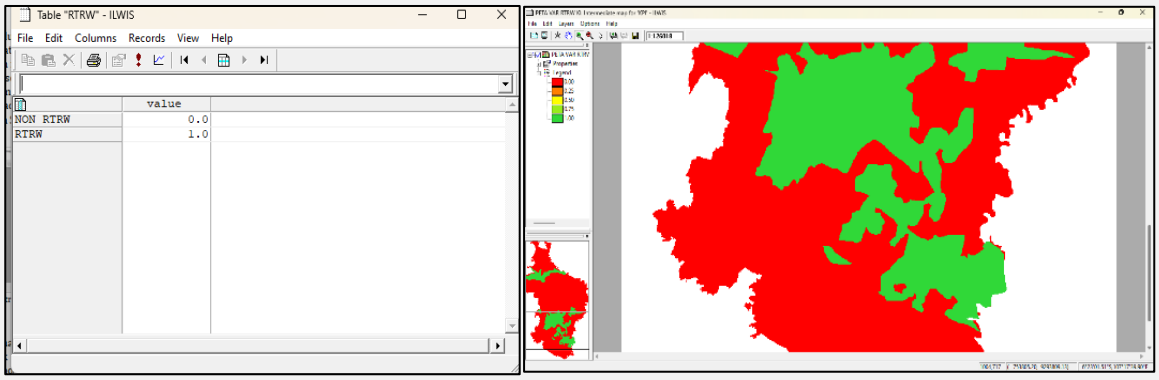
Figure 6. (a) standardization of slope variable values, and (b) suitability results of slope variables for East Cikarang District.

Hazra et al. (2017) and Salui & Hazra (2017) both utilized GIS and AHP for industrial site suitability, recognizing the role of physical geography. The current research's focus on topography, specifically the preference for flatter terrains, offers a clear criterion for industrial development that complements these earlier studies by providing a specific threshold for slope suitability.

Industrial Designation and Spatial Planning

Lastly, the alignment with the regional spatial plan for industrial designated areas serves as a foundational variable. Figure 7 contrasts the spatial plan's designated industrial areas (green) against non-designated areas (red), emphasizing the importance of government zoning in facilitating industrial development. This approach aligns with Bekasi Regency's regulatory framework, ensuring that industrial development is both strategic and compliant with long-term spatial planning goals (Bekasi Regency Regional Regulation No. 12 of 2011).

The current study's alignment with regional spatial planning for industrial designated areas is a critical advancement over previous research. While other studies, such as Sarkar et al. (2014), have used GIS techniques for land suitability analysis, our research directly links these analyses to governmental zoning and planning regulations, ensuring that industrial development is strategically aligned with long-term regional objectives.



(a) (b)

Figure 7. (a) standardization of industrial designated areas variable values, and (b) suitability results of industrial designated areas variables for East Cikarang District.

This research on industrial area suitability provides significant insights for both scientific exploration and practical applications in urban and industrial planning. It introduces a nuanced multi-criteria decision-making methodology that integrates geographic information systems (GIS) with environmental, economic, and social factors, enriching the field of spatial analysis and sustainability science. This methodological framework offers a detailed approach to assessing the complexity of industrial location dynamics, highlighting the balance between economic efficiency, environmental sustainability, and social implications.

For policymakers and urban planners, the findings serve as a data-driven foundation for informed zoning and land-use regulation, supporting sustainable urban and industrial growth strategies. Industrial developers gain a valuable tool for site selection that mitigates environmental and social risks, enhancing project feasibility and community relations. Furthermore, by aligning with regional spatial planning, the research ensures that industrial development contributes to broader land-use objectives, optimizing land use and supporting regional economic goals.

This study advances our understanding of sustainable industrial development, providing practical solutions for environmental management, community engagement, and strategic planning. It underscores the importance of a balanced approach to industrial planning that prioritizes ecological integrity and social well-being alongside economic objectives.

