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Research Paper

Multi-Criteria Decision-Making for Cement Plant Location Selection Using SMART Method: A Case Study of PT. RKB

Toman Nico Felani Sihombing[1]*, Utomo Sarjono Putro[1]

[1] Bandung Institute of Technology, Indonesia

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Abstract

The strategic selection of a cement plant location is crucial for optimizing operational efficiency, sustainability, and market positioning. This study examines the optimal location for PT. RKB's new cement plant in West Java, Indonesia, uses the quantitative Simple Multi-Attribute Rating Technique (SMART) within a Multi-Criteria Decision-Analysis (MCDA) framework. The SMART method transforms various criteria into measurable insights, ensuring a systematic evaluation of alternative sites. Key criteria included economic viability, technical feasibility, environmental impact, and socio-economic considerations. A comprehensive analysis of three potential sites revealed Location C as the most suitable, offering the best balance of economic benefits, technical advantages, manageable environmental impacts, and strong community support. Sensitivity analysis confirmed the robustness of this decision under various scenarios. This study provides a data-driven methodology for strategic site selection in the cement industry, contributing to PT. RKB's sustainable growth and competitive positioning. Theoretically, this research advances the application of MCDA in industrial site selection, while practically, it offers a replicable model for decision-makers in similar industries.

Keywords *Cement Plant Location, Multi-Criteria Decision-Analysis, SMART Method, Site Selection, Strategic Planning, Decision-Making*

INTRODUCTION

The strategic selection of a cement plant location is a critical decision that can significantly influence a company's operational efficiency, sustainability, and market positioning. This decision-making process involves evaluating numerous factors, including operational, environmental, strategic, and socio-economic considerations, which are relevant not only locally but also globally. As a major resource user, the global cement industry presents opportunities and challenges regarding sustainable growth and competitive positioning. Cement is an essential construction material and a crucial economic indicator that reflects a country's infrastructure and development goals. A report by CW Group (2024) highlights that global cement consumption is expected to reach 4,3 billion tons by 2028, with significant growth in regions outside China, such as Asia ex-China and the Middle East, which are projected to see annual growth rates of 4,9% and 3,0% respectively. The global cement market is poised for substantial growth, driven by increasing urbanization, infrastructure development, and economic recovery post-pandemic. This global context highlights the importance of strategic planning and location selection for cement plants to capitalize on market opportunities and sustain competitive advantage. Analyzing how companies in different countries deal with these challenges can provide valuable insights and recommendations for the global cement industry.

PT. RKB, a prominent Indonesian cement plant developer with limestone and clay mining concessions in West Java Province, is currently facing the challenge of determining the optimal

Corresponding author's email: nico_sihombing@sbm-itb.ac.id

location for its new cement plant. This decision is compounded by a variety of concerns, including operational, environmental, strategic, and socio-economic considerations. Indonesia, being the fifth-largest consumer of cement globally, presents substantial growth potential driven by a young and dynamic population and significant investments in infrastructure (ICR Research, 2023). The industry has been the focus of numerous studies, each highlighting different aspects crucial for strategic planning. For instance, Siringo et al. (2023) analyze the relationship between regional development, GDP, and cement consumption, providing insights into how infrastructure development influences regional economic performance. Their findings underscore the importance of strategic considerations when selecting plant locations, particularly in regions experiencing rapid economic growth.

The Asian Development Bank (2023) provides a broader regional context, highlighting improved economic prospects for developing Asia, including Indonesia, due to the reopening of the People's Republic of China. The report forecasts Indonesia's economic growth to rise from 4.2% in 2022 to 4.8% in 2023 and 5% in 2024, with inflation expected to moderate closer to pre-pandemic levels, highlighting the impact of commodity booms waning and the normalization of domestic demand. The latest information from the Indonesian Central Bureau of Statistics (2024) shows Indonesia's economy grew positively in Quarter 2-2024, higher than the same period in 2023. In Q2-2024, Inodnesia's GDP expanded by 5,05% year on year (y-on-y) compared to Q2-2023. This growth trajectory is expected to continue, with projections indicating a 5.2% growth rate in 2025, supported by efforts to enhance domestic consumption and a smooth government transition. This further underscores the importance of strategic decision-making in the current economic climate. These optimistic projections align with Indonesia's economic outlook, emphasizing the critical timing for PT. RKB's strategic expansion.

Infrastructure development projects, such as the construction of Indonesia's new capital city, Nusantara (IKN), are expected to significantly boost cement demand. As reported by Natalia (2024), the cement sector's bright outlook appears to be maintained as a result of the IKN's construction and several National Strategic Projects (PSN). Nationally, the cement market performed well in 2023. Sales volume reached 6,23 million tons at the end of December 2023, recorded to grow 14,2% (y-on-y) and 1,1% on a monthly basis (m-on-m). According to PT. Indocement Tunggal Prakarsa Tbk. (2024), the projection of cement demand in Indonesia shows a gradual increase from 2024 and beyond. Domestic cement consumption is expected to reach 67,3 million tons, up from 65,3 million tons in 2023. The compound annual growth rate (CAGR) for cement demand from 2022 to 2025 is +2,9%, indicating a recovery phase following recent economic difficulties. By 2025, demand is predicted to rise to 69,3 million tons, followed by a continuous increase trend, with demand reaching 75,7 million tons in 2030. Beyond 2025, the CAGR is predicted to remain around +3,0% as infrastructure projects, urbanization, and national development initiatives continue to fuel demand, showing steady growth in the construction and infrastructure industries. The increase in cement demand highlights the need for strategic planning and optimal site selection to meet future market needs effectively. The National Strategic Project, the Getaci toll road, spanning 206,65 km across West Java and Central Java, faces challenges such as delays and financial difficulties (PWC Indonesia, 2023). Coordinated efforts in licensing, land procurement, and financing are crucial to ensure the completion of such infrastructure projects, which can significantly impact regional development and the strategic positioning of industrial players like PT. RKB.

However, PT. RKB faces specific challenges in determining the optimal site for its new cement plant. The delay in site selection disrupts the project timeline, leading to potential cost escalations and lost revenue opportunities. Additionally, without a confirmed location, PT. RKB faces challenges in securing necessary permits, negotiating land acquisitions, and planning logistics and supply chain operations efficiently. These challenges can lead to increased administrative and operational costs, further straining the company's financial resources. Moreover, the uncertainty affects investor confidence and stakeholder relations, potentially impacting investment inflows and the company's stock performance.

To address these challenges, this study leverages the Simple Multi-Attribute Rating Technique (SMART) method within the Multi-Criteria Decision Analysis (MCDA) framework. Previous research on plant location selection has employed various methodologies to address this complex decision-making process. Ataei (2005) utilized the Analytic Hierarchy Process (AHP) to evaluate alternative locations for an alumina-cement plant in East Azerbaijan, Iran, considering criteria such as transportation, water supply, power supply, fuel supply, and land. This systematic approach highlights the importance of a multi-criteria decision-making framework in ensuring optimal location selection for industrial projects.

