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An Evaluative Analysis of Performance Factors and Improvement Strategies in the Cement Deep Mixing (CDM) Project Based on Importance–Performance Analysis (IPA) and the Customer Satisfaction Index (CSI): A Case Study of the ABC Port Project

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Cement Deep Mixing; Importance–Performance Analysis (IPA); Customer Satisfaction Index (CSI); Project Performance; Performance Improvement.

ABSTRACT
The implementation of port infrastructure development often faces challenges related to soft soil conditions that require effective ground improvement methods. Cement Deep Mixing (CDM) has become one of the widely applied techniques for enhancing soil strength and stability; however, its performance is influenced by various technical, managerial, external, and implementation quality factors. This study aimed to evaluate the performance factors affecting the CDM project, identify gaps between the importance and actual performance of these factors, and determine improvement priorities using Importance–Performance Analysis (IPA) and the Customer Satisfaction Index (CSI). A quantitative approach using a survey method was applied to the ABC Port Project, involving 85 respondents consisting of contractors, main contractors, and supervisory consultants directly involved in CDM implementation. Data were collected through questionnaires based on 15 indicators covering technical factors, managerial factors, external conditions, and implementation quality, and were analyzed using IPA and CSI methods. The results showed that the overall CDM project performance was categorized as good, with a CSI value of 87.57%, indicating a very high level of stakeholder satisfaction. However, the analysis revealed a negative performance gap of -0.06 between stakeholder expectations and actual project performance. The highest improvement priorities were related to technical training (M2) and operator and technician competency (M1), indicating the need for stronger human resource development and technical control. This study concludes that the integration of IPA and CSI provides an effective evaluation framework for identifying critical factors and developing targeted strategies to improve CDM project performance.

INTRODUCTION

Infrastructure development plays a strategic role in promoting economic growth and improving regional connectivity, particularly in the port sector, which functions as a key node in logistics distribution systems (Chen & Hasan, 2023; Li et al., 2023; Lin et al., 2025; Netirith & Ji, 2024; Ramadan & Nugraha, 2026; Wang & Chen, 2025). However, port development projects often encounter challenges associated with soft soil conditions characterized by low bearing capacity and high deformation potential, requiring the application of effective and reliable ground improvement methods (Ha, 2020). One widely applied method is Cement Deep Mixing (CDM), a ground improvement technique that involves the in-situ mixing of binding materials, such as cement, with soil to enhance strength and stability. This method offers advantages by improving geotechnical properties without requiring large-scale soil replacement, making it a more efficient and environmentally favorable alternative (Ito et al., 2024; Kitazume, 2013).

The successful implementation of the CDM method is determined not only by technical aspects but also by managerial factors, external conditions, and overall construction quality. Technical factors include material quality, mixture consistency, and equipment performance. Managerial factors involve workforce competency, supervision effectiveness, and coordination among project stakeholders. Meanwhile, external factors relate to environmental conditions, regulatory requirements, and social aspects that may influence project execution (Petchgate et al., 2025; Pooranampillai et al., 2011).

Various studies have shown that construction project failures are frequently caused by weaknesses in managerial aspects rather than purely technical issues. Factors such as inadequate supervision, ineffective planning, and limited workforce competency are among the main determinants affecting project performance (Love et al., 2015). Furthermore, management's ability to allocate and control resources effectively has been demonstrated as an important factor influencing overall project success (Muntu et al., 2021). In the context of CDM projects, implementation quality serves as a critical link between influencing factors and project performance. Implementation quality reflects the extent to which construction activities comply with established technical specifications and standards. Previous research has demonstrated that implementation quality significantly affects project performance, particularly in terms of quality, schedule, and cost dimensions (Muntu et al., 2021).

However, project implementation often reveals a gap between the perceived importance of a factor and its actual performance. Some factors considered highly important may demonstrate inadequate performance, while less critical factors may perform relatively well. This condition indicates an imbalance in project resource allocation that may reduce implementation effectiveness. To identify such gaps, an analytical method is required to systematically compare the importance and performance levels of project factors. One commonly applied method is Importance–Performance Analysis (IPA), which categorizes indicators into four quadrants based on their importance and performance levels, allowing improvement priorities to be identified clearly (Pontan et al., 2024; Subagyo & Isradi, 2025).