Results of Industrial Suitability Areas in East Cikarang District

In the comprehensive assessment of industrial suitability within East Cikarang District, the research deployed a balanced weightage approach, allocating an equal 20% significance to each of the five scrutinized variables via ILWIS software, culminating in a cumulative weightage of 100% (Astuty et

al., 2023). This equal weight distribution, mirroring methodologies from preceding studies, aims to foster a comparative analysis, enriching the discourse on industrial area development. The spatial model showcased in Figure 8 categorizes industrial area suitability into five distinct classifications, revealing a gradient from high suitability (greener areas) to low suitability (redder areas), thereby providing a visual depiction of industrial potential across East Cikarang District.

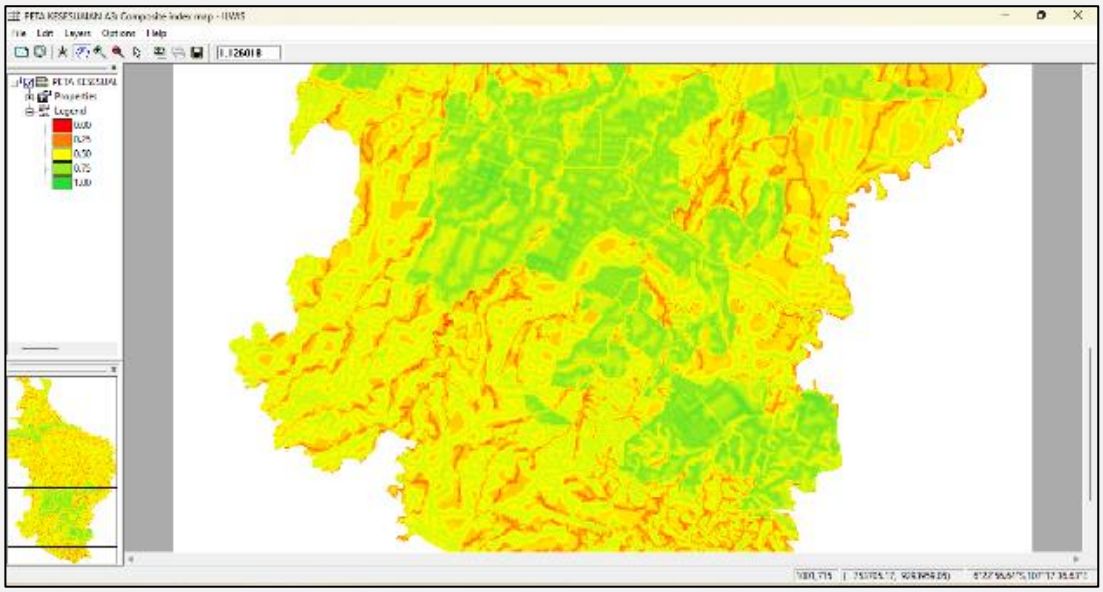


Figure 8. Spatial Model of Industrial Suitability Areas in East Cikarang District.

Transitioning from raster to polygon data via ArcMap software facilitated a detailed area calculation, segmenting the suitability into four precise classes: suitable, quite suitable, less suitable, and not suitable. The findings revealed a predominant suitability, with 48.55% of the area classified as suitable, underscoring East Cikarang's industrial potential (Figure 9). Contrasting these results with similar studies, such as Astuty et al. (2023) and Nurhuda et al. (2020), highlights varying outcomes possibly attributed to the differential variable consideration, showcasing the importance of tailored criteria in industrial suitability assessments.