As highlighted by Timoteo et al. (2023), attributes are crucial in decision-making, with millennial voters prioritizing integrity. Similarly, understanding attributes in site selection aligns decisions with strategic goals and stakeholder expectations, ensuring effectiveness and sustainability. This approach will facilitate a thorough evaluation of potential sites, ensuring a robust and transparent decision-making process for PT. RKB.

The primary objectives of this study are: 1) To identify and prioritize the critical criteria influencing the site selection for PT. RKB’s new cement plant, 2) To evaluate alternative locations and recommend the most suitable site based on these criteria. This research aims to provide a strategic benchmark for future plant location decisions by addressing these objectives, ensuring PT. RKB's continued growth and competitiveness in the Indonesian cement industry. The novelty of this study lies in its comprehensive and integrated approach, combining quantitative analysis through the SMART method with subjective assessments of decision-makers to address the specific challenges faced by PT. RKB. This study not only contributes to the theoretical understanding of site selection in the cement industry but also provides practical implications for decision-makers in similar contexts globally.

LITERATURE REVIEW

Industrial Location Theory

The strategic decision to select an optimal location for a cement plant encapsulates a multidimensional challenge that transcends simple geographical considerations. Industrial location theory provides a robust framework for understanding the complexities involved in these decisions. This section critically evaluates, re-organizes, and synthesizes key theoretical contributions to industrial location theory, highlighting their relevance to the context of PT. RKB's strategic plan to develop a new cement plant in West Java, Indonesia.

Alfred Weber's seminal work, "Theory of the Location of Industries", is foundational in the field of industrial location theory (Weber & Friedrich, 1929). Weber introduced a systematic approach to determine the optimal site for industrial activity based on transportation and labour costs (Fearon, 2002). Central to Weber's model is the concept of "location triangles," which emphasizes minimizing the combined costs of transporting raw materials to the production site and finished goods to the market. Building on Weber's foundation, Hanink (2017) extended traditional models by incorporating complex spatial dependencies and transportation costs. He highlights Weber's concept of the "material index," which dictates whether an industry will be more oriented towards raw materials or markets based on the weight-to-finished-product ratio. These modern extensions illustrate how reduced costs due to proximity to other producers can justify higher transportation costs, thereby refining the applicability of Weber's theories in contemporary contexts.

Furthermore, Marianov and Eiselt (2024) provide a comprehensive review of the advancements in location theory over fifty years, tracing the development from Weber's initial formulations to modern applications in operational research and economics. These advancements underscore the increasing complexity and multidimensional nature of industrial location decisions, necessitating a more holistic approach to site selection.

In practical applications, Ataei (2005) exemplifies the use of modern location theory through a study that uses the Analytic Hierarchy Process (AHP) to evaluate potential locations for an alumina-cement plant in East Azerbaijan, Iran. This study considers factors such as transportation, water, power, fuel, and land, highlighting the importance of a systematic and scientific approach to plant location selection. By integrating multiple criteria, Ataei's (2005) research underscores the complexity of modern industrial location decisions, which must balance technical, economic, and environmental factors to ensure operational efficiency and profitability. This approach is particularly relevant to the cement industry, where strategically selecting plant locations can significantly impact operational success and market competitiveness.

By leveraging these insights, PT. RKB can navigate the complexities of establishing a new cement plant in West Java, Indonesia. The strategic selection of a plant location, informed by these theoretical underpinnings, will align with PT. RKB's operational goals and also contribute to sustainable economic development within Indonesia's dynamic infrastructure landscape.

Decision–Making and Multi–Criteria Decision Analysis (MCDA) Method

The integration of Multi-Criteria Decision Analysis (MCDA) methods into decision-making processes has become increasingly relevant as organizations seek to optimize outcomes in complex scenarios. This section critically evaluates, reorganizes, and synthesizes key contributions to the field of decision-making and MCDA, highlighting their relevance to PT. RKB's strategic plan to develop a new cement plant in West Java, Indonesia.

The Behavioral Theory of the Firm, introduced by Cyert and March (1963) and reviewed by Shubik et al. (1965), highlights a foundational understanding of organizational decision-making. This theory challenges the classical economic assumption of perfect rationality, positing instead that decision-makers operate under constraints of bounded rationality–limited by cognitive capacity, information availability, and time. For PT. RKB, this perspective underscores the necessity of incorporating behavioural factors and organizational learning into the decision-making process for plant location selection. Ahmed et al. (2014) extensively reviewed the strategic decision-making process, emphasizing its multidisciplinary nature and applicability to various organizational contexts. The review highlights the need for integrating empirical evidence with theoretical models to enhance practical relevance. This integration is crucial for PT. RKB as it involves evaluating multiple criteria and stakeholder perspectives in selecting an optimal plant location.

The integration of sustainability considerations into facility location decisions was reviewed by Terouhid et al. (2012). Their work emphasizes the need to balance economic, environmental, and social criteria, aligning with broader sustainable development goals. The inclusion of sustainability criteria in MCDA frameworks highlights the evolving nature of decision-making models, which must adapt to contemporary challenges such as environmental impact and social responsibility. In their book, Munier et al. (2019) discuss a strategic approach in MCDA, focusing on the integration of strategic considerations into the decision-making process. This approach highlights the importance of strategic alignment in enhancing the effectiveness and relevance of MCDA applications.

Comparative studies highlight the strengths and limitations of different MCDA methods by Kahar et al. (2021) compared SMART with Fuzzy Multi-Criteria Decision Making (FMCDM) in smartphone selection, demonstrating that both methods can produce reliable recommendations.

This comparative analysis underscores the importance of selecting appropriate MCDA methods based on the specific context and nature of the decision problem. In addition, empirical studies in the cement industry, such as those by Mousavi et al. (2013), present an integrated MCDA methodology combining Delphi, AHP, and PROMETHEE techniques for plant location selection. The study demonstrates the effectiveness of this methodology in addressing complex decision-making scenarios, balancing expert judgment with structured decision-making processes.

The Simple Multi-Attribute Rating Technique (SMART) is another widely used MCDA method that is valued for its simplicity and efficiency. Risawandi et al. (2016) describe SMART's process of assigning weights to various criteria and normalizing them to facilitate comparison and ranking of alternatives. The method's flexibility and computational efficiency make it suitable for a wide range of decision-making scenarios, including project site selection and strategic business evaluations.

Moreover, Himawan (2021) uses the SMART method to describe a decision support system (DSS) for selecting mining land in Magelang. The system helps in evaluating potential mining sites based on criteria such as distance from settlements, highways, area, type of mine, and location. The application of the SMART method in this context is practical and demonstrates the method's utility in real-world scenarios. This technique is used for decision support that applies a multi-criteria decision analysis method to assist decision-makers in selecting alternatives based on desired criteria.

The reviewed literature provides a comprehensive understanding of the theoretical and practical aspects of decision-making and MCDA. By synthesizing these insights, it is clear that decision-making in the context of PT. RKB's plant location selection requires a multifaceted approach that incorporates behavioural insights, systematic evaluation frameworks, and sustainability considerations. The integration of MCDA and SMART methods, combined with strategic alignment and ethical considerations, offers a robust methodology for navigating the complexities of site selection.