In addition to IPA, the Customer Satisfaction Index (CSI) approach can be used as a complementary evaluation method. CSI enables the measurement of stakeholder satisfaction levels regarding project performance based on perceptions of quality, timeliness, cost, and managerial aspects, thereby helping identify improvement areas and evaluate the effectiveness of managerial interventions (Debora et al., 2023). The combination of IPA and CSI provides a more comprehensive evaluation perspective, as IPA focuses on identifying gaps between importance and performance, while CSI emphasizes quantitative measurement of stakeholder satisfaction.

In this study, IPA and CSI methods were applied to evaluate CDM project performance based on 15 indicators covering technical factors, managerial factors, external conditions, and implementation quality. This approach enabled the identification of factors requiring priority improvement as well as factors that should be maintained. The case study was conducted on the ABC Port Project, which applied the CDM method in a complex construction environment involving various interacting technical and non-technical factors, making it suitable for evaluation using both approaches. Based on this context, this study aimed to evaluate the factors influencing CDM project performance, analyze the gap between importance and performance levels, and identify improvement priorities to enhance project outcomes. This research is expected to provide practical contributions to construction project management and academic contributions to the development of performance evaluation methods based on IPA and CSI.

METHOD

This study employed a quantitative approach using a survey method to evaluate the performance of the Cement Deep Mixing (CDM) project and identify improvement priorities based on the perceptions of project stakeholders. The quantitative approach was selected to systematically measure the importance and performance levels of factors influencing construction project success. The analysis was conducted using Importance–Performance Analysis (IPA), which is effective for identifying attributes requiring priority improvement (Martilla & James, 1977; Slack, 1994).

The research object was the ABC Port construction project, which applied the CDM method for soft soil improvement. The project was selected due to its complexity in terms of technical, managerial, and environmental aspects. The research population consisted of parties directly involved in the project, including contractors, consultants, and field supervisors. Purposive sampling was applied, with respondents selected based on their direct involvement in CDM implementation. A total of 85 respondents participated in the study, providing a representative overview of actual project conditions.

The research instrument was a questionnaire developed based on 15 indicators representing four main factors: technical factors, managerial factors, external factors, and implementation quality. The indicators were developed through a literature review and adjusted to the conditions of the CDM project, considering that project performance is influenced by the interaction among technical, managerial, and environmental factors.

Table 1. Research Indicators

No	Variabel	Code	Indicator
1	Technical Factors	T1	Performance of CDM equipment (mixing equipment and slurry pump)
2		T2	Accuracy of measurement instruments (flowmeter and densitometer)
3		T3	Control of operational parameters (penetration, rotation, injection pressure)
4		T4	Effectiveness of process monitoring and control systems
5	Managerial Factors	M1	Operator and technician competencies
6		M2	Implementation of technical training
7		M3	Realistic scheduling
8		M4	Effectiveness of field surveillance

9	External Factors	E1	Soft soil conditions
10		E2	Influence of groundwater and seawater intrusion
11		E3	Rainfall
12		E4	Characteristics of the project site (reclamation/alluvial plains)
13	Quality of Implementation	Q1	CDM column strength as per design specification
14		Q2	Consistency of implementation according to work methods
15		Q3	Fulfillment of project technical quality requirements

Data collection was carried out through the distribution of questionnaires that used the Likert scale of 1–5 to measure two main dimensions, namely the importance level and the performance level of each indicator. This approach allows for the identification of gaps between expectations and actual conditions on the ground. In addition to primary data, the research also utilizes secondary data in the form of project reports and technical documents as support for the analysis. The use of respondents' perceptions as a basis for evaluation is considered effective in reflecting the operational conditions of construction projects. Data analysis was carried out using a combination of Importance–Performance Analysis (IPA) and Customer Satisfaction Index (CSI) through several stages. In the science method, the average value of the level of importance and performance for each indicator (T1–T4, M1–M4, E1–E4, and Q1–Q3) is first calculated.

Second, the degree of compatibility between performance and importance is calculated, then the overall average value is determined as the cut-off point in the Cartesian diagram. Furthermore, each indicator is mapped into four quadrants, namely the main priority quadrant, the maintain performance quadrant, the low priority quadrant, and the redundant quadrant. Meanwhile, CSI is used to measure the overall level of satisfaction by taking into account the importance of each indicator. This approach allows for the assessment of project performance from a stakeholder perspective, thus identifying the attributes that have the most influence on the satisfaction and effectiveness of project implementation. The combination of IPA and CSI provides an advantage in producing strategic recommendations based on performance improvement priorities while considering stakeholder satisfaction levels. With this approach, the research is expected to be able to systematically identify critical factors that affect the performance of CDM projects and formulate targeted improvement strategies to improve the quality of construction project implementation.

