COST EFFICIENCY ANALYSIS AND RISK MANAGEMENT OF THE SELF-MANAGED BATCHING PLANT METHOD MUSI TOLL KAYU AGUNG-PALEMBANG-BETUNG BRIDGE PROJECT

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Abstract. This study was conducted on the Musi Bridge Project of the Kayu Agung–Palembang–Betung Toll Road to determine the most efficient and controlled concrete supply method, considering the high proportion of concrete costs, potential distribution delays, and structural quality requirements in strategic infrastructure projects. The research aimed to compare the self-managed batching plant method and the ready-mix method in terms of cost efficiency, technical and non-technical risks, and concrete quality performance. A quantitative descriptive-comparative approach was applied using primary data from project documents, including cost summaries, material quantities and prices, job mix formulas, risk matrices, and quality testing reports, supported by field observations. The analysis involved cost calculations, risk scoring and categorization, and evaluation of compliance with technical specifications. The results show that the self-managed method achieved cost savings of 15.7% and lower risk levels compared to the ready-mix method, while both methods met structural quality requirements. Therefore, the study concludes that self-managed batching plants are more effective for large-scale projects when supported by adequate technical and operational capacity.

Keywords: concrete supply method, self managed batching plant, ready-mix concrete, cost and risk analysis

1. Introduction

Toll road development in Indonesia has become a national priority to enhance connectivity, improve the mobility of goods and services, and accelerate regional economic growth. Data from the Ministry of Public Works and Housing (PUPR) indicate that the operational toll road network reached 2,816 km by the end of 2023 and was targeted to expand to 3,196 km in 2024, reflecting rapid progress in transportation infrastructure development [1]. One of the strategic projects supporting this expansion is the Trans-Sumatra Toll Road, particularly the Kayu Agung–Palembang–Betung section, which includes the construction of the Musi Bridge as a major crossing over the Musi River. The bridge employs a segmental prestressed concrete box girder system supported by bored pile foundations and involves multiple stakeholders, requiring efficient and reliable construction material management.

Figure 1. Musi Bridge documentation photo
(Source: Documentation, 2025)

During construction, the distance between vendor batching plants and the casting location is approximately 45 km with travel times of 90–120 minutes, creating potential delays in ready-mix delivery. Meanwhile, the project requires concrete strengths of fc' 42 MPa for box girders and fc' 35 MPa for piers and abutments, demanding consistent quality control. The total concrete demand of the Musi Bridge Project is summarized in Table 1.

Table 1. Concrete demand in the Musi Bridge Project of the Kayu Agung–Palembang–Betung Toll Road

Structural Type	Concrete Grade	Volume (m³)
Box Girder	fc' 42 MPa	15.476,89
Pier & Abutment	fc' 35 MPa	32.563,75
Total		47.040,64

Previous studies reported that self-managed concrete production can reduce costs by up to 12% in large bridge projects [2], and risk matrix approaches are essential for identifying technical and non-technical uncertainties [3]. Internal recommendations also suggest adopting self-managed batching plants for projects exceeding 30,000 m³ due to better economic performance [4]. However, integrated evaluations covering cost, quality, time, and risk remain limited.

Considering compliance with national construction standards such as SNI 03-2847-2019, this study aims to analyze cost efficiency, concrete quality, and risk levels of self-managed batching plant operations compared to ready-mix procurement in the Musi Bridge Project. The findings are expected to contribute to construction project management literature and provide practical recommendations for stakeholders in selecting efficient and reliable concrete supply methods for large-scale infrastructure projects.

This study aims to identify the cost structure of concrete supply in the Musi Bridge Project of the Kayu Agung–Palembang–Betung Toll Road by comparing self-managed batching plant and ready-mix methods, as well as to analyze their cost efficiency and contribution to budget control. Furthermore, the study evaluates technical and non-technical risks using a risk matrix to determine dominant risk categories, and assesses concrete quality based on material parameters and compliance with SNI 03-2847-2019 standards.

2. Material and Methods

2.1. Research Design

This study employed a quantitative approach with a descriptive–comparative design to compare two concrete supply methods, namely self-managed batching plant and ready-mix delivery, in the Musi Bridge Project of the Kayu Agung–Palembang–Betung Toll Road. Numerical data including project cost, concrete volume, risk parameters, and concrete quality test results were analyzed to evaluate cost efficiency, technical and non-technical risks, and material performance. This design was selected to provide objective and measurable findings that contribute both academically and practically to construction project management.

2.2. Study Location

The research was conducted on the Musi Bridge construction project in South Sumatra, Indonesia, a National Strategic Project executed by PT Waskita Karya (Persero) Tbk. The project applies both concrete supply methods simultaneously, enabling direct comparative analysis. Its large concrete demand (±47,040.64 m³), complex logistics, and verified technical documentation make it suitable as a case study.