Environmental and Socio-economic Consideration

The strategic decision to select a location for a cement plant involves a multifaceted analysis encompassing a wide range of environmental, social, and economic factors. This section critically evaluates, reorganizes, and synthesizes key contributions to the field of environmental and socio-economic considerations in industrial location decision-making, with a particular focus on the cement industry.

John Elkington's seminal work on the Triple Bottom Line (TBL) emphasizes the need for businesses to integrate environmental, social, and economic dimensions into their decision-making processes (Elkington, 1998). This holistic approach to sustainability underscores the importance of balancing financial performance with social equity and environmental stewardship. Elkington's (1998) framework is foundational for understanding the broader impacts of industrial projects, advocating for sustainable development practices. He highlights the strategic importance of partnerships between businesses, NGOs, and the public sector to achieve sustainability goals, emphasizing that effective long-term collaborations are essential for meaningful progress. Furthermore, Allenby's (2003) concept of industrial ecology supports the integration of sustainability into industrial operations, promoting the notion that industries should mimic the cyclical efficiency of natural ecosystems. By integrating environmental factors into the core of technological and economic development, industrial ecology offers a pathway for more resilient and adaptive environmental management practices.

Moreover, Panjaitan et al. (2020) delve into emissions reduction practices within the cement industry in Indonesia, illustrating the potential for integrating environmental sustainability into operational strategies. Their study highlights the cement industry's significant contribution to greenhouse gas (GHG) emissions and underscores the importance of adopting best practices for emissions reduction to mitigate these impacts. The authors identify key strategies such as clinker substitution, the use of alternative fuels, and technological innovations to enhance energy efficiency. Additionally, Environmental Impact Assessment (EIA) methodologies, as Noble (2011) elaborated, provide a structured process for evaluating the potential environmental impacts of industrial projects, ensuring that decision-making incorporates environmental considerations from the outset. The authors emphasize the importance of continuous monitoring and adaptive management to ensure the efficacy of EIA in mitigating adverse environmental impacts.

Vanclay et al. (2015) provide a comprehensive framework for assessing the social impacts of industrial projects, emphasizing the importance of considering the social fabric of local communities in industrial location decisions. Social Impact Assessment (SIA) involves analyzing, monitoring, and managing projects' intended and unintended social consequences. Integrating SIA with EIA and Health Impact Assessments (HIA) addresses the interconnectedness of social, environmental, and health issues, contributing to holistic project management. In addition, Kashfi and Hanna (2022) emphasize the importance of socio-economic impact assessments in evaluating the broader impacts of industrial projects, advocating for a comprehensive approach that includes community regulation and oversight. Soejanto et al. (2022) highlight that community support is crucial for successful initiatives. Understanding social dynamics in location selection ensures project acceptance and sustainability, aligning the chosen site with operational needs and socio-economic benefits.

Furthermore, Fard et al. (2016) present a case study on the sustainable location of a cement plant in Florida, utilizing the Multi-Criteria Decision Analysis (MCDA) approach to balance technical requirements with environmental and community impacts. The study acknowledges the significant impacts of the cement industry and emphasizes the need to consider sustainability criteria in depth. The authors highlight the importance of evaluating social acceptability, including factors such as poverty, public health status, regional economic performance, and employment status. This comprehensive approach ensures that the site selection process addresses operational efficiency while contributing positively to environmental stewardship and social responsibility.

Integrating these theoretical foundations and empirical insights is invaluable for navigating Indonesia's complex landscape of cement plant location selection. For PT. RKB, adopting a strategic and holistic approach to site evaluation aligns with the country's sustainable development goals and regulatory frameworks. By incorporating environmental and socio-economic considerations into the decision-making process, PT. RKB can ensure that its site selection process not only addresses operational efficiency but also contributes positively to environmental stewardship and social responsibility.

Economic Viability and Technical Feasibility

Economic viability and technical feasibility are critical components in the strategic selection of industrial locations, particularly for cement plants. These considerations ensure that the chosen location not only supports operational efficiency but also aligns with broader economic and technical criteria essential for long-term sustainability and competitive advantage.

The concept of economic viability is foundational in industrial location theory, which seeks to optimize the balance between transportation and production costs. This approach helps identify optimal locations that reduce logistical expenses and ensure proximity to raw materials and markets, enhancing operational efficiency and profitability (Fearon, 2002). Furthermore, Kazem (2022) expanded on Weber’s principles, emphasizing the importance of economic viability in generating sufficient economic benefits to justify investments. This methodology allows for detailed evaluations of various locational scenarios, ultimately identifying the point of least transportation cost, which is crucial for the long-term success and sustainability of industrial projects. Cebi and Otay (2015) address the complexity of facility location selection under conditions of uncertainty using multi-criteria decision-making techniques. This method systematically balances various economic criteria, ensuring that the selected location maximizes profitability and competitive advantage.

Technical feasibility involves assessing the infrastructural and logistical capabilities essential for the operation of a cement plant. This includes evaluating the accessibility and quality of necessary infrastructure such as roads, ports, and utilities, as well as the availability and consistency of raw material supplies. Barney's (1991) Resource-Based View (RBV) emphasizes the strategic management of firm resources to achieve a competitive edge. In the context of site selection, the RBV highlights the importance of unique resources or capabilities, such as advantageous infrastructure or access to high-quality raw materials, which can be leveraged for operational excellence. Demir et al. (2019) provide a comprehensive approach to technical feasibility through an iterative methodology for locating a cement plant. Their study integrates essential parameters such as the locations of resources and their significance in the manufacturing process, using the Weber problem to reinforce the decision-making process. This approach ensures that the chosen site meets the necessary technical requirements, minimizing transportation costs and optimizing resource accessibility.

Integrating economic viability and technical feasibility reflects a comprehensive approach to site selection. It acknowledges the imperative to balance cost-efficiency with infrastructural robustness, aiming for a site that offers both financial advantages and technical capabilities. For PT. RKB, this analysis not only informs the immediate decision-making process but also aligns with broader strategic objectives, ensuring that the location of the new cement plant facilitates sustainable growth, operational excellence, and competitive advantage. The integration of economic viability and technical feasibility is crucial in the site selection process for industrial facilities. Theoretical insights from seminal works like those of Weber and Barney, combined with modern methodologies from Kazem (2022), Cebi and Otay (2015), and Demir and Kockal (2019), provide a comprehensive framework for making informed, strategic decisions. This holistic perspective is essential for navigating the complexities of global competition and evolving market demands, positioning PT. RKB to capitalize on opportunities while mitigating risks associated with site selection.

RESEARCH METHOD

This study employs a mixed-methods approach to identify the optimal location for PT. RKB's new cement plant combines qualitative and quantitative research to capture subjective insights and empirical data. Semi-structured interviews with key decision-makers and observational visits to potential sites provide in-depth qualitative data on logistical, environmental, and strategic considerations. Quantitative analysis using the Simple Multi-Attribute Rating Technique (SMART) transforms these insights into measurable criteria, ensuring a systematic and applicable evaluation of alternative sites. For instance, Kurniawan et al. (2023) used a mixed-methods approach, combining qualitative interviews and quantitative AHP analysis, to evaluate market growth strategies.