RESULT AND DISCUSSION

Respondent Characteristics

The respondents in this study were 85 people who had direct involvement in the implementation of *the Cement Deep Mixing (CDM) project* in the construction of ABC Port. Based on the type of company, the majority of respondents came from CDM specialist contractors as many as 59 people (69.41%), followed by main contractors as many as 17 people (20.00%), and supervisory consultants as many as 9 people (10.59%). The dominance of respondents from CDM contractors shows that most of them have direct involvement in the technical aspects of the implementation of the work, especially in the process of mixing soil-cement and controlling operational parameters in the field. Respondents from the main contractors play a role in coordinating the overall implementation of the project, while the

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supervising consultant is responsible for quality control and the conformity of the work to technical specifications.

Based on work experience, most respondents had more than three years of experience, namely 50 people (58.82%), followed by respondents with 1-3 years of experience as many as 30 people (35.29%), and respondents with less than one year of experience as many as 5 people (5.88%). This distribution shows that the majority of respondents have adequate experience in the field of construction, especially land improvement work, so that they are able to provide an accurate assessment of the performance of the CDM project.

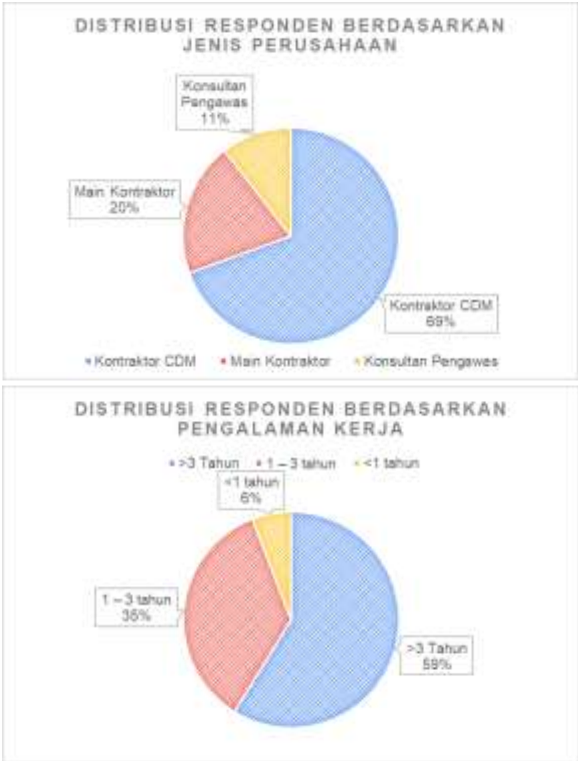

Figure 1. Distribution of respondents by company type and work experience

Results of *Importance–Performance Analysis (IPA)* and *Customer Satisfaction Index (CSI)*

The performance analysis and level of importance in this study was carried out using *the Importance–Performance Analysis (IPA)* and *Customer Satisfaction Index (CSI)* approaches to evaluate 15 indicators representing technical (T), managerial (M), external (E), and implementation quality (Q) factors. The results of this calculation are presented quantitatively to identify gaps and determine improvement priorities based on respondents' perceptions.

Table 2. Calculation results of MIS, MSS, WF, WS, and GAP.

Indicator	MIS	MSS	WF	WS	Performance	Hope	GAP
T1	4,74	4,55	7,13	32,45	4,55	4,74	-0,19
T2	4,58	4,51	6,88	31,00	4,51	4,58	-0,07
T3	4,62	4,48	6,95	31,15	4,48	4,62	-0,14
T4	4,62	4,48	6,95	31,15	4,48	4,62	-0,14
M1	4,62	4,21	6,95	29,27	4,21	4,62	-0,41
M2	4,66	4,22	7,00	29,58	4,22	4,66	-0,44
M3	4,33	4,35	6,51	28,33	4,35	4,33	0,02

