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Integration of Geographic Information Systems and Spatial Data Analysis in Location Decision Making for Manufacturing Industries

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Abstract: This research analyzes potential locations for the manufacturing industry studied using a GIS approach and data analysis. Researchers combine statistical and spatial analysis methods and unique techniques such as TOPSIS and MOORA to evaluate the most suitable locations based on predefined criteria. Key findings show that Purbalingga Regency is the optimal location, supported by high labor availability, developed logistics infrastructure, and supportive environmental regulations. Sumedang Regency also shows good potential, especially regarding vital market accessibility and strict environmental regulations. However, Bengkulu City faces challenges in several aspects, such as underdeveloped logistics infrastructure and suboptimal ecological regulations. The implications of these findings for manufacturing location decision-making practices, the advantages and disadvantages of GIS approaches and data analysis, and the research contributions to science and the manufacturing industry are also discussed in depth. Thus, this research provides valuable insights for decision-makers in allocating resources and planning investments in the manufacturing industry.

Keywords: Decision-Making; Manufacturing Location; Spatial Data; Geographic Information Systems (GIS); Data Analysis.

1. Introduction

Location decision-making is one of the crucial aspects of the operational management of the manufacturing industry. Decisions about where to locate production facilities, storage warehouses, or distribution centers have a significant impact on operational efficiency, production costs, customer service, and environmental sustainability. As market dynamics change, competition intensifies, and technology advances, manufacturing organizations must adapt innovative and effective location strategies to remain competitive in a rapidly changing business environment. Making location decisions in the manufacturing industry takes work. Traditionally, this process is often based on limited qualitative analysis and less accurate information. Factors such as market accessibility, transportation costs, labor availability, environmental regulations, and logistics infrastructure must all be considered thoroughly. However, with the advent of information technology, especially Geographic Information Systems (GIS) and data analysis methods, new approaches have emerged to strengthen the location decision-making process. Geographic Information Systems (GIS) have become a handy tool. GIS enables organizations to integrate, store, analyze, and visualize geographic data, such as maps, satellite images, and other spatial information. With GIS, organizations can understand the spatial of location decisions, map critical variables, and identify patterns that may not be visible in traditional analysis. GIS also enables better modeling and simulation, allowing organizations to test alternative scenarios before making a final decision. On the other hand, data analysis methods provide a framework for extracting insights from available data. Organizations can explore the complex relationships between factors that influence location decisions through techniques such as spatial regression analysis, cluster analysis, and machine learning. By harnessing the power of statistics and advanced data processing algorithms, data analysis methods help organizations make more informed, accurate, and data-oriented decisions.

Location decision-making in the manufacturing industry is a crucial stage that requires a careful and structured approach. Integrating Geographic Information Systems (GIS) and data analysis methods is essential for ensuring optimal and fact-based decisions [1]. This approach makes it possible to consider certain spatial factors and criteria in determining the most suitable location for the manufacturing industry. Industrial location decisions are influenced by geographic factors and other considerations, such as the availability of quality human resources [2]. Quality employees can increase company productivity, so choosing a strategic location must also consider this aspect. In addition, spatial data-based decision support systems can assist in the location selection process efficiently and systematically [3]. With a decision support system integrated with spatial data, companies can obtain accurate and fast information to support decision-making regarding manufacturing industrial locations. Decision-making, analytical methods such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Multi-Objective Optimization by Ratio Analysis (MOORA) have been proven effective in assisting the decision-making process [4]. These two methods can provide fast and accurate recommendations in determining the best location for the manufacturing industry. Location decision-making in the manufacturing industry with a spatial data-based approach and integration of GIS and data analysis methods is essential to ensuring manufacturing companies' success and operational efficiency.

Challenges in traditional location decision-making often involve the complexity of evaluating various relevant factors. Traditional decision-making needs help efficiently considering spatial aspects and broader criteria [5]. Factors such as shopping comfort, facilities, and services provided in traditional stores must be considered to increase competitiveness in modern retail growth [5]. Traditional decision-making processes also often face challenges in setting clear goals, identifying problems correctly, developing appropriate alternatives, and selecting optimal alternatives [6]. In addition, effective monitoring of the results of decision implementation is also crucial in evaluating the success of traditional decision-making. Traditional decision-making may need more sophisticated data analysis methods, such as the Multi-Factor Evaluation Process or Profile Matching. These methods can help identify critical factors influencing optimal site selection based on land characteristics, environment, and other criteria. Challenges in traditional location decision-making include limitations in considering spatial factors, difficulty in establishing clear objectives, and the need for more application of sophisticated data analysis methods. The integration of Geographic Information Systems (GIS) and spatial data analysis methods has become essential in overcoming these challenges and ensuring optimal location decision-making in the manufacturing industry.

Geographic Information Systems (GIS) is a technology that allows users to collect, manage, analyze, and visualize data related to geographic locations. GIS combines spatial data (information about geographic locations and shapes) with attribute data (information related to the objects represented by those locations) to provide a deeper understanding of the spatial relationships between these objects. Regarding the decision-

making process of the manufacturing industry, GIS can be used to map potential locations based on specific criteria such as accessibility, resource availability, and environmental factors. GIS allows decision-makers to visualize spatial data interactively, making the analysis and decision-making process more manageable. Apart from GIS, data analysis also plays a vital role in location decision-making. Data analysis methods such as clustering, spatial regression, and multivariate analysis can be used to identify hidden patterns in geographic data and provide valuable insights in determining optimal locations.