Similarly, Prasetyo et al. (2024) integrated qualitative stakeholder analysis with AHP to prioritize carbon emission reduction strategies, demonstrating the value of combining diverse data sources for effective strategic decision-making. This comprehensive mixed methodology balances strategic perspectives with empirical rigour, guiding PT. RKB to a well-informed, sustainable site selection.

Research Design

The research design for this study is grounded in a mixed-methods approach, integrating both qualitative and quantitative methodologies to ensure comprehensive data collection and analysis. This approach, informed by Creswell and Creswell (2009), allows for a robust examination of the factors influencing the optimal location for PT. RKB's new cement plant.

The design process is visually represented in Figure 1, illustrating the sequential steps from research objectives to strategic decision evaluation and recommendation. As illustrated in the diagram flow, the research framework systematically addresses the research questions and objectives. It begins with clearly defined the primary objective of this research is to identify the optimal location for a new cement plant for PT. RKB considers environmental, socio-economic, and operational factors. Followed by meticulous data collection from both primary and secondary sources. The primary sources include semi-structured interviews and observations, while secondary sources encompass a comprehensive literature review. A comprehensive review of existing literature on industrial location theory, decision-making processes, and Multi-Criteria Decision Analysis (MCDA) methods is conducted. This review includes sources such as academic journals, industry reports, and case studies, ensuring a robust theoretical foundation for the research. The data analysis phase employs the Simple Multi Attribute Rating Technique (SMART), a well-established MCDA method. The SMART technique is chosen for its simplicity and effectiveness in handling multiple criteria Risawandi et al. (2016).

The research design culminates in evaluating the strategic decision and formulating recommendations. This phase integrates the findings from the SMART analysis with broader strategic considerations, ensuring that the chosen site not only meets operational requirements but also aligns with environmental and socio-economic goals (Ivankova et al., 2006).

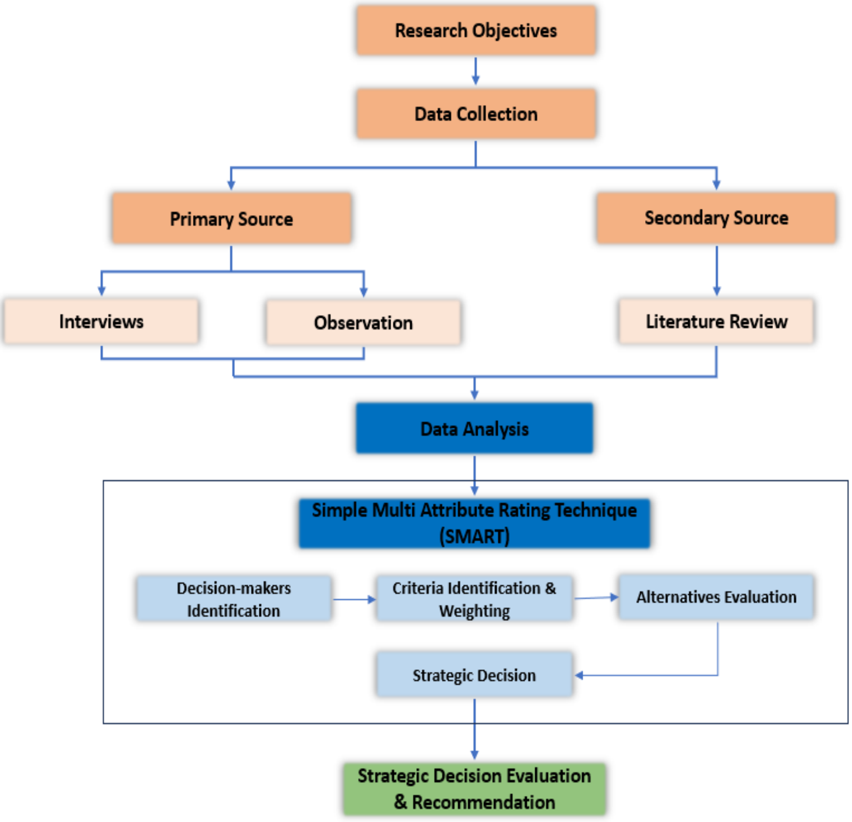

Figure 1. Research Design

Data Collection Methods

The primary objective of this research is to identify the optimal location for a new cement plant for PT. RKB considers environmental, socio-economic, and operational factors. The data collection process involves both primary and secondary sources. Primary data were gathered through semi-structured interviews and field observations with key stakeholders, aligning with Ahmad and Putro (2024) approach, while secondary data were collected from a comprehensive literature review. This dual approach ensures that the research is informed by both empirical evidence and established theoretical frameworks.

Primary Data Collection

Semi-structured interviews are conducted with key stakeholders, including top management, project directors, and relevant staff members. These interviews aim to capture insights into the decision-making criteria and priorities of those directly involved in the project. Following the guidelines set by Creswell and Creswell (2009), the interview process ensures consistency and reliability in data collection.

Field observations are carried out to gather firsthand information on potential site locations. This includes assessing geographical features, infrastructure availability, and environmental conditions. Observations provide a contextual understanding that complements the data obtained from interviews and literature.

Secondary Data Collection

A comprehensive review of existing literature on industrial location theory, decision-making processes, and Multi-Criteria Decision Analysis (MCDA) methods is conducted. This review includes sources such as academic journals, industry reports, and case studies, ensuring a robust theoretical foundation for the research (Bryman, 2016).

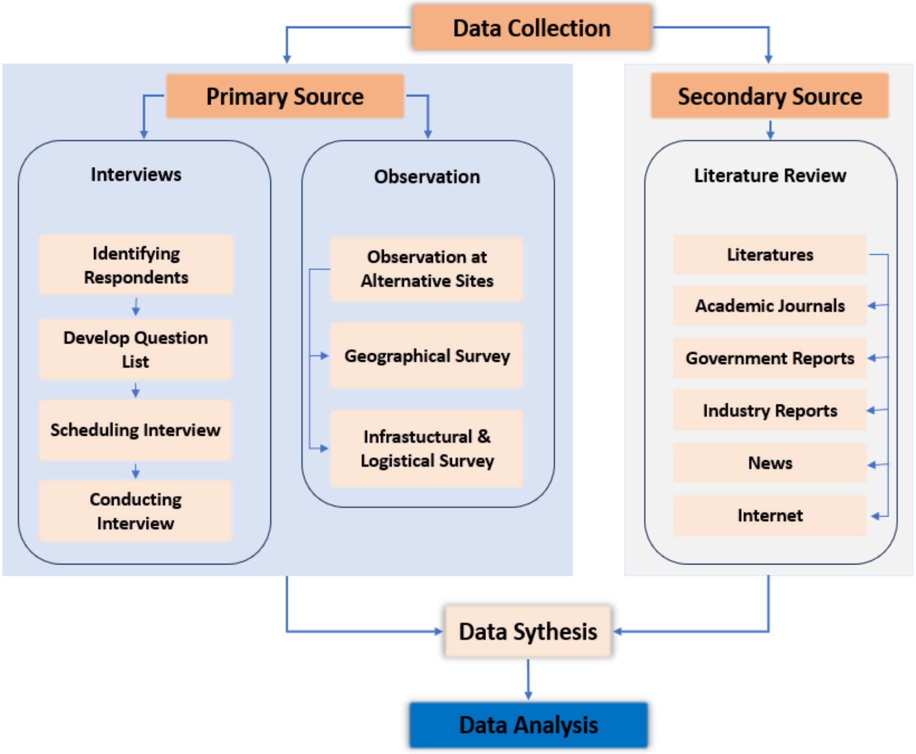

Figure 2. Data Collection Method

Data Analysis Method

The data analysis phase employs the Simple Multi Attribute Rating Technique (SMART), a well-established MCDA method. The process involves several key steps:

1. Stage 1: Identify the decision maker (s)
   In the context of this research, the decision makers are PT. RKB's project key personnel and top management team include the CEO, Project Director, Engineering Manager, External Relation Manager and Project Finance Manager. These individuals possess the authority and expertise to assess and decide on the most suitable location for the new cement plant.
2. Stage 2: Identify the alternative potential locations
   For PT. RKB, the alternatives are the potential locations being considered for the new cement plant. The research has identified 3 (three) feasible sites, each with unique characteristics and potential benefits. These sites are the focus of the evaluation and will be compared against each other using the defined criteria.
3. Stage 3: Identify the relevant attributes
   In this research, each attribute is essential to the decision-making process and is identified through a combination of decision-maker interviews, observations, and secondary data analysis.
4. Stage 4: Assign the value to measure the performance of each alternative based on chosen attributes
   Each potential location will be assessed based on how well it scores against each attribute with intervals 0-100. These scores provide a quantitative measure of each site's suitability. Measuring how well the alternative locations perform on each attribute can be used for direct rating for abstract value. The Value Function is utilized to convert "actual value" to the ranking that is more suited to the decision-maker's preference.
5. Stage 5: Determine the weight for each attribute
   The importance of each attribute is weighted according to decision-makers' priorities and strategic alignment with PT. RKB's long-term goals. Weights can be derived from the importance placed on each attribute by decision-makers during interviews and observations, reflecting their strategic preferences and the impact of each attribute on the company's operations.

   After determining the priority weight of each attribute, the next step is to normalize each criterion by using the formula:

   $$\boldsymbol{Normalized\,weight} = \frac{Wj}{\sum Wj} \times 100\%$$

   Where:
   Wj = original weight of an attribute
   $\sum Wj$ = total original weight of all attributes
6. Stage 6: Calculate weighted averages for each alternative
   The scores from stage 4 are multiplied by the corresponding weights from stage 5 to compute a weighted average for each site. This step amalgamates the various attribute scores into a single, comprehensive score for each alternative, allowing for direct comparison across all potential sites.
7. Stage 7: Make a provisional decision
   Based on the weighted scores, a provisional decision is made, with less suitable alternatives eliminated from consideration. This focuses the final decision-making process on the most promising locations, streamlining further analysis and final site selection.
8. Stage 8: Perform sensitivity analysis
   Finally, sensitivity analysis is conducted to test the robustness of the decision. This involves

adjusting the weights of various attributes to see how changes might affect the ranking of the locations. This step is crucial for ensuring that the decision is not overly dependent on any single attribute and that the chosen site remains the best option under various scenarios.

FINDINGS AND DISCUSSION

SMART Method Result

The results were obtained by applying the Simple Multi-Attribute Rating Technique (SMART) in evaluating alternative locations for PT. RKB's new cement plant. The SMART method facilitated a systematic and objective comparison of potential sites by assessing various critical aspects of the company's strategic objectives.

1. Identify the Decision-Makers

   The decision-making body comprised senior executives and key project personnel, including the CEO, Project Director, Engineering Manager, External Relations Manager, and Project Finance Manager. Each member contributed unique perspectives, ensuring a comprehensive evaluation of the potential sites.
2. Identify the Alternative Courses of Action

   Three potential sites were considered for the new cement plant:

Table 1. Alternative Location

No.	Alternative Name
1.	Location-A
2.	Location-B
3.	Location-C

   Each location has been selected based on rigorous criteria, including land availability, potential for operational expansion, and compliance with government zoning regulations.
3. Identify the Relevant Attributes

   The relevant attributes for site selection were identified through interviews, observations, and secondary data analysis. The attributes were categorized under four main criteria shown in Table 2:

Table 2. Relevant Attributes

Criteria	Attribute	Attribute Name
Economic Viability (C-01)	Land acquisition costs	Attr-01
	Transportation and logistic costs	Attr-02
Technical Feasibility (C-02)	Proximity to major roads	Attr-03
	Proximity to raw material sources	Attr-04
	Existing industrial infrastructure	Attr-05
Environmental Impact (C-03)	Potential for air and water pollution	Attr-06
	Effects on local flora and fauna	Attr-07
	Employment opportunities for local residents	Attr-08

Criteria	Attribute	Attribute Name
Socio-Economic Considerations (C-04)	Community support	Attr-09

The hierarchy of the identified criteria and relevant attributes is presented in Figure 3, providing a clear framework for the decision-making process.

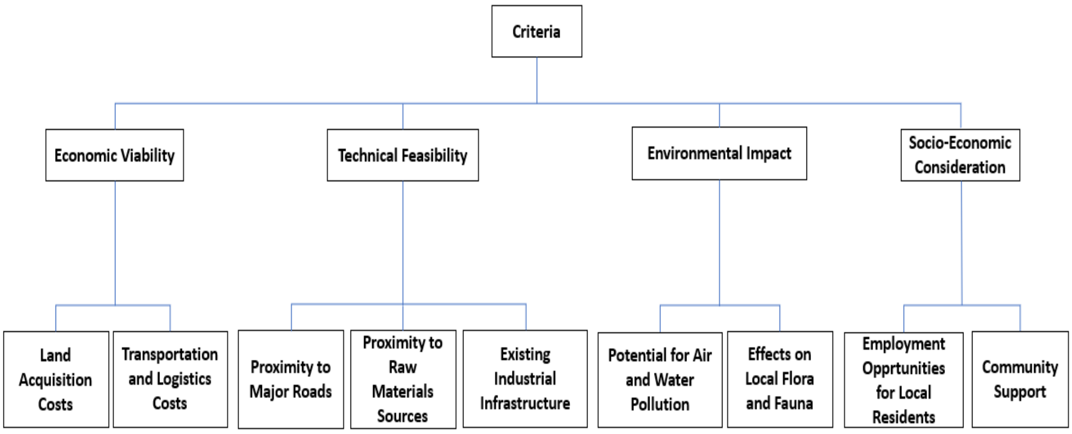

Figure 3. Criteria and Relevant Attributes Tree

4. Assign Value to Measure Performance of Each Alternative
   Values were assigned to measure each location's performance based on the identified attributes. The scores ranged from 0 to 100, reflecting how well each site met the criteria. The performance values indicated distinct strengths and weaknesses for each location. The values are derived from the preferences of decision-makers, combining their insights and observations with synthesized data collected from secondary sources. Table 3 summarizes the performance scores for each alternative location across all relevant attributes.