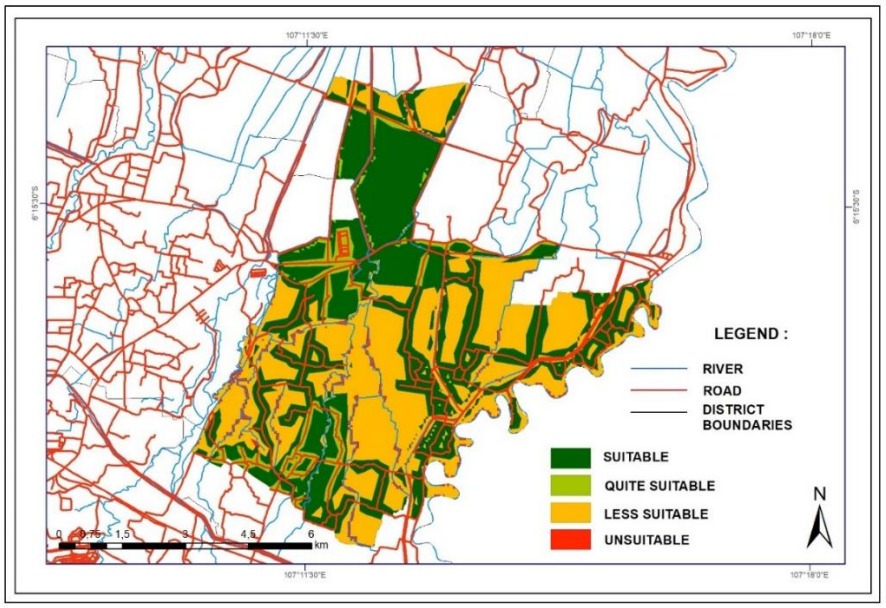


Figure 9. Industrial Suitability Area for East Cikarang District.

The evaluation against industrial designated areas further validates the research's robustness, revealing a high congruence (98.1% suitability) with governmental industrial zoning, save for a minor segment falling into the unsuitable category due to proximal river constraints. This alignment, depicted in Figure 10, underscores the efficacy of spatial multi-criteria analysis (SMCA) in urban planning and policy formulation, particularly for industrial development. Despite the inherent limitation of SMCA's reliance on expert knowledge, the study mitigates this through a comprehensive review of prior research, ensuring a grounded and insightful analysis.

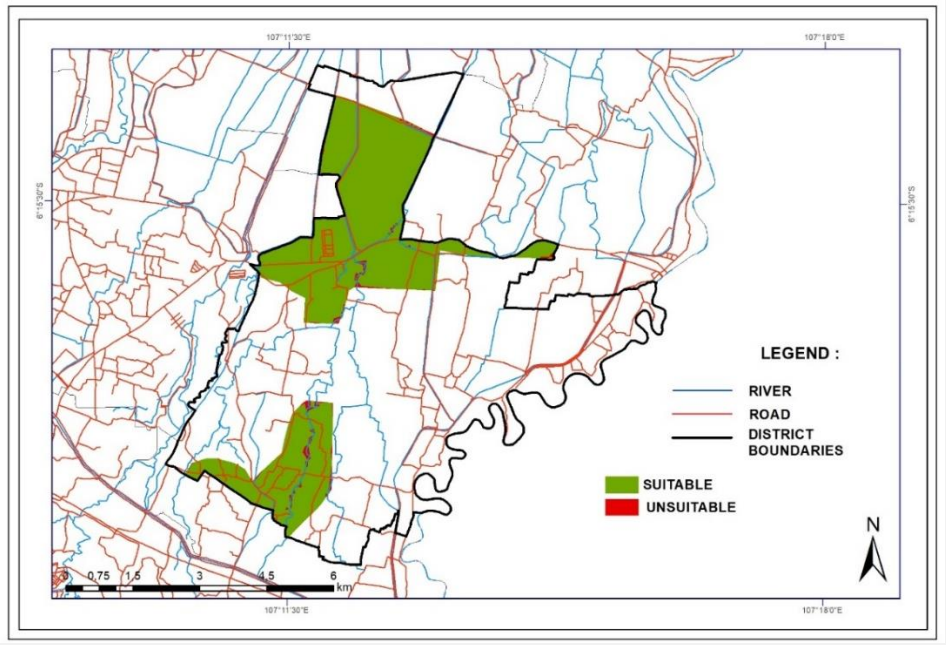


Figure 10. Evaluation of Industrial Suitability Areas Against Industrial Designated Areas.