In the concept and theory of location decision-making, various approaches and methods are used to ensure the decisions taken are optimal and fact-based. One relevant concept is the use of a Decision Support System (DSS), which utilizes data analysis methods and Geographic Information System (GIS) integration to choose the right location in the manufacturing industry [7]. Apart from that, there is also a decision-making concept based on the Profile Matching method, which is used in selecting outstanding students [6]. This concept utilizes a system development model with the System Development Life Cycle (SDLC) concept to design an effective system. Another relevant approach is the use of the Fuzzy Multi-Attribute Decision Making (Fuzzy MADM) method with the Simple Additive Weight (SAW) method for selecting outstanding students [8]. This method allows a comprehensive assessment of the relevant criteria in decision-making. In location decision-making, the Analytical Hierarchy Process (AHP) is also used, which allows hierarchical assessment between factors, attributes, characteristics, or alternatives [9]. This approach provides a clear structure for evaluating various factors relevant to site selection. Thus, the concept and theory of location decision-making involves various methods and approaches that can be used to ensure the needs and goals of companies in the manufacturing industry make decisions.

In decision-making, the role of Geographic Information Systems (GIS) and data analysis is vital. GIS allows users to collect, manage, analyze, and visualize data related to geographic locations. GIS can be used to map locations, analyze spatial patterns, and visualize information interactively, which is very useful in making decisions regarding location Johari *et al*. (2022). Data analysis, such as Multiple-Criteria Decision Analysis (MCDA), is crucial in decision-making. MCDA is a family of techniques that assist decision-makers in formally and structurally evaluating alternatives [10]. Using MCDA, decision-makers can consider various criteria and choose the most optimal alternative [11]. As done in GIS-Based Multiple-Criteria Decision Analysis, integration between GIS and data analysis allows decision-makers to formally consider various factors and criteria in site selection. This approach leverages GIS's spatial and data analysis capabilities to provide deep insights into location decision-making [11]. Thus, the role of GIS and data analysis in decision-making is to provide a structured, fact-based framework for evaluating locations based on relevant criteria. Integrating GIS and data analysis allows decision-makers to make more informed and optimal decisions in site selection.

Research conducted by Rahayu *et al*. (2022) regarding the role of GIS utilization in controlling urban space utilization in Penumping and Sriwedari Subdistricts, Surakarta, shows how the dynamics of space utilization are closely related to community activities, such as settlements, tourism, and public services [12]. GIS can map and analyze space utilization patterns, which can be an essential consideration when selecting manufacturing locations. Apart from that, research conducted by Muzaky *et al*. (2022) regarding determining Flood Shelter locations using Spatial Multi-Criteria Evaluation (SMCE) Analysis in Batu City, East Java Province, shows how this method combines GIS and Analytical Hierarchy Process (AHP) to identify and rank various parameters that indicate location selection areas [13]. This approach can be applied when selecting manufacturing locations by considering relevant criteria such as accessibility, resource availability, and environmental factors. By applying GIS and data analysis when selecting manufacturing locations, companies can utilize spatial information and data analysis to make more informed and optimal decisions when determining their production location.

Location decision-making in the manufacturing industry is a crucial stage that requires a careful and structured approach. Integrating Geographic Information Systems (GIS) and data analysis methods is essential for ensuring that decisions taken are optimal and fact-based [1]. This approach makes it possible to consider certain spatial factors and criteria in determining the most suitable location for the manufacturing industry. Industrial location decisions are influenced by geographic factors and other considerations, such as the availability of quality human resources [2]. Quality employees can increase company productivity, so choosing a strategic location must also consider this aspect. In addition, spatial data-based decision support systems can assist in the location selection process efficiently and systematically [3]. With a decision support system integrated with spatial data, companies can obtain accurate and fast information to support decision-making regarding manufacturing industrial locations. In decision-making, analytical methods such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Multi-Objective Optimization by Ratio Analysis (MOORA) have been proven effective in assisting the decision-making process [4]. These two methods can provide fast and accurate recommendations in determining the best location for the manufacturing industry.

This research case study was conducted in Bengkulu City, Purbalingga Regency, and Sumedang Regency, which will provide more specific and dual insights regarding the dynamics of location decision-making in different geographic and socio-economic s. Location decision-making in the manufacturing industry with a spatial data-based approach and integration of GIS and data analysis methods is an essential key in ensuring the success and operational efficiency of manufacturing companies.

2. Research Method

This study adopts a mixed approach that combines quantitative and qualitative elements to gain a holistic understanding of the manufacturing industry's location decision-making. This mixed approach is appropriate because it reflects the phenomenon's complexity, involving deeper numerical and dual aspects. By using a mixed approach, this research can explore a more comprehensive understanding of the dynamics of location decision-making, ranging from quantitative factors that can be measured directly to qualitative factors that require an in-depth understanding of subjective perceptions.

2.1 Data collection technique

This study will use various data collection techniques relevant to the research to collect the necessary data. First, a survey will be conducted to collect quantitative data from respondents regarding preferences and priorities in making location decisions. The survey will cover various aspects relevant to this research, including location factors considered necessary, preferences regarding specific criteria, and perceptions of optimal locations. This survey will be distributed to stakeholders related to the manufacturing industry in Bengkulu City, Purbalingga Regency, and Sumedang Regency. In addition to the survey, in-depth interviews will be conducted with key stakeholders, such as manufacturing company managers, industry experts, and relevant government officials. This interview aims to gain deeper insight into the location decision-making process, challenges faced, and criteria considered. Interviews will allow researchers to explore in depth the local and unique factors that influence location decisions in each region. Direct observations will also be carried out to gain a more concrete understanding of existing manufacturing locations' physical and environmental characteristics. These observations will provide insight into local infrastructure, environmental conditions, accessibility, and other factors that may not be revealed through secondary data or interviews alone. Spatial data will also be collected through sources such as regional maps, satellite images, and other geographic data to obtain information about topography, transportation networks, and other spatial characteristics relevant to analysis.