Table 3. Value of Each Alternative Location Perform on Attributes

Alternative Location	Attr-01	Attr-02	Attr-03	Attr-04	Attr-05	Attr-06	Attr-07	Attr-08	Attr-09
Location-A	50	75	85	50	87	70	80	65	75
Location-B	23	85	80	55	70	60	80	75	60
Location-C	78	65	60	85	70	85	90	55	90

5. Determine the Weight for Each Attribute
   Weights were assigned to each attribute to reflect their importance to the decision-makers. These weights were then normalized to facilitate a balanced comparison. Table 4 displays the original weights assigned and then normalized to each attribute based on their importance.

Table 4. Original Weight and Normalized Weight from Each Attribute

Attribute Name	Original Weight	Normalized Weight
Attr-01	78	0,12
Attr-02	75	0,12
Attr-03	83	0,13
Attr-04	85	0,13
Attr-05	80	0,13
Attr-06	65	0,10
Attr-07	63	0,10
Attr-08	45	0,07
Attr-09	68	0,11
Total Original Weight	**640**	

Figure 4 illustrates the ranking level of importance for each attribute, depicting the best and worst performances based on the original weights. This ranking aligns with PT. RKB's strategic goals and priorities emphasize the most critical factors in the decision-making process.

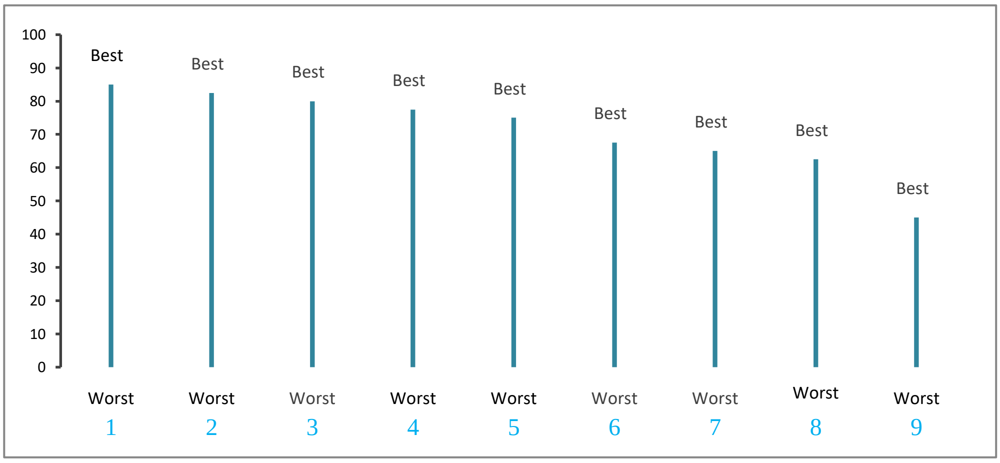

Figure 4. Ranking Level of Importance of Each Attribute

6. Calculate Weighted Averages for Each Alternative
   Each location's performance scores were integrated with their corresponding normalized weights to derive a composite index. The weighted scores, presented in Table 5, provided a holistic assessment of each site's suitability.

Table 5. Aggregate of Weighted Value from Each Location

Alternative	Attr-04 (0,13)	Attr-03 (0,13)	Attr-05 (0,13)	Attr-01 (0,12)	Attr-02 (0,12)	Attr-09 (0,11)	Attr-06 (0,10)	Attr-07 (0,10)	Attr-08 (0,07)	Aggregate of Weighted Value
Location-A	50	85	87	50	75	75	70	80	65	**71**
Location-B	55	80	70	23	85	60	60	80	75	**66**

Alternative	Attr-04 (0,13)	Attr-03 (0,13)	Attr-05 (0,13)	Attr-01 (0,12)	Attr-02 (0,12)	Attr-09 (0,11)	Attr-06 (0,10)	Attr-07 (0,10)	Attr-08 (0,07)	Aggregate of Weighted Value
Location-C	85	60	70	78	65	90	85	90	55	**76**

7. Make a Provisional Decision
   Based on the weighted scores, Location-C emerged as the most suitable site for PT. RKB's new cement plant. Location-C's high scores in land acquisition costs, proximity to raw materials, and community support outweighed its moderate scores in transportation and logistics.
8. Perform Sensitivity Analysis
   Sensitivity analysis was conducted to test the decision's robustness by adjusting the weights of various attributes. The analysis confirmed that the decision to prioritize Location-C was robust under various weighting scenarios, validating its selection as the optimal site.

Discussion

The application of the Simple Multi-Attribute Rating Technique (SMART) for PT. RKB's new cement plant site selection highlighted several key insights, particularly in economic viability, technical feasibility, environmental impact, and socio-economic factors. This study revealed several significant insights that extend beyond the immediate case study, offering broader implications for industry practitioners and policymakers.

Economic Viability

Location-C emerged as the most economically viable option due to lower land acquisition and transportation costs, which aligns with the findings of (Kazem, 2022). However, unlike Kazem's (2022) emphasis on transportation cost minimization alone, our study integrates additional cost factors, providing a more comprehensive economic analysis. This finding is not only applicable to PT. RKB also serves as a strategic insight for the cement industry, where economic constraints are often a decisive factor in location decisions. This underscores the importance of considering a broad range of economic variables to ensure a comprehensive evaluation.

Technical Feasibility

The proximity to raw materials made Location-C technically superior, echoing the work of Mousavi et al. (2013), which stressed the importance of resource availability. Our findings further elaborate by considering resource proximity and the impact on operational efficiency, which was less emphasized in previous studies. The broader implication here is that industries reliant on heavy raw materials, such as cement manufacturing, must prioritize locations that offer logistical efficiency and resource accessibility. This insight can inform policy-making, particularly in regions seeking to attract industrial investments, by highlighting the availability of necessary resources.

Environmental Impact

Location-C presented manageable environmental impacts a result consistent with the principles of industrial ecology highlighted by Allenby (2003). Unlike Panjaitan et al. (2020), who focused extensively on emission reduction strategies, our study provides a more holistic framework for site selection, integrating a broader range of environmental considerations, including regulatory compliance and community health. This approach can guide policymakers in developing environmental regulations that balance industrial growth with ecological sustainability, particularly in developing economies with rapid industrial expansion.

Socio-Economic Considerations

High community support and job creation potential at Location C were critical socio-economic factors. This strong backing facilitates smoother project execution and long-term sustainability, aligning with the need for community engagement in industrial projects. This insight highlights the critical role of community engagement and job creation in gaining local support for industrial projects. For practitioners, this suggests that successful site selection must consider not just economic and technical factors but also the socio-economic benefits to the surrounding community, ensuring long-term project sustainability. This finding can inform policies aimed at fostering community-industry partnerships, particularly in regions undergoing industrialization.

Sensitivity Analysis

Robustness through sensitivity analysis confirmed Location-C's suitability under various scenarios, validating the reliability of the SMART method. As noted by Cebi et al. (2015), this approach provides a more structured and reliable framework compared to previous methodologies.

Broad Contributions and Practical Applications

This study contributes to the broader field of industrial site selection by offering a data-driven methodology that integrates multiple critical factors. The SMART method, validated through sensitivity analysis, provides a robust framework that can be adapted for use in various industries beyond cement manufacturing. Practitioners can leverage this approach to make informed, balanced decisions that align with both operational goals and broader strategic objectives. Additionally, the study's insights can inform policymakers in areas such as environmental regulation, community engagement, and industrial zoning, ultimately contributing to more sustainable industrial development.