2.3. Research Variables

The independent variable was the concrete supply method (self-managed and ready mix), while dependent variables included project cost, project risk, and concrete quality. Cost efficiency was measured through preparation, material, and operational expenses. Risk was assessed using a 15-parameter risk matrix scored on a 1–5 scale. Concrete quality was evaluated based on compressive strength, aggregate gradation, mud content, and water pH according to SNI 03-2847-2019 standards.

Table 2. Operational definition of research variables

No	Variable	Conceptual Definition	Operational Definition	Indicators	Instrument / Measurement Tool	Measurement Scale
1	Concrete Supply Method (X)	According to Pratama et al. (2021), the concrete supply method refers to the approach used to fulfill concrete demand in a construction project, either through self-managed production or ready-mix supply.	Comparison between two concrete supply methods applied in the Musi Bridge Project.	(1) Self-managed (own batching plant) (2) Ready-mix (vendor-supplied)	Project documents, concrete production reports	Nominal
2	Project Cost (Y1)	Project cost refers to all expenditures required to complete construction works (Project Management Institute, 2021;	Total cost calculated based on preparation, material, and operational components.	(1) Preparation cost (2) Material cost (3) Operational cost	Project cost summary, financial reports	Ratio (IDR)

		PMBOK, 2021).				
3	Project Risk (Y2)	Risk is the probability of an event that may negatively affect project objectives (PMBOK, 2021; Siregar, 2020).	Scoring of technical and non-technical risks using a 15-parameter risk matrix.	(1) Technical risks (material quality, production capacity, distribution) (2) Non-technical risks (regulation, weather, market)	Project risk matrix, risk management documents	Ordinal (Scale 1–5)
4	Concrete Quality (Y3)	Concrete quality refers to the degree of conformity of concrete properties with the technical requirements of SNI 03-2847-2019.	Evaluation of concrete quality test results based on applicable standards.	(1) Compressive strength (fc') (2) Aggregate gradation (3) Mud content (4) Water pH (5) Slump test	Concrete laboratory test results	Ratio (MPa, %)

2.4. Data Sources and Sampling

The population consisted of all concrete supply activities within the project between 2022–2025. Samples were purposively selected in the form of numerical datasets representing each method, including cost summaries, risk matrices, and laboratory test results. Data were secondary and obtained from official contractor, owner, and supervision documents. Validity was ensured through document verification, and reliability through cross-checking across multiple sources.

2.5. Data Collection

Data were collected through documentation study, literature review, and limited technical observation of laboratory results. The datasets included cost reports, material quantities, risk matrices, quality test results, and progress reports. Instruments consisted of cost recapitulation sheets, risk matrices, and laboratory test records.

2.6. Equipment Depreciation Analysis

For the self-managed method, equipment costs were calculated using proportional depreciation since project machinery was internally owned. The straight-line method was applied based on acquisition value, residual value, economic life, project duration, and utilization factor. This approach reflects realistic cost allocation without including new capital expenditure.

2.7. Data Analysis Techniques

Descriptive statistics were used to present cost, risk, and quality data in tables and graphs. Comparative cost analysis determined percentage savings between methods. Risk evaluation categorized scores into recommended, caution, or not recommended levels. Concrete quality was assessed by comparing laboratory results with national standards. These analyses provided integrated evaluation of efficiency, safety, and performance.

2.8. *Validity and Reliability Testing*

Instrument validity was tested using Pearson correlation for risk parameters and standard compliance for quality measurements. Reliability was evaluated using Cronbach's Alpha ($\alpha \geq 0.70$) and test–retest consistency checks. Triangulation and documentation verification minimized bias and ensured data credibility.

2.9. *Research Procedure*

The research followed sequential stages including literature review, data acquisition, classification, verification, quantitative analysis of cost, risk, and quality, and interpretation of results to determine the most efficient concrete supply method.

3. Results and Discussion

3.1. *Overview of the Study*

This section presents the results and discussion of the comparison between self-managed batching plant production and ready-mix supply in the Musi Bridge Project. The analysis examines cost structure, cost efficiency, technical and non-technical risks, and concrete quality based on compliance with technical standards. By integrating these aspects, the study provides a basis for identifying the most suitable concrete supply method and offers practical insights for decision-making in large-scale infrastructure construction.

3.2. *Cost Structure Identification of Concrete Supply*

This section addresses the first research objective, which is to identify the cost structure of concrete supply in the Musi Bridge Project on the Kayu Agung–Palembang–Betung Toll Road by comparing self-managed batching plant and ready-mix methods. The analysis aims to provide a clearer understanding of the cost components involved and their implications for total expenditure, enabling the identification of major cost drivers and factors contributing to cost differences between the two approaches. In this study, cost structure represents the composition of all expenditure elements forming the total concrete supply cost, and the analysis examines not only total values but also how these costs are distributed across relevant categories. Based on quantitative secondary data, the cost structure is classified into three main components: preparation costs, material costs, and operational costs.