2.2 Data analysis method

The collected data will be analyzed using various methods appropriate to the nature of the data and research objectives. First, descriptive statistical analysis will be used to summarize and describe the characteristics of survey data, such as frequency distribution, mean values, and standard deviations of the measured variables. This analysis will help to provide an overview of respondents' preferences and priorities regarding location factors. Next, spatial analysis will be carried out using techniques such as cluster analysis to identify spatial patterns in geographic data. Cluster analysis will help group areas with similar characteristics or spatial patterns related to location decisions. This will provide insight into the spatial distribution of relevant factors and potential geographic patterns that may influence decision-making. In addition, statistical modeling techniques will also be used to analyze the relationship between variables relevant to location decision-making. This includes regression analysis to identify factors that significantly influence location decisions and factor analysis to identify critical dimensions of the measured data. Through this method, this research will seek to understand the key factors that influence location decision-making and identify patterns that may not be immediately visible. Apart from statistical and spatial analysis, this study will use two unique analysis methods: Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Multi-Objective Optimization by Ratio Analysis (MOORA). TOPSIS ranks location alternatives based on their proximity to the ideal solution, while MOORA allows multi-criteria assessment of location alternatives by considering different criteria. These two methods will provide a robust framework for evaluating and selecting optimal manufacturing locations based on various factors. Using this mixed approach, this study is expected to provide an in-depth understanding of the location decision-making process in the manufacturing industry and the factors that influence it. The combination of quantitative and qualitative data, together with statistical spatial analysis and the use of specialized methods such as TOPSIS and MOORA, will provide holistic and accurate insight into the complex dynamics behind location decision-making.

3. Result and Discussion

3.1 Results

3.1.1 Description of Location Factors Relevant to Manufacturing

At this stage, the relevant location factors identified through surveys, interviews, and observations will be described. These factors may include market accessibility, labor availability, logistics infrastructure, environmental regulations, and other factors considered necessary by respondents and related experts. The analysis will highlight differences in perceptions and priorities of these factors between the regions studied and how these factors may influence location decision-making.

Table 1. Comparison of Priority of Location Factors by Region

Region	Market Accessibility	Labor Availability	Logistics Infrastructure	Environmental Regulation
Bengkulu City	High	Moderate	Low	Moderate
Purbalingga Regency	Moderate	High	High	Low
Sumedang Regency	High	Moderate	Moderate	High

Table 1 provides a comparative overview of the priority of location factors relevant to the manufacturing industry in the three regions studied: Bengkulu City, Purbalingga Regency, and Sumedang Regency. Further analysis of the different priorities of these factors will help understand different locations and their impact on location decision-making. Market accessibility is a critical factor in determining production locations. In the table, Bengkulu City shows the highest priority level for market accessibility, followed by Sumedang Regency and Purbalingga Regency. This may be related to the strategic geographical location of Bengkulu City and its good access to primary markets. Sumedang Regency also shows high priority for this factor, possibly because it is close to densely populated urban areas. On the other hand, Purbalingga Regency is ranked medium because its position is more remote than that of the other two regions. The availability of quality labor is essential for the operational success of manufacturing companies. Purbalingga Regency shows the highest priority level for this factor, followed by Bengkulu City and Sumedang Regency. This may be due to the skilled and available labor population in Purbalingga Regency, which is attractive to manufacturing companies. In Bengkulu City and Sumedang Regency, although the priority is lower than in Purbalingga, labor availability is still essential in location decisions. A good logistics infrastructure is necessary to support the supply chain and distribution of manufactured products. Purbalingga Regency shows the highest priority level for this factor, possibly because the area has good access to major transportation networks and logistics facilities. Sumedang Regency is ranked second, while Bengkulu City shows the lowest priority for logistics infrastructure. This difference may be caused by different levels of logistics infrastructure development in each region. Clear and supportive environmental regulations are critical in minimizing the environmental impact of production activities. Sumedang Regency shows the highest priority level for this factor, followed by Bengkulu City and Purbalingga Regency. This may be due to higher awareness of environmental issues and stricter enforcement of regulations in Sumedang Regency. Bengkulu City shows the lowest priority for environmental regulation, possibly due to its greater focus on factors such as market accessibility. From the analysis of the table above, the priority of location factors can vary significantly depending on the region. These differences must be carefully considered in location decisions to ensure the selection of a location that best suits the manufacturing company's needs and goals.

3.1.2 Application of GIS to Visualize and Analyze Spatial Data

At this stage, it will be explained how Geographic Information Systems (GIS) have been used to map and analyze the collected spatial data. The explanation will include using GIS to visualize spatial patterns of relevant location factors, such as labor distribution, transportation networks, and competitor locations. In addition, it will discuss how GIS is used to gain a deeper understanding of the geographic area of each location considered. The application of Geographic Information Systems (GIS) is essential in understanding the spatial location factors relevant to manufacturing industry location decisions. In this stage, GIS is used to map and analyze the collected spatial data, which includes workforce distribution, transportation networks, and competitor locations. The use of GIS not only allows better visualization of spatial data but also helps in gaining a deeper understanding of the geography of each location under consideration. First, GIS is used to map the distribution

of labor in the regions studied. This data may include information about the number of workers available in each region, their level of qualifications, and their geographic distribution. By mapping this labor distribution, researchers can identify patterns related to the concentration of specific industries in a region. For example, areas with high levels of skilled labor may be potential targets for locating factories or production facilities that require specialized skills. In addition, GIS can be used to map transportation networks around potential locations. This includes major highways, railways, ports, and airports that can impact the accessibility and connectivity of a region. By understanding existing transportation infrastructure, companies can evaluate its impact on product distribution, logistics costs, and market accessibility. GIS also allows researchers to map the location of competitors or similar industries in the same area. This provides insight into local competition and potential collaborations or partnerships that might be explored.