The current research on assessing the suitability of industrial areas in East Cikarang District, which implements a balanced weighting approach for variables and employs ILWIS and ArcMap software for spatial analysis, stands as a significant advancement when juxtaposed with prior studies in the literature. This study's methodology of equal weight distribution (20% each for five variables) for assessing industrial area suitability provides a comprehensive framework that complements and extends the findings of previous research.

Negi & Jain (2008) utilized a spatial multicriteria approach focusing on groundwater pollution risks from industrial sites, highlighting the importance of environmental and socio-economic factors in site suitability analysis. The current study's holistic approach, which equally weighs multiple variables, including environmental factors, offers a broader perspective, thereby enhancing the sustainability aspect of industrial development.

Pedrazzani et al. (2018) emphasized the integration of ecotoxicological factors in evaluating industrial processes, showcasing the importance of environmental considerations in industrial suitability assessments. The current research aligns with this perspective by factoring in proximity to rivers and residential areas, thus addressing potential environmental and social impacts.

Baghel (2022) and Kang et al. (2021) demonstrated the effectiveness of GIS and multicriteria decision analysis in land-use suitability assessments for industrial and other urban developments. The methodology employed in the current study, particularly the use of GIS technology for spatial modeling and classification, complements these approaches by providing a detailed analysis of industrial suitability based on specific environmental and socio-economic variables.

The findings from the evaluation of industrial suitability areas in East Cikarang District offer significant scientific and practical implications. Scientifically, the application of Spatial Multi Criteria Analysis (SMCA) with a balanced weighting approach across five key variables (road access, proximity to rivers, residential areas, land slope, and industrial designated areas) provides a methodological advancement in industrial area suitability assessment. This research aligns with and extends the work of

Astuty et al. (2023), offering a nuanced understanding of how spatial factors contribute to industrial area designation.

Practically, the results have direct implications for urban planning and policy-making. The identification of areas within East Cikarang District that are suitable, quite suitable, less suitable, and not suitable for industrial development aids in informed decision-making for local government and developers. Specifically, the findings that 48.55% of the area is suitable for industrial purposes underscore the district's potential for industrial expansion, supporting economic growth while also highlighting areas where development might be restricted due to environmental or social concerns.

Moreover, the research's validation of government-designated industrial areas through the lens of SMCA underscores the effectiveness of current zoning regulations while suggesting areas for revision based on empirical evidence. The nearly complete alignment (98.1% suitability) between the SMCA results and the industrial designated areas outlined in the Bekasi Regency's spatial plan for 2011-2031 demonstrates the robustness of the region's planning processes. However, the identification of a small portion of designated industrial areas as unsuitable due to proximity to rivers reflects the need for ongoing evaluation and potential adjustment of zoning regulations to protect environmental resources and ensure sustainable development practices.

This study emphasizes the importance of integrating scientific methodologies into the urban planning process, offering a replicable model for assessing industrial area suitability that can be applied in other contexts. The comprehensive analysis not only facilitates evidence-based policy-making but also contributes to the broader discourse on sustainable industrial development, balancing economic objectives with environmental and social imperatives.

CONCLUSION

The conclusion of this study underscores the critical role of spatial multi-criteria analysis (SMCA) in determining the suitability of industrial areas within East Cikarang District. By integrating key variables such as road access, proximity to rivers, residential areas, topography, and existing industrial designated areas, the research provides a comprehensive framework for assessing industrial location suitability. This approach not only advances the methodological toolkit available for urban planning and policy-making but also aligns with sustainable development goals, emphasizing the importance of environmental protection, economic efficiency, and social well-being.

The findings reveal that a significant portion of East Cikarang District is suitable for industrial development, with particular emphasis on areas that are well-connected to road networks, distanced from sensitive environmental zones such as rivers, and strategically positioned relative to residential areas to minimize potential conflicts. These insights are instrumental for stakeholders, including government authorities, industrial developers, and urban planners, offering a data-driven basis for future industrial zoning and development initiatives.