M4	4,44	4,45	6,67	29,65	4,45	4,44	0,01
E1	4,21	4,32	6,33	27,33	4,32	4,21	0,11
E2	4,20	4,22	6,31	26,66	4,22	4,20	0,02
E3	3,79	4,02	5,69	22,91	4,02	3,79	0,24
E4	4,13	4,32	6,21	26,80	4,32	4,13	0,19
Q1	4,53	4,46	6,81	30,36	4,46	4,53	-0,07
Q2	4,45	4,45	6,68	29,73	4,45	4,45	0,00
Q3	4,61	4,54	6,93	31,48	4,54	4,61	-0,07
Total	**66,53**	**65,59**		**437,83**	**4,37**	**4,44**	**-0,06**

Calculation Description

The calculation begins by determining the Mean *Importance Score* (MIS) and the Mean *Satisfaction Score* (MSS) using Equations (1) and (2). To illustrate:

$$MIS_{T1} = \frac{\sum IP}{n} = 4{,}74$$

$$MSS_{T1} = \frac{\sum PE}{n} = 4{,}55$$

Next, the gap is calculated using Equation (3):

$$GAP_{T1} = MSS - MIS = 4{,}55 - 4{,}74 = -0{,}19$$

The calculation *of Weight Factor* (WF) is carried out by dividing the MIS value of each indicator by the total MIS using equation (3):

$$WF_{T1} = \frac{4{,}74}{66{,}53} = 0{,}0713 \qquad \approx 7{,}13\%$$

Then *the Weight Score* (WS) is calculated using equation (5):

$$WS_{T1} = WF \times MSS = 0{,}0713 \times 4{,}55 = 0{,}3245 \qquad \approx 32{,}45$$

This step is carried out for all indicators until a total Weight Score (WT) of 437.83 is obtained (based on equation 6).

GAP Analysis and Science Interpretation

Based on the calculation results presented in Table 4, the average performance score *(Mean Satisfaction Score / MSS)* of 4.37 is still below the average importance *level (Mean Importance Score / MIS)* of 4.44, with an average GAP value of -0.06. This condition shows that in general, the performance of the implementation of the CDM project has not fully met the expectations of the respondents, although the difference is relatively small. Conceptually, a negative GAP value indicates a need to improve performance in attributes that are considered important by respondents. A more detailed analysis showed that the indicators with the largest negative GAP came from managerial factors, namely M2 (implementation of technical training) of -0.44 and M1 (competence of operators and technicians) of -0.41. This indicates that the human resource aspect, especially related to competency improvement and technical training, is the factor that requires the most attention in efforts to improve project performance. In addition, indicators on technical factors (T1–T4) also show a negative GAP, which indicates that equipment performance, instrument accuracy, and operational parameter control are still not optimal compared to their importance. On the other hand, some indicators on external factors, such as E3 and E4, show a positive GAP, which indicates that performance in those aspects has met or even exceeded respondents' expectations.

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To obtain a more comprehensive understanding, the results of the MIS and MSS calculations are mapped into a science cartesian diagram. This mapping uses the mean value of MIS (4.44) as the vertical axis (importance) and the mean value of MSS (4.37) as the horizontal axis (performance), so that all indicators can be classified into four priority quadrants. Quadrant I reflects attributes of high importance but low performance, which are top priorities for improvement; Quadrant II indicates attributes of importance and high performance, which need to be maintained; Quadrant III describes attributes with low importance and performance, which are low priorities; while Quadrant IV indicates attributes with high performance but relatively low importance, which is classified as excessive. The visualization of the distribution of the position of each indicator in the science cartesian diagram provides a clear picture of the priority of improving the performance of the CDM project, so that it can be the basis for the formulation of a focused and targeted improvement strategy. The position of each indicator on the science cartesian diagram is illustrated as follows (Figure 2.):