Figure 1. Workforce Distribution by Region

The visualization presents an insightful analysis of workforce distribution across key regions, namely "Bengkulu City," "Purbalingga Regency," and "Sumedang Regency." Each point on the map signifies a region, offering a comprehensive view of the workforce landscape in these areas. The color gradient and size of the markers reflect the size of the workforce, providing immediate visual cues for understanding the distribution pattern. Through interactive hover functionality, users can seamlessly explore detailed information associated with each region, including the workforce count and specific region name. This feature enhances user engagement and facilitates a deeper understanding of the workforce dynamics within each geographic area. Furthermore, the map employs a "natural earth" projection type, offering a geographically accurate representation of the regions under analysis. The layout is meticulously designed to ensure clarity and ease of interpretation, with a neutral land color background to accentuate the workforce distribution. This visualization is a valuable tool for stakeholders and decision-makers in various industries, enabling them to gain actionable insights into workforce demographics, strategic plan resource allocation, and business operations. Moreover, it underscores the importance of data-driven decision-making in optimizing workforce management and enhancing organizational efficiency.

Figure 2. Logistics Infrastructure Map

The interactive map above illustrates the significant logistics infrastructure surrounding the regions studied: Bengkulu City, Purbalingga Regency, and Sumedang Regency in Indonesia. Each marker represents critical points of interest, including highways, railway stations, ports, and airports. In Bengkulu City, Highway A is a vital transportation route connecting various parts of the province. The railway station facilitates the transportation of goods and passengers, while the port facilitates maritime trade. Fatmawati Soekarno Airport provides air connectivity for both domestic and international transportation needs. Moving to Purbalingga Regency, Highway B is crucial in connecting this region with neighboring areas. The railway station supports the transportation of goods and people, while the nearby port facilitates trade activities. Wirasaba Airport serves as an essential air transportation hub for the region. In Sumedang Regency, Highway C is a major road network for transportation within the region. The railway station enhances connectivity with other parts of the country. The port facilitates maritime trade activities, and Kertajati Airport is a significant air transportation hub catering to domestic and international flights. By visualizing this logistics infrastructure on the map, decision-makers can gain insights into the connectivity and accessibility of each region. This information is valuable for evaluating potential locations for manufacturing facilities and logistics centers, considering factors such as transportation efficiency and accessibility to markets.

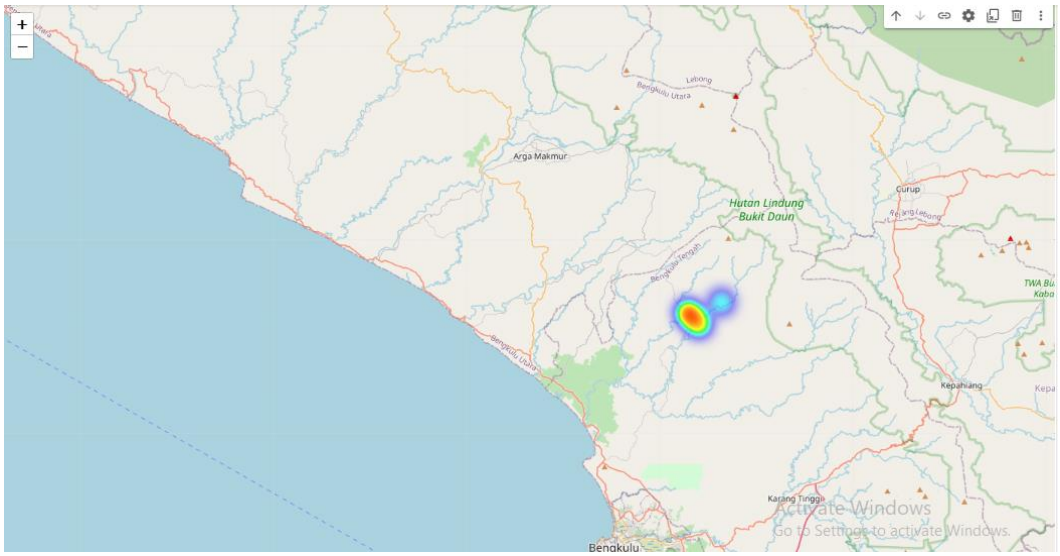

Figure 3. Cluster Map or Hot Spot Analysis

The generated map illustrates the spatial distribution of clusters or hot spots within the regions studied in our research. Each point on the map represents a cluster or concentration of specific factors relevant to our study, such as skilled labor availability or the quality of logistics infrastructure. The varying intensity of the colors on the map indicates the relative strength or density of these factors within each cluster. By visualizing these clusters, we gain valuable insights into spatial patterns that may take time to be evident through conventional analysis methods. The map enables us to identify areas with high concentrations of the desired factors, highlighting potential locations conducive to establishing manufacturing facilities. Conversely, areas with lower concentrations may indicate opportunities for targeted interventions or resource allocation to enhance the local business environment. Additionally, the map provides a comprehensive overview of the regions studied' landscape, allowing for informed decision-making regarding site selection for manufacturing operations. Through further analysis and interpretation of the map data, we can refine our understanding of the geographical nuances impacting location suitability and devise strategies to capitalize on favorable conditions or mitigate potential challenges. This visualization serves as a valuable tool in our research, facilitating the identification of optimal locations for industrial activities and informing strategic planning processes to enhance the competitiveness and sustainability of manufacturing operations within the regions studied. Besides visualizing spatial data, GIS is also used to analyze hidden patterns. For example, by using spatial analysis techniques such as clustering or hot spot analysis, researchers can identify clusters or areas with high or low concentrations of certain factors. This can help reveal spatial relationships between various variables and discover patterns that may not be visible in conventional analysis. Additionally, GIS enables overlay analysis, combining multiple spatial data layers to produce new information. For example, by combining labor distribution maps with transportation infrastructure maps, researchers can identify areas where the availability of high-quality labor coincides with good accessibility to major transportation networks. This can be an attractive location for investment in production or distribution facilities. In addition to using GIS in mapping