However, the study acknowledges the limitations inherent in the SMCA approach, notably its dependence on the quality and comprehensiveness of input data and the subjective nature of weighting and ranking processes. Future research should explore the integration of more diverse data sources, including socio-economic and environmental impact assessments, to enrich the analysis. Additionally, there is a need for developing more dynamic models that can adapt to changing urban landscapes and industrial demands.

This research contributes to the existing body of knowledge by providing a detailed examination of industrial area suitability using a spatially explicit method. It emphasizes the significance of carefully planned industrial development in achieving balanced economic growth while safeguarding environmental resources and enhancing community well-being. The methodology and findings of this study offer a valuable reference for similar assessments in other regions, promoting more sustainable and informed industrial planning practices worldwide.

ACKNOWLEDGEMENT

The authors would like to thank Geography-Universitas Indonesia for supporting this research. We also thank the anonymous reviewers.

REFERENCES

Akpinar, M., Yiğit, M., Dogan, E., & Aliüstüner, M. (2018). Deciding The Best Vehicle Alternative by Using A Multi Criteria Decision Making Methodology. *International Journal of Engineering Technologies and Management Research, 5*(1), 108–114. https://doi.org/10.29121/ijetmr.v5.i1.2018.53

Alder, S., Shao, L., & Zilibotti, F. (2013). Economic reforms and industrial policy in a panel of Chinese cities. *Journal of Economic Growth, 21*, 305-349. https://doi.org/10.2139/ssrn.2369416

Aldiansyah, S., & Wibowo, A. (2022). Aplikasi Metode Spatial Multi Criteria Analisysis untuk Pengembangan Kawasan Permukiman (Studi Kasus: Re-Evaluasi RTRW Provinsi Sulawesi Tenggara). *Jurnal Geografi, Edukasi Dan Lingkungan (JGEL)*, *6*(2), 136–152. https://doi.org/10.22236/jgel.v6i2.7481

Astuty, Y. I., Noer, M., Stevany, D., Arham, B., Maria R., B., & Wibowo, A. (2023). Evaluasi Kesesuaian Kawasan Peruntukan Industri Menggunakan Model Spasial (Studi Kasus : Kabupaten Bekasi). *Jurnal Pendidikan Geografi Undiksha*, *11*(2), 123–132. https://doi.org/10.23887/jjpg.v11i2.61536

Azaria, V. P., Bela, P. A., & Deliyanto, B. (2020). Studi Kelayakan Perumahan Bersubsidi Penunjang Kawasan Industri (Lokasi: Saga, Balaraja, Kabupaten Tangrang). *Jurnal Sains, Teknologi, Urban, Perancangan, Arsitektur (Stupa)*, *2*(2), 2586–2602. https://doi.org/10.24912/stupa.v2i2.8871

Baghel, A. (2022). GIS-based Industrial Land Suitability Analysis for locating Industrial Parks in Raipur and Nava Raipur. *IOP Conference Series: Earth and Environmental Science, 1032*, 012024. https://doi.org/10.1088/1755-1315/1032/1/012024

Colapinto, C., Jayaraman, R., Ben Abdelaziz, F., & La Torre, D. (2020). Environmental sustainability and multifaceted development: multi-criteria decision models with applications. In *Annals of Operations Research* (Vol. 293, Issue 2, pp. 405–432). Springer. https://doi.org/10.1007/s10479-019-03403-y

Contreras-Masse, R., Ochoa-Zezzatti, A., García, V., Pérez-Dominguez, L., & Elizondo-Cortés, M. (2020). Implementing a novel use of multicriteria decision analysis to select IIoT platforms for smart manufacturing. *Symmetry, 12*(3), 368. https://doi.org/10.3390/sym12030368