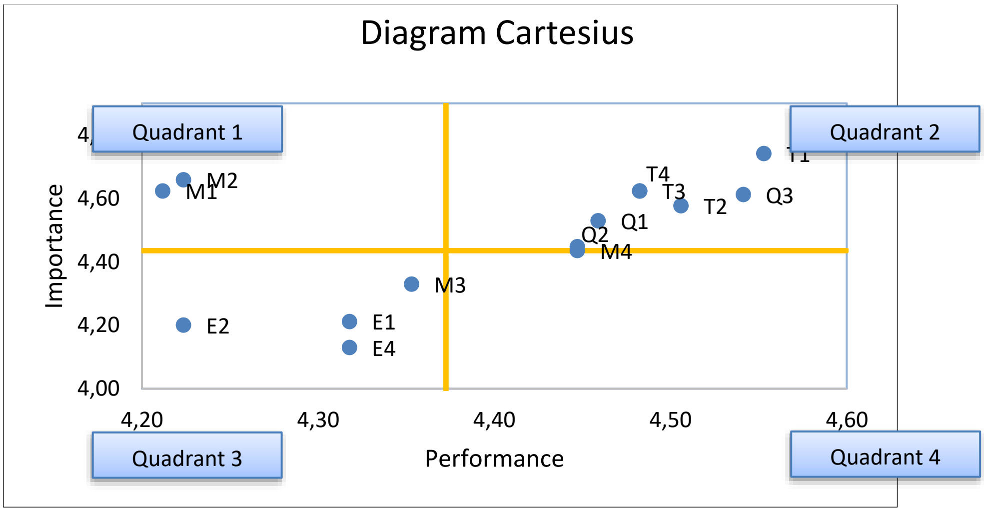

Figure 2. Cartesian Diagram CDM Project Performance Indicators

Perhitungan *Customer Satisfaction Index (CSI)*

Based on Equation (7), the CSI value is calculated as follows:

$$CSI = \frac{WT}{Skala\ max} \times 100\% = \frac{437{,}83}{5 \times 100} \times 100\% = 87{,}57\%$$

The CSI value of 87.57% indicates that the satisfaction level of respondents is in the very satisfied category.

The results of this study show that although the overall level of satisfaction is relatively high, there is still a mismatch between expectations and performance in several critical aspects, especially in technical and managerial factors. These findings are in line with previous research that confirms that the success of construction projects is greatly influenced by the quality of human resource management as well as the effectiveness of technical control in the field. The dominance of negative gaps in managerial factors shows that improving workforce competencies, technical training, and field supervision are aspects that require major attention (Munianday et al., 2024; Bassioni, H. A., Price, A. D. F., Hassan, 2004). In addition, technical factors such as equipment performance and control of operational parameters also need to be optimized to improve the consistency of CDM work quality. On the other hand, external factors that show a positive gap indicate that the environmental conditions of the project have been well managed. Overall, the combination of the IPA and CSI methods proved effective in providing a comprehensive picture of project performance and improvement priorities. The IPA method allows the identification of critical attributes that need improvement, while the CSI provides an indication of the level of stakeholder satisfaction in the aggregate. Thus, the results of this research can be used as a basis for formulating a strategy to improve the performance of CDM projects that are more directed, systematic, and data-based.

CONCLUSION

The results of the analysis using the Importance–Performance Analysis (IPA) and Customer Satisfaction Index (CSI) methods showed that the performance of the Cement Deep Mixing (CDM) project at the ABC Port Project was categorized as good, with a high level of stakeholder satisfaction (CSI = 87.57%). However, the mean performance score (MSS = 4.37) remained slightly lower than the mean importance score (MIS = 4.44), resulting in a GAP value of -0.06, which indicated a discrepancy between stakeholder expectations and actual project performance. Managerial factor indicators, particularly technical training (M2) and workforce competency (M1), were identified as the highest priorities for improvement due to their largest negative GAP values. Technical factors also required further improvement, while external factors and implementation quality had relatively met stakeholder expectations and should be maintained. These findings confirmed that CDM project success was strongly influenced by human resource management quality, technical control effectiveness, and effective managerial coordination. The integration of IPA and CSI proved effective in providing a comprehensive evaluation of project performance and identifying improvement priorities.

Based on these findings, recommended improvement strategies include strengthening continuous technical training programs for operators and technicians, improving field supervision systems to ensure consistent implementation, and optimizing equipment performance through regular instrument calibration to enhance the accuracy and stability of the CDM process. Future studies are recommended to expand the analysis variables by incorporating additional factors, such as technological innovation, digitalization of project monitoring, and the influence of communication and coordination among project teams. The application of mixed-method approaches combining quantitative and qualitative analyses may also provide deeper insights into the factors influencing CDM performance and the effectiveness of improvement strategies, resulting in more comprehensive and applicable recommendations for enhancing sustainable construction project implementation.

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