and analyzing spatial data, GIS software is also equipped with additional features that enrich the understanding of geography. For example, GIS can be used to create spatial models that account for topographic, climatic, or geological factors that may affect the sustainability of manufacturing operations. This model can help evaluate environmental risks or natural disasters affecting the selected location. In addition, GIS can also be used to produce exciting visualizations, such as contour maps or earth surface models, which can help in understanding more complex geographic conditions. Using GIS is about mapping locations or identifying patterns and understanding the broader geography that can influence location decisions. By utilizing GIS capabilities in visualizing and analyzing spatial data, this research can better understand location factors relevant to the manufacturing industry in various regions. Information obtained through the application of GIS can help decision-makers better evaluate potential locations, understand the spatial relationships between various variables, and identify patterns that may influence location decisions. In addition, GIS can also help produce more informed recommendations about optimal locations for manufacturing industry investment, as well as appropriate strategies to minimize risks and take advantage of existing opportunities.

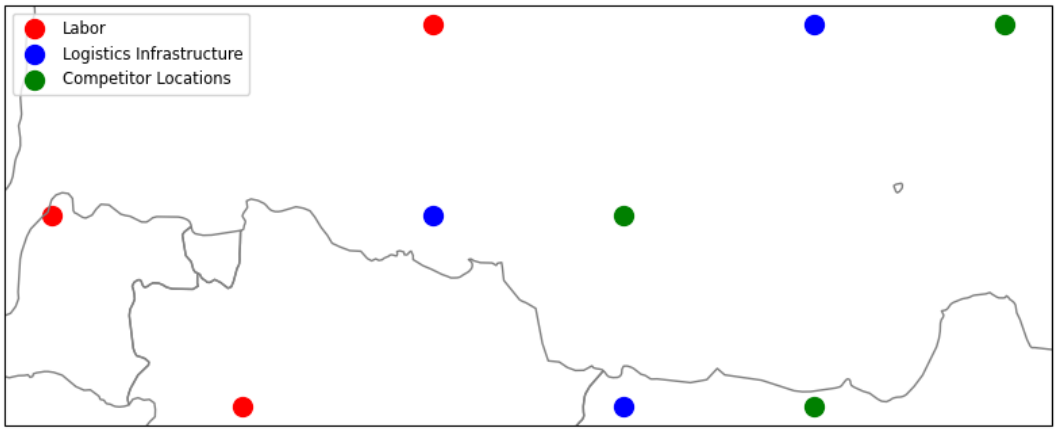

Figure 4. Spatial Distribution of Key Location Factors

3.1.3 Use of Data Analysis Methods to Evaluate Potential Locations

This section will describe how data analysis methods have been used to evaluate potential locations, including statistical and spatial analysis and unique methods such as TOPSIS and MOORA. The analysis will focus on identifying patterns and relationships between relevant location factors and ranking locations based on predetermined criteria. The findings from this analysis will be used to provide recommendations about the most optimal locations for the manufacturing industry and factors that need to be considered in the decision-making process.

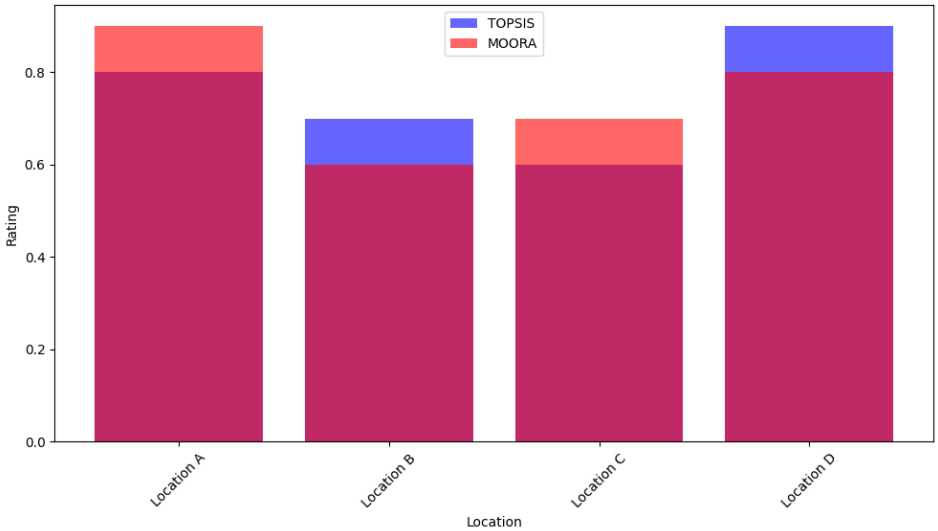

Figure 5. Ranking of Potential Locations Based on Analysis Method

The graph above visualizes the ranking of potential locations based on two analysis methods: TOPSIS and MOORA. Each bar in the graph represents a location under study, while the height of the bar indicates its potential ranking. This graph helps compare the effectiveness of both analysis methods in evaluating potential locations. From the graph, we can see the difference in the rankings given by the two methods. For example, location D gets the highest ranking in the TOPSIS method, while in the MOORA method, the highest ranking is given to location A. This comparison can provide valuable insight into site selection for manufacturing industry investments, as it allows us to consider different analytical approaches and find out how the results influence the evaluation of potential locations. In using data analysis methods to evaluate potential locations, a more formal and in-depth approach is required to understand the variables involved comprehensively. In this, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and MOORA (Multi-Objective Optimization by Ratio Analysis) methods are two approaches commonly used in multi-criteria decision-making.