Ebrahimi, M., Nejadsoleymani, H., & Daneshvar, M. R. M. (2019). Land suitability map and ecological carrying capacity for the recognition of touristic zones in the Kalat region, Iran: a multi-criteria analysis based on AHP and GIS. *Asia-Pacific Journal of Regional Science*, *3*(3), 697–718. https://doi.org/10.1007/s41685-019-00123-w

Eldamaty, T. A., Ahmed, A. G., & Helal, M. M. (2023). GIS-Based Multi Criteria Analysis for Solar Power Plant Site Selection Support in Mecca. *Engineering, Technology and Applied Science Research*, *13*(3), 10963–10968. https://doi.org/10.48084/etasr.5927

Feng, J., Xu, S., & Li, M. (2021). A novel multi-criteria decision-making method for selecting the site of an electric-vehicle charging station from a sustainable perspective. *Sustainable Cities and Society, 65*, 102623. https://doi.org/10.1016/j.scs.2020.102623.

Foria, F., Miceli, G., Tamburini, A., Villa, F., Rech, A., & Epifani, F. (2021). Application of Spatial Multi-Criteria Analysis (SMCA) to assess rockfall hazard and plan mitigation strategies along long infrastructures. *IOP Conference Series: Earth and Environmental Science*, *833*(1). https://doi.org/10.1088/1755-1315/833/1/012074

Hazra, S., Mukhopadhyay, A., Ghosh, A., Mitra, D., & Dadhwal, V. (2017*). Environment and Earth Observation: Case Studies in India*. Springer. https://doi.org/10.1007/978-3-319-46010-9

Iskandar, E. (2023). *Jejak Sejarah Berkembangnya Kawasan Industri di Kabupaten Bekasi*. Radarbekasi.Id. https://radarbekasi.id/2023/08/24/jejak-sejarah-berkembangnya-kawasan-industri-di-kabupaten-bekasi

Jensen, P., Basson, L., Hellawell, E., & Leach, M. (2012). 'Habitat' Suitability Index Mapping for Industrial Symbiosis Planning. *Journal of Industrial Ecology, 16,* 38-50. https://doi.org/10.1111/j.1530-9290.2011.00438.x

Kang, Z., Wang, S., Xu, L., Yang, F., & Zhang, S. (2021). Suitability assessment of urban land use in Dalian, China using PNN and GIS. *Natural Hazards, 106*, 913 - 936. https://doi.org/10.1007/s11069-020-04500-z

Meyer, P. (1986). Assessing improvement area policy. *Local Economy: The Journal of the Local Economy Policy Unit, 1*, 35 - 43. https://doi.org/10.1080/02690948608725837

Negi, P., & Jain, K. (2008). Spatial Multicriteria Analysis for Siting Groundwater Polluting Industries. *Journal of Environmental Informatics, 12*, 54-63. https://doi.org/10.3808/JEI.200800124

Nurhuda, A., Kurniawansyah, A., R, C. A., & Huda, D. N. (2020). Evaluation of Land Suitability for Industrial Zone in Bekasi Regency, West Java. In *Seminar Nasional Geomatika 2020: Informasi Geospasial Untuk Inovasi Percepatan Pembangunan Berkelanjutan* (pp. 551–560).

Pagone, E., Salonitis, K., & Jolly, M. (2020). Automatically weighted high-resolution mapping of multi-criteria decision analysis for sustainable manufacturing systems. *Journal of Cleaner Production, 257*, 120272. https://doi.org/10.1016/j.jclepro.2020.120272

Pedrazzani, R., Cavallotti, I., Bollati, E., Ferreri, M., & Bertanza, G. (2018). The role of bioassays in the evaluation of ecotoxicological aspects within the PEF/OEF protocols: The case of WWTPs. *Ecotoxicology and Environmental Safety, 147*, 742-748 . https://doi.org/10.1016/j.ecoenv.2017.09.031

Ravichandran, R., Ayyavoo, R., Rajangam, L., Madasamy, N., Murugaiyan, B., & Shanmugam, S. (2022). Identification of groundwater potential zone using analytical hierarchical process (AHP) and multi-criteria decision analysis (MCDA) for Bhavani river basin, Tamil Nadu, southern India. *Groundwater for Sustainable Development*, *18,* 100806. https://doi.org/10.1016/j.gsd.2022.100806