3.3. *Cost Structure Identification of Concrete Supply*

a. Preparation costs

Initial costs consist of batching plant installation, equipment calibration to ensure measurement accuracy, and early operational expenses including fuel, electricity, and other supporting requirements necessary to commence operations.

Table 3. Preparation Costs

PREPARATION ITEM	Total Cost (IDR)
Mobilization	40.000.000,00
Crane Rental for Setup	19.000.000,00
Batching Plant Setup	15.000.000,00
Miscellaneous Costs	20.000.000,00
Total Preparation Cost	94.000.000,00

b. Material costs

This cost category covers all materials required for concrete production, including coarse and fine aggregates, cement, water, and chemical admixtures. Material costs are influenced by market price fluctuations; therefore, accurate analysis is essential to ensure that the project budget adequately accommodates all material requirements.

Table 4. Material Costs

Job Mix Formula (JMF) for Concrete Strength fc' 42 MPa

No	Material	Unit	Mix Proportion (per m³)	Concrete Volume fc' 42 MPa (m³)	Total Requirement	Procurement Unit	Procurement Quantity	Unit Price (IDR)	Total Procurement Cost (IDR)
1	Cement	kg	560	15,476.89	8,667,058.79	kg	8,667,058.79	990	8,580,388,204.18
2	Crushed	kg	1,081.00		16,730,518.85	m³	9,294.73	250,000.00	2,323,683,173.18
3	Sand	kg	689		10,663,577.69	m³	7,616.84	150,000.00	1,142,526,181.33
4	Water	liter	110		1,702,457.98	liter	1,702,457.98	100	170,245,797.70
5	Admixtur	liter	7.03		108,802.54	liter	108,802.54	79,500.00	8,649,802,058.97
6	Silica	kg	20		309,537.81	kg	309,537.81	16,500.00	5,107,373,931.06
TOTAL PROCUREMENT COST									25,974,019,346.42

Job Mix Formula (JMF) for Concrete Strength fc' 35 MPa

No	Material	Unit	Mix Proportion (per m³)	Concrete Volume fc' 35 MPa (m³)	Total Requirement	Procurement Unit	Procurement Quantity	Unit Price (IDR)	Total Procurement Cost (IDR)
1	Cement	kg	530	32,563.75	17,258,786.27	kg	17,258,786	990	17,086,198,403.00
2	Crushed	kg	1,140.00		37,122,672.35	m³	20,623	250,000.00	5,155,926,714.00
3	Sand	kg	580		18,886,973.65	m³	13,490	150,000.00	2,023,604,319.00
4	Water	liter	170		5,535,837.10	liter	5,535,837	100	553,583,710.00
5	Admixtur	kg	1.06		34,517.57	kg	34,517	18,370.00	634,087,807.00
TOTAL PROCUREMENT COST									25,453,400,955.00

c. Operational costs

Table 5. Operational Costs

Description	Volume	Unit	Unit Price (IDR)	Total Cost (IDR)
Diesel Fuel	7	liters/mon	10,182.00	71,274,000.00
Excavator	1	unit	50,000,000.00	50,000,000.00
Truck Mixer (TM)	3	units	2,800,000.00	8,400,000.00
Additional TM Driver	0	person	5,500,000.00	–
BP Depreciation	1	month	100,000,000.00	100,000,000.00
Docket	0	docket	–	–
Labor	1	month	19,700,000.00	19,700,000.00
Sludge Disposal	1	month	–	–
Maintenance	1	month	5,000,000.00	5,000,000.00
Monthly Operational Cost				254,374,000.00
Project Duration Based on Schedule (Months)				13
Total Operational Cost (Completion)				3,306,862,000.00

The detailed cost analysis of the self-managed batching plant shows that the total concrete production cost amounted to IDR 54,828,282,301, consisting of preparation, material, and operational costs. This classification is intended to clearly identify the main cost drivers and provide a transparent evaluation of the self-managed method, as all expenditures are directly linked to project-specific concrete production activities. The preparation cost reached IDR 94,000,000 (approximately 0.17% of the total cost), reflecting initial site preparation, infrastructure adjustment, equipment calibration, and early operational management, while material cost dominated the total expenditure at IDR 51,427,420,301 (approximately 93.80%), covering cement, aggregates, water, and chemical admixtures in accordance with the Job Mix Formula (JMF) to meet concrete strength requirements of fc' 35 MPa and fc' 42 MPa. Operational cost accounted for IDR 3,306,862,000 (approximately 6.03%), including labor, energy consumption, equipment maintenance, electricity, and internal production support, indicating that although continuous operational expenses are required, the self-managed approach maintains efficient operational control with material cost remaining the primary determinant of total expenditure.