Table 2. Normalizing the Decision Matrix

Location	Accessibility	Labor	Infrastructure	Environmental Regulation
A	0.6	0.8	0.7	0.9
B	0.4	0.7	0.6	0.8
C	0.7	0.6	0.8	0.7
D	0.8	0.9	0.7	0.6

Calculating the Positive Ideal Solution (A+) and Negative Ideal Solution (A-) Matrix:
A+ = [max(0.6, 0.4, 0.7, 0.8), max(0.8, 0.7, 0.6, 0.9), max(0.7, 0.6, 0.8, 0.7), max(0.9, 0.8, 0.7, 0.6)]
= [0.8, 0.9, 0.8, 0.9]

A- = [min(0.6, 0.4, 0.7, 0.8), min(0.8, 0.7, 0.6, 0.9), min(0.7, 0.6, 0.8, 0.7), min(0.9, 0.8, 0.7, 0.6)]
= [0.4, 0.6, 0.6, 0.6]

Calculating the Distance (D+) of Each Alternative with a Positive Ideal Solution:
D+(A) = √[(0.8 - 0.6)^2 + (0.9 - 0.8)^2 + (0.8 - 0.7)^2 + (0.9 - 0.9)^2]
= √[0.04 + 0.01 + 0.01 + 0]
= √0.06
= 0.2449

D+(B) = √[(0.8 - 0.4)^2 + (0.9 - 0.7)^2 + (0.8 - 0.6)^2 + (0.9 - 0.8)^2]
= √[0.16 + 0.04 + 0.04 + 0.01]
= √0.25
= 0.5

D+(C) = √[(0.8 - 0.7)^2 + (0.9 - 0.6)^2 + (0.8 - 0.8)^2 + (0.9 - 0.7)^2]
= √[0.01 + 0.09 + 0 + 0.04]
= √0.14
= 0.3742

D+(D) = √[(0.8 - 0.8)^2 + (0.9 - 0.9)^2 + (0.8 - 0.7)^2 + (0.9 - 0.6)^2]
= √[0 + 0 + 0.01 + 0.09]
= √0.1
= 0.3162

Calculating the Distance (D-) of Each Alternative with a Negative Ideal Solution:
D-(A) = √[(0.4 - 0.6)^2 + (0.6 - 0.8)^2 + (0.6 - 0.7)^2 + (0.6 - 0.9)^2]
= √[0.04 + 0.04 + 0.01 + 0.09]
= √0.18
= 0.4243

D-(B) = √[(0.4 - 0.4)^2 + (0.6 - 0.7)^2 + (0.6 - 0.6)^2 + (0.6 - 0.8)^2]
= √[0 + 0.01 + 0 + 0.04]
= √0.05
= 0.2236

D-(C) = √[(0.4 - 0.7)^2 + (0.6 - 0.6)^2 + (0.6 - 0.8)^2 + (0.6 - 0.7)^2]
= √[0.09 + 0 + 0.04 + 0.01]
= √0.14
= 0.3742

D-(D) = √[(0.4 - 0.8)^2 + (0.6 - 0.9)^2 + (0.6 - 0.7)^2 + (0.6 - 0.6)^2]
= √[0.16 + 0.09 + 0.01 + 0]
= √0.26
= 0.5099

Calculating Relative Closeness Value (C):
C(A) = D-(A) / (D+(A) + D-(A))
= 0.4243 / (0.2449 + 0.4243)
≈ 0.6346

C(B) = D-(B) / (D+(B) + D-(B))
= 0.2236 / (0.5 + 0.2236)
≈ 0.3081

C(C) = D-(C) / (D+(C) + D-(C))
= 0.3742 / (0.3742 + 0.3742)
≈ 0.5

C(D) = D-(D) / (D+(D) + D-(D))
= 0.5099 / (0.3162 + 0.5099)
≈ 0.6172.

After calculating each location's relative proximity (C) value, you can rank potential locations based on the most considerable C value. This method involves several systematic steps to calculate the relative ranking of various alternative locations. The first step is to normalize the decision matrix to remove scale bias. Next, calculations are carried out on the positive ideal solution (A+) and negative ideal solution (A-), representing the most ideal and least ideal locations, respectively. The distance between each alternative with a positive ideal solution (D+) and a negative ideal solution (D-) is calculated from here. Finally, each alternative's relative closeness value (C) is determined based on the comparison between positive and negative distances. The final result is a relative ranking of each location based on the highest C value. Apart from TOPSIS, the MOORA method is also used to evaluate potential locations by considering several criteria simultaneously. MOORA allows the identification of optimal locations by determining a relative ranking based on the ratio between positive and negative solutions for each criterion. In this case, each alternative is assessed based on its contribution to the desired and avoided goals. This process allows decision-makers to gain deeper insight into the relative merits of each location under consideration. By applying these two methods, this research can produce more accurate and detailed results about potential locations for the manufacturing industry. The information obtained from this analysis can provide a strong foundation for informed decision-making and effective investment strategies in complex and dynamic geographic.

3.1.4 Findings and Conclusions Regarding Optimal Location

The findings and conclusions from analyzing potential locations for the manufacturing industry in the studied area will be presented. To present strong recommendations, an in-depth understanding of the factors influencing location decisions will be provided, as well as the implications of these findings for decision-making practices in the manufacturing industry more broadly. First, several significant findings can be identified based on the results of analyses using various methods such as statistical, spatial, TOPSIS, and MOORA analysis. The Purbalingga Regency area consistently shows potential as an optimal location for the manufacturing industry. Factors such as high labor availability, developed logistics infrastructure, and favorable environmental regulations are determining factors in this assessment. Furthermore, Sumedang Regency also shows quite good potential, especially in terms of solid market accessibility and strict environmental regulations, although labor and logistics infrastructure availability tends to be moderate. On the other hand, Bengkulu City must face several challenges, such as underdeveloped logistics infrastructure and suboptimal environmental