The research findings align with existing literature on the need for a multi-criteria approach yet offer a more integrated and holistic perspective. The SMART method identified Location-C as the optimal site, offering balanced economic, technical, environmental, and socio-economic benefits, thereby supporting PT. RKB's strategic objectives for sustainable growth. The findings from this study not only benefit PT. RKB but also offer valuable lessons for the broader industry and policymakers. By emphasizing the integration of economic, technical, environmental, and socio-economic considerations, this research provides a comprehensive approach to site selection that can be applied across various contexts, thereby contributing to sustainable industrial growth on a global scale.

CONCLUSIONS

This study aimed to identify and prioritize the critical criteria influencing the site selection for PT. RKB's new cement plant and to evaluate alternative locations to recommend the most suitable site. Utilizing the Simple Multi-Attribute Rating Technique (SMART) within the Multi-Criteria Decision Analysis (MCDA) framework, we systematically assessed potential sites against key criteria, including economic viability, technical feasibility, environmental impact, and socio-economic considerations.

Key Findings

1. Identifying Critical Criteria

The study identified four primary criteria essential for site selection: economic viability, technical feasibility, environmental impact, and socio-economic considerations. These criteria were derived from extensive qualitative data obtained through interviews with PT. RKB's decision-makers and quantitative data from secondary sources. Economic viability, including land acquisition and transportation costs, emerged as a critical factor. Technical feasibility focused on proximity to raw materials and existing industrial infrastructure. Environmental impact assessed potential pollution and effects on local ecosystems. Socio-economic considerations emphasized community support and job creation potential.

2. Evaluating Alternative Locations

Three potential sites were evaluated: Location A, Location B, and Location C. The SMART method facilitated a detailed, weighted comparison of these sites based on the identified criteria. Location-C emerged as the most suitable site, scoring highest in critical areas such as proximity to raw materials and community support, which significantly influence operational efficiency and sustainability.

The study findings confirmed Location-C as the optimal site, presenting the best balance across all evaluated attributes. Economically, Location-C benefits from lower land acquisition and transportation costs, aligning with and expanding upon existing research by incorporating a comprehensive range of cost factors. Technically, its proximity to raw materials and supportive infrastructure enhances operational efficiency, validating prior studies while emphasizing a broader set of technical requirements.

Sensitivity analysis reinforced the robustness of our decision, confirming that Location-C remains the most suitable site under various weighting scenarios. This validation underlines the reliability and comprehensiveness of the SMART method in making strategic site selection decisions.

This study advances the field by integrating a holistic and structured approach to site selection, addressing the limitations of previous research. By providing a robust methodology tailored to the Indonesian cement industry's dynamics, this work not only supports PT. RKB's strategic expansion but also sets a benchmark for future industrial location decisions, ensuring sustainable growth and competitive advantage in a rapidly developing market.

By addressing the research objectives and presenting a clear, data-driven rationale for selecting Location-C, this study contributes valuable knowledge to industrial facilities' strategic planning and operational management. The recommendations for practical implementation and suggestions for future research ensure that PT. RKB can achieve its long-term growth and sustainability goals while reinforcing its leadership position in the Indonesian cement market.

LIMITATION & FURTHER RESEARCH

The limitations of this study stem from the inherent challenges in data collection and the dynamic nature of the external environment. Firstly, the reliance on qualitative data from interviews and observations may introduce subjectivity despite efforts to ensure consistency and reliability. Secondly, Indonesia's rapidly changing economic and regulatory landscape could affect some criteria' relevance over time.

Future studies could also explore the socio-economic impacts of the new plant on the local community, including employment generation and economic changes. Moreover, optimizing supply chain and logistics processes can enhance operational efficiency and reduce costs, providing valuable insights into continuous improvement. In addition, comparative studies of different decision-making frameworks, such as AHP and PROMETHEE, could further validate the robustness of the methodologies used in strategic site selection. These studies would provide a broader perspective on the effectiveness of various approaches, ensuring that the selected framework is the most suitable for specific contexts.

By addressing these gaps, future research can build on this study's findings, offering more comprehensive and adaptive strategies for industrial site selection and contributing to sustainable development in the cement industry.

REFERENCES

Ahmad, Z., & Putro, U. S. (2024). Advancing competitive positioning in the photovoltaic module market with system thinking: A Case of PT. Indonesia Solar Global. *Advanced Qualitative Research*, *2*(2), 1–18. https://doi.org/10.31098/aqr.v2i2.2261

Ahmed, A. H., Bwisa, H., Otieno, R., & Karanja, K. (2014). Strategic decision making: Process, models, and theories. *Business Management and Strategy*, *5*(1), 78. https://doi.org/10.5296/bms.v5i1.5267

Allenby, B. (2003). Industrial Ecology. In *Inventing for the Environment* (pp. 339–372). The MIT Press. https://doi.org/10.7551/mitpress/3934.003.0029

Asian Development Bank. (2023). *Asian development outlook April 2023: Brighter prospects amid ongoing challenges*. https://www.adb.org/sites/default/files/page/871161/full-presentation-ado-april2023.pdf

Ataei, M. (2005). Multi-criteria selection for an alumina-cement plant location in East Azerbaijan province of Iran. *Journal of the South African Institute of Mining and Metallurgy*, *105*(7), 507–514. https://www.saimm.co.za/Journal/v105n07p507.pdf

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Bryman, A. (2016). *Social research methods*. Oxford University Press. https://www.google.co.id/books/edition/Social_Research_Methods/N2zQCgAAQBAJ?hl=en&gbpv=1&dq=Social+research+methods+(Bryman,+2016)&printsec=frontcover

Cebi, F., & Otay, İ. (2015). Multi-criteria and multi-stage facility location selection under interval type-2 fuzzy environment: A case study for a cement factory. *International Journal of Computational Intelligence Systems*, *8*(2), 330. https://doi.org/10.1080/18756891.2015.1001956

Central Bureau of Statistics. (2024). *Ekonomi Indonesia triwulan II-2024 tumbuh 3,79 Persen (Q-to-Q), ekonomi Indonesia triwulan II-2024 tumbuh 5,05 persen (Y-on-Y), dan ekonomi Indonesia semester I-2024 tumbuh 5,08 persen (C-to-C)*. https://www.bps.go.id/id/pressrelease/2024/08/05/2381/ekonomi-indonesia-triwulan-ii-2024-tumbuh-3-79-persen-q-to-q-ekonomi-indonesia-triwulan-ii-2024-tumbuh-5-05-persen-y-on-y-dan-ekonomi-indonesia-semester-i-2024-tumbuh-5-08-persen-c-to-c-.html

Creswell, J. W., & Creswell, J. D. (2009). *Research design qualitative, quantitative, and mixed methods approaches* (3rd Ed.). Sage publications. https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf

CW Group. (2024). *Global cement market outlook 2023-2028: Growth projections and regional trends*. https://cwgrp.com/about/news/global-cement-market-outlook-2023-2028-growth-projections-and-regional-trends

Cyert, R. M., & March, J. G. (1963). *A behavioral theory of the firm*. Prentice Hall/Pearson Education.