Ruiz, M. C., Romero, E., Pérez, M. A., & Fernández, I. (2012). Development and application of a multi-criteria spatial decision support system for planning sustainable industrial areas in Northern Spain. *Automation in Construction*, *22*, 320–333. https://doi.org/https://doi.org/10.1016/j.autcon.2011.09.009

Salui, C., & Hazra, P. (2017). Geospatial Analysis for Industrial Site Suitability Using AHP Modeling: A Case Study. , 3-21. Springer. https://doi.org/10.1007/978-3-319-46010-9_1

Saputra, R. B., Sasmito, A., & Wardianto, G. (2021). Study Of Manager Circulation In Industrial Area. *Journal of Architecture*, *7*(1), 54–58.

Sarkar, A., Ghosh, A., & Banik, P. (2014). Multi-criteria land evaluation for suitability analysis of wheat: a case study of a watershed in eastern plateau region, India. *Geo-spatial Information Science, 17*, 119 - 128. https://doi.org/10.1080/10095020.2013.774106

Setiawan, H., Wibowo, A., & Supriatna, S. (2021). Pembuatan peta curah hujan untuk evaluasi kesesuaian rencana tata ruang kawasan hutan Kabupaten Bogor. *Geomedia Majalah Ilmiah Dan Informasi Kegeografian* , *19*(2), 113–121. https://journal.uny.ac.id/index.php/geomedia/index

Tirkolaee, E., Dashtian, Z., Weber, G., Tomásková, H., Soltani, M., & Mousavi, N. (2021). An Integrated Decision-Making Approach for Green Supplier Selection in an Agri-Food Supply Chain: Threshold of Robustness Worthiness. *Mathematics, 9*(11), 1304. https://doi.org/10.3390/MATH9111304

Wibowo, A., & Semedi, J. M. (2011). Model Spasial dengan SMCE untuk Kesesuaian Kawasan Industri (Studi Kasus Di Kota Serang). *Globe*, *13*, 50–59. https://doi.org/10.24895/MIG.2011.13-1.%25x

Wibowo, K. M., Kanedi, I., & Jumadi, J. (2015). Sistem Informasi Geografis (SIG) Menentukan Lokasi Pertambangan Batu Bara Di Provinsi Bengkulu Berbasis Website. *Jurnal Media Infotama*, *11*, 51–60. https://media.neliti.com/media/publications/151176-ID-sistem-informasi-geografis-sig-menentuka.pdf

Widiawaty, M. A. (2019). *Faktor-Faktor Urbanisasi di Indonesia*. https://doi.org/10.31227/osf.io/vzpsw

Yang, M., Qian, X., Zhang, Y., Sheng, J., Shen, D., & Ge, Y. (2011). Spatial multicriteria decision analysis of flood risks in aging-dam management in China: A framework and case study. *International Journal of Environmental Research and Public Health*, *8*(5), 1368–1387. https://doi.org/10.3390/ijerph8051368

Yildiz, S. S. (2024). Spatial multi-criteria decision making approach for wind farm site selection: A case study in Balıkesir, Turkey. *Renewable and Sustainable Energy Reviews*, *192*, 114158. https://doi.org/10.1016/j.rser.2023.114158

Zaenuri, Z. (2011). Dampak Pengoprasian Industri Terhadap Kualitas Udara dan Kebisingan di Kawasan Simongan Kota Semarang. *Sainteknol: Jurnal Sains dan Teknologi, 9*(2), 169–178.

Zwolak, A., Sarzyńska, M., Szpyrka, E., & Stawarczyk, K. (2019). Sources of Soil Pollution by Heavy Metals and Their Accumulation in Vegetables: a Review. *Water, Air, and Soil Pollution*, *230*(7), 164. https://doi.org/10.1007/s11270-019-4221-y