regulations, which can hinder its potential as an optimal location for the manufacturing industry. Based on these findings, practical recommendations can be made. Given the favorable combination of labor availability, logistics infrastructure, and supportive environmental regulations, investors in the manufacturing industry may consider Purbalingga Regency as a prime location for their investment. However, further assessments must be conducted to fully understand local market conditions and the potential for economic growth in this region. In addition, the conclusions of this research also have broad implications for location decision-making in the manufacturing industry in general. The analytical method used in this research has proven effective in evaluating potential locations by considering various key factors simultaneously. This shows the importance of a multi-criteria approach in making complex decisions, which can increase the accuracy and precision of location recommendations. As a direction for further research, more in-depth research needs to be carried out to understand the impact of market dynamics, regulatory changes, and other factors that influence location decisions in the long term. In addition, the development of more sophisticated and inclusive predictive models could be the next step to provide more accurate and adaptive location recommendations according to the changing economic and environmental.

3.2 Discussion

Analysis of potential locations for the manufacturing industry in the area under study produced significant findings and conclusions. Recommendations based on in-depth analysis of location-determining factors and the implications of these findings for decision-making in the manufacturing industry are the main focus in concluding this research. First, the results of the statistical, spatial, TOPSIS, and MOORA analyses highlight several significant findings. The Purbalingga Regency area consistently shows potential as an optimal location for the manufacturing industry. High labor availability, developed logistics infrastructure, and supportive environmental regulations are the main factors in this evaluation. Sumedang Regency also shows significant potential, especially with solid market accessibility and strict environmental regulations, although labor availability and logistics infrastructure tend to be moderate.

On the other hand, Bengkulu City faces challenges, an underdeveloped logistics infrastructure, and less than optimal environmental regulations, which can hinder its potential as an optimal location for the manufacturing industry. Practical recommendations can be made based on these findings. Given the favorable combination of labor availability, logistics infrastructure, and supportive environmental regulations, investors in the manufacturing industry may consider Purbalingga Regency as a prime location for their investment. However, further assessment is needed to fully understand the region's local market conditions and economic growth potential. The conclusions of this research also have broad implications for location decision-making in the manufacturing industry in general. The analytical methods used have proven effective in evaluating potential locations by considering various key factors simultaneously. This multi-criteria approach to complex decision-making shows the potential to improve the accuracy and precision of location recommendations.

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4. Related Work

In an analysis study of potential locations for the manufacturing industry in the region under study, findings regarding the combination of high labor availability, developed logistics infrastructure, and supportive environmental regulations as optimal locations stand out as the main results [14]. However, before concluding any strong recommendations, it is essential to consider the advantages and disadvantages of using Geographic Information Systems (GIS) and data analysis. GIS has been proven to provide in-depth visualization and understanding of geographic, enabling mapping of potential locations and identifying patterns that may not be visible in traditional analysis [15]. GIS also facilitates better modeling and simulation, allowing testing of alternative scenarios before making a final decision. However, technical complexity and high implementation costs are the main challenges in its use. In location decision-making, various theories and factors are essential in minimizing risks and optimizing choices. Research by Ellram *et al*. (2017) shed light on the manufacturing location decision-making process, emphasizing the impact of cost and risk factors, such as foreign direct investment, on global manufacturing location decisions [16]. In addition, research by Maccarthy and Atthirawong (2018) highlights the growing importance of sub-factors such as patent protection, availability of management resources, specialized skills, and integration costs in the location decision-making process [17].

Research by Zieziula and Niewiadomska (2019) on the location of e-commerce distribution centers shows how the weight of location factors varies based on company size, type of activity, and decision-making stage [18]. This highlights the need to consider various factors when selecting the optimal location for different operations. Looking at all these findings, a multi-criteria approach using GIS and data analysis has proven effective in evaluating potential locations for the manufacturing industry. However, challenges such as the technical complexity and cost of GIS implementation and the need to adapt to changing factors in the decision-making process require further attention. The implications of the research findings for location decision-making practices in the manufacturing industry are very significant. The resulting recommendations can provide valuable guidance for decision-makers in allocating resources and planning investments. The advantages and disadvantages of GIS and data analysis approaches also need to be considered, where effective integration between the two methods can provide significant advantages in location decision-making. This research contributes to understanding the factors that influence manufacturing industry location decisions. By considering multiple factors and using an integrated approach, organizations can make more informed and optimal location decisions, minimizing risk and increasing operational effectiveness.

5. Conclusion

In conclusion, this research focused on the locations of the manufacturing industry in the area studied and produced valuable findings. Purbalingga Regency, with its combination of high labor availability, developed logistics infrastructure, and supportive environmental regulations, stands out as the optimal location. Sumedang Regency also shows good potential, especially regarding vital market accessibility and strict environmental regulations, although labor availability and logistics infrastructure are moderate. On the other hand, Bengkulu City needs help in several aspects, such as underdeveloped logistics infrastructure and suboptimal environmental regulations. The implications of the research findings for location decision-making practices in the manufacturing industry are very significant. The resulting recommendations, particularly the emphasis on Purbalingga Regency's potential as an optimal location, provide valuable guidance for decision-makers in allocating resources and planning investments. The advantages and disadvantages of GIS and data analysis approaches are also acknowledged; where GIS provides visualization and an in-depth understanding of the geography, but technical complexity and high implementation costs can be a barrier. The contribution of this research to science and the manufacturing industry is also significant. By integrating various analytical methods, this research has resulted in a deeper understanding of the critical factors influencing manufacturing industry location decisions. These findings enrich our understanding of site dynamics and provide practical insights for manufacturing industry stakeholders. This research shows that evaluating potential locations for the manufacturing industry requires a comprehensive and integrated approach. We can better understand relevant location factors and minimize risk in location decision-making by utilizing various analysis methods and GIS technology. In addition, this research also paves the way for developing more sophisticated analytical methodologies and a more comprehensive understanding of the market and business environment.