Demir, E., & Kockal, N. U. (2019). Iterative methodology on locating a cement plant. *Journal of Inequalities and Applications*, *2019*(1), 174. https://doi.org/10.1186/s13660-019-2122-7

Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, *8*(1), 37–51. https://doi.org/10.1002/tqem.3310080106

Fard, M. M., Kibert, C. J., & Chini, A. R. (2016). Decision-making for sustainable location of a cement plant in the state of Florida. *International Journal of Sustainable Engineering*, *9*(2), 76–92. https://doi.org/10.1080/19397038.2015.1050971

Fearon, D. (2002). *Alfred Weber, Theory of the Location of Industries, 1909.* CSISS Classics. https://escholarship.org/uc/item/1k3927t6

Hanink, D. M. (2017). Industrial Location Theory. In *International Encyclopedia of Geography* (pp. 1–11). Wiley. https://doi.org/10.1002/9781118786352.wbieg0216

Himawan, G. H. (2021). Decision support system for mining land clearing in Magelang Regency using the simple multi-attribute rating technique (SMART) method. *Jurnal Mandiri IT*, *9*(2), 35–39. https://ejournal.isha.or.id/index.php/Mandiri/article/view/110/218

ICR Research. (2023). *Indonesia Country Report 2023*. Cemnet.Com. https://www.cemnet.com/Publications/Item/182042/indonesia-country-report-2023.html

Ivankova, N. V, Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods*, *18*(1), 3–20. https://www.dedoose.com/publications/using%20mixed-methods%20sequential%20explanatory%20design%20from%20theory%20to%20practice.pdf

Kahar, N., & Riki. (2021). Comparative study of SMART and FMCDM methods in smartphone selection decision support system. *International Journal of Image, Graphics and Signal Processing*, *13*(4), 1–13. https://doi.org/10.5815/ijigsp.2021.04.01

Kashfi, M. A. S. J. & Hanna, P. (2022). How could local communities regulate companies to assess the overlooked environmental and social impacts of industrial projects?. In: G. Wood, J. Górski, G. Mete (Eds.) *The Palgrave Handbook of Social License to Operate and Energy Transitions. Palgrave Studies in Energy Transitions* (pp. 1-24). Springer Link. https://doi.org/10.1007/978-3-030-74725-1_12-1

Kazem, H. K. (2022). Determine the optimal location for the industrial facility. *Journal Port Science Research*, *4*(4). https://doi.org/10.36371/port.2021.4.1

Kurniawan, C., & Hermawan, P. (2023). Optimizing market growth strategies in South Sulawesi: A comprehensive evaluation using multi-criteria decision making and the Analytic Hierarchy Process (AHP) - A case study of PT MCM. *Applied Quantitative Analysis*, *3*(1), 1–20. https://doi.org/10.31098/quant.1599

Marianov, V. & Eiselt, H. A. (2024). Fifty years of Location Theory - A selective review. *European Journal of Operational Research, 318*(3), 701-718. https://doi.org/10.1016/j.ejor.2024.01.036

Mousavi, S. M., Tavakkoli-Moghaddam, R., Heydar, M., & Ebrahimnejad, S. (2013). Multi-criteria decision making for plant location selection: An integrated Delphi–AHP–PROMETHEE methodology. *Arabian Journal for Science and Engineering*, *38*(5), 1255–1268. https://doi.org/10.1007/s13369-012-0361-8

Munier, N., Hontoria, E., & Jiménez-Sáez, F. (2019). *Strategic Approach in Multi-Criteria Decision Making* (Vol. 275). Springer International Publishing. https://doi.org/10.1007/978-3-030-02726-1

Natalia, T. (2024, March 28). *Permintaan semen meroket 91% karena proyek IKN, ini datanya*. CNBC Indonesia. https://www.cnbcindonesia.com/research/20240328144152-128-526350/permintaan-semen-meroket-91-karena-proyek-ikn-ini-datanya

Noble, B. F. (2011). Environmental Impact Assessment. In *Encyclopedia of Life Sciences*. Wiley. https://doi.org/10.1002/9780470015902.a0003253.pub2

Panjaitan, T. W. S., Dargusch, P., Wadley, D., & Aziz, A. A. (2020). Toward the best practice emissions reduction in an emerging economy: an analysis of cement manufacturing in Indonesia. *Entrepreneurship and Sustainability Issues*, *8*(1), 103–122. https://doi.org/10.9770/jesi.2020.8.1(7)

Prasetyo, B., & Putro, U. S. (2024). Strategic analysis of international oil and gas companies' response to global carbon emission reduction initiatives. *Applied Quantitative Analysis*, *4*(1), 54–68. https://doi.org/10.31098/quant.2038

PT. Indocement Tunggal Prakarsa Tbk. (2024). *Public Expose: 25 March 2024*. Indocement. https://indocement.co.id/resource/03.%20Investor/3.4%20Paparan%20Publik/2024_Rev%20Materi%20PE%20with%20FS%2025%20Mar%2024%20Eng_INTP_220324.pdf

PWC Indonesia. (2023, July 20). *National strategic project: Getaci toll road's fate at the end of Jokowi's administration*. PWC Indonesia. https://www.pwc.com/id/en/media-centre/infrastructure-news/july-2023/national-strategic-project-getaci-toll-roads-fate-at-the-end-of-jokowis-administration.html

Risawandi, R. R. (2016). Study of the Simple Multi-Attribute Rating Technique for Decision Support. *International Journal of Scientific Research in Science and Technology*. https://doi.org/10.31227/OSF.IO/XNHTJ

Shubik, M., Cyert, R. M., & March, J. G. (1965). A behavioral theory of the firm. *Journal of the American Statistical Association*, *60*(309), 378. https://doi.org/10.2307/2283171

Siringo, R., Suwardi, E., Haryono, E., & Kurniawan, A. (2023). Analyzing regional development in Indonesia based on GDP and cement consumption from 2010 to 2020. *IOP Conference Series: Earth and Environmental Science*, *1190*(1), 012008. https://doi.org/10.1088/1755-1315/1190/1/012008

Soejanto, I., Berlianty, I., & Prangawayu, N. (2022). Construction of community perceptions on Government effort in managing the Covid-19 pandemic: A Covid score-10 approach. *Applied Quantitative Analysis*, *2*(1), 1–9. https://doi.org/10.31098/quant.806

Terouhid, S. A., Ries, R., & Fard, M. M. (2012). Towards sustainable facility location – A literature review. *Journal of Sustainable Development*, *5*(7). https://doi.org/10.5539/jsd.v5n7p18

Timoteo Jr., E. N. (2023). Millennial votes in the 2019 Philippine National Election: A quantitative approach. *Applied Quantitative Analysis*, *2*(2), 28–41. https://doi.org/10.31098/quant.558

Vanclay, F., Esteves, A. M., Aucamp, I., & Franks, D. (2015). *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.* https://typeset.io/papers/social-impact-assessment-guidance-for-assessing-and-managing-4p4vyzitkz

Weber, A. & Friedrich, C. J. (1929). *Alfred Weber's Theory of the Location of Industries*. University of Chicago Press.