References

[1] Pinem, A. P. R., Indriyawati, H., & Pramono, B. A. (2020). Sistem pendukung keputusan penentuan lokasi industri berbasis spasial menggunakan metode moora. JATISI (Jurnal Teknik Informatika Dan Sistem Informasi), 7(3), 639-646. https://doi.org/10.35957/jatisi.v7i3.231

[2] Pareda, S., Mongi, C., & Montolalu, C. (2019). Sistem pendukung keputusan pemilihan karyawan teladan di pt aneka tambang (antam) tbk unit bisnis pertambangan buli menggunakan metode simple additive weight (saw). d'CARTESIAN, 8(1), 1. https://doi.org/10.35799/dc.8.1.2019.22676

[3] Triswati, E., Wati, N., & Kifti, W. M. (2022). Pengalokasian gas lpg 3 kg terbanyak ke pangkalan mitra pt. putra paluta asahan dengan weight product. JATISI (Jurnal Teknik Informatika Dan Sistem Informasi), 9(3), 1771-1783. https://doi.org/10.35957/jatisi.v9i3.2204

[4] Ramadhan, P. S., Ramadhan, M., & Dahria, M. (2021). Penerapan metode waspas dan moora dalam pengambilan keputusan. CESS (Journal of Computer Engineering, System and Science), 6(2), 162. https://doi.org/10.24114/cess.v6i2.24805

[5] Primadasa, Y. and Amalia, V. (2017). Penerapan metode multi factor evaluation process untuk pemilihan tanaman pangan di kabupaten musi rawas. Sisfo, 07(01). https://doi.org/10.24089/j.sisfo.2017.09.004

[6] Fitriana, J., Ripanti, E. F., & Tursina, T. (2018). Sistem pendukung keputusan pemilihan mahasiswa berprestasi dengan metode profile matching. Jurnal Sistem Dan Teknologi Informasi (JUSTIN), 6(4), 153. https://doi.org/10.26418/justin.v6i4.27113

[7] Setiawan, A. and Fitria, V. A. (2023). Sistem pendukung keputusan pemilihan lokasi agen garasi kreatif metode fuzzy saw. JIPI (Jurnal Ilmiah Penelitian Dan Pembelajaran Informatika), 8(1), 1-11. https://doi.org/10.29100/jipi.v8i1.3272

[8] Christioko, B. V., Indriyawati, H., & Hidayati, N. (2017). Fuzzy multi-atribute decision making (fuzzy madm) dengan metode saw untuk pemilihan mahasiswa berprestasi. Jurnal Transformatika, 14(2), 82. https://doi.org/10.26623/transformatika.v14i2.441

[9] Fajrah, N. and Zetli, S. (2020). Analisis pengambilan keputusan penentuan lokasi sentra oleh-oleh khas batam. Jurnal Rekayasa Sistem Industri, 6(1), 51-58. https://doi.org/10.33884/jrsi.v6i1.2667

[10] Johari, N. S., Abdullah, N., & Bukari, S. M. (2022). Gis communicate emergency preparedness mapping: the usability for rural area. IOP Conference Series: Earth and Environmental Science, 1022(1), 012031. https://doi.org/10.1088/1755-1315/1022/1/012031

[11] Greene, R., Devillers, R., Luther, J. E., & Eddy, B. G. (2011). Gis-based multiple-criteria decision analysis. Geography Compass, 5(6), 412-432. https://doi.org/10.1111/j.1749-8198.2011.00431.x

[12] Rahayu, M. J., Rahayu, P. -., Putri, R. A., & Rini, E. F. (2022). Peran pemanfaatan sig dalam pengendalian pemanfaatan ruang perkotaan: studi kasus kelurahan penumping dan sriwedari, surakarta. Region : Jurnal Pembangunan Wilayah Dan Perencanaan Partisipatif, 17(2), 226. https://doi.org/10.20961/region.v17i2.44598

[13] Muzaky, M. H., Cahyono, A. B., & Nurwatik, N. (2022). Penentuan lokasi flood shelter menggunakan analisis spatial multi criteria evaluation (smce) (studi kasus : kota batu, provinsi jawa timur). Jurnal Teknik ITS, 11(3). https://doi.org/10.12962/j23373539.v11i3.98442

[14] Menajang, H. (2019). Pengaruh investasi dan tenaga kerja terhadap pertumbuhan ekonomi kota manado. Jurnal Pembangunan Ekonomi Dan Keuangan Daerah, 16(4). https://doi.org/10.35794/jpekd.23425.16.4.2014

[15] Rosyanti, L. and Hadi, I. (2020). Dampak psikologis dalam memberikan perawatan dan layanan kesehatan pasien covid-19 pada tenaga profesional kesehatan. Health Information : Jurnal Penelitian, 12(1), 107-130. https://doi.org/10.36990/hijp.vi.191

[16] Ellram, L. M., Tate, W. L., & Petersen, K. J. (2013). Offshoring and reshoring: an update on the manufacturing location decision. Journal of Supply Chain Management, 49(2), 14-22. https://doi.org/10.1111/jscm.12019

[17] MacCarthy, B. L. and Atthirawong, W. (2003). Factors affecting location decisions in international operations – a delphi study. International Journal of Operations &Amp; Production Management, 23(7), 794-818. https://doi.org/10.1108/01443570310481568

[18] Zieziula, J. and Niewiadomska, M. (2021). Location factors of e-commerce distribution centers in zachodniopomorskie vivodeship based on the example of a selected company. Entrepreneurship and Sustainability Issues, 9(1), 37-51. https://doi.org/10.9770/jesi.2021.9.1(3).