3.4. Components of Ready-Mix Concrete Cost

Table 6. Total Ready-Mix Concrete Cost

No	Work	Concrete	Unit	Volume	Total	Unit Price	Total Cost (IDR)
1	Concrete	fc' 42	m³	11,396.77	15,476.89	1,785,000.00	27,626,249,899.00
2	Concrete	fc' 42	m³	4,080.12			
3	Concrete	fc' 35	m³	2,000.58	32,563.75	1,150,000.00	37,448,309,822.00
4	Concrete	fc' 35	m³	21,603.17			
5	Bored	–	m³	8,960.00			
TOTAL READY-MIX COST							65,074,559,721.00

Table 6 clearly illustrates the cost structure of the ready-mix approach, showing that material and vendor charges, represented by the unit price of concrete per cubic meter, account for the largest share of total cost at 74.1%. Transportation costs, including delivery fleet operation, toll fees, and fuel consumption, contribute 15.8%, while waiting costs caused by delays at the project site account for 10.1%. Understanding the proportional distribution of these cost components enables project managers to implement targeted budget optimization strategies and minimize the risk of unforeseen cost overruns.

3.5. The Comparison of Cost Structure

Table 6. Total Ready-Mix Concrete Cost

No	Cost Component	Ready-Mix (IDR)	Self-Managed (IDR)	Cost Savings (IDR)
1	Preparation	–	94,000,000.00	94,000,000.00
2	Material	65,074,559,721.00	51,427,420,301.00	13,647,139,420.00
3	Operational	–	3,306,862,000.00	3,306,862,000.00
	Total Cost	**65,074,559,721.00**	**54,828,282,301.00**	**10,246,277,420.00**

Overall, this cost structure analysis provides valuable insights into the efficiency and effectiveness of each method and can serve as a key consideration for future project planning, particularly in terms of budget management and cost control.

3.6. Cost Efficiency Calculation

Table 7. Comparison of Cost Index and Efficiency Between Ready-Mix and Self-Managed Methods

Method	Total Cost (%)	Cost Index (Ready-Mix = 100)	Efficiency(%)
Ready Mix	100%	100	-
Self Managed	84,3%	84,3	15,7

Based on the results presented in the table, the total cost of the ready-mix method is set at 100% as the reference value for the cost index calculation. In comparison, the self-managed method records a lower total cost of 84.3%, indicating a cost saving of 15.7%. This result demonstrates that the self-managed approach provides a clear cost advantage over the ready-mix method.

3.7. Implications for Project Budget

A cost saving of 15.7% has a significant positive impact on overall project budget control, allowing contractors to reallocate funds to other needs and enhance project quality and competitiveness. For example, the savings can be used for improved equipment maintenance, extending service life and reducing future costs. Based on the cost calculation, the total cost of the ready-mix method is IDR 65,074,559,721.96, while the self-managed method amounts to IDR 54,828,282,301.66.

3.8. Cost Efficiency Chart

The analysis compares the total costs of the ready-mix and self-managed methods, showing higher expenses for ready-mix due to procurement and transportation costs, while the self-managed method provides greater budget flexibility. The comparison is illustrated in Figure 2.

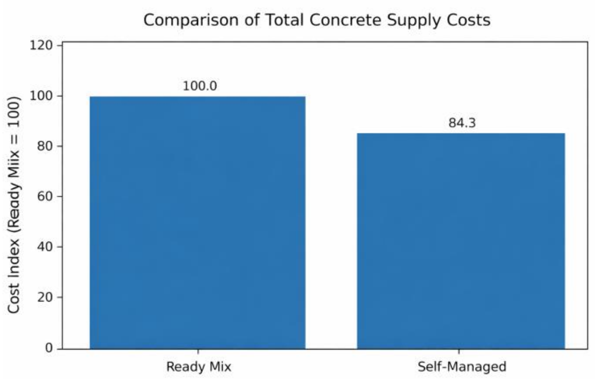

Figure 2. Comparison of Total Concrete Supply Costs Between Ready-Mix and Self-Managed Methods

3.9. Evaluation of Technical and Non-Technical Risk Levels

This study analyzes and compares risk levels and operational efficiency between the ready-mix and self-managed batching plant methods using a 15-parameter approach covering cost, quality control, time, and operational constraints. Each parameter is rated on an ordinal scale of 1–5, where higher values indicate greater risk and implementation difficulty. The assessment results for both concrete supply methods are presented in Table 8.

Table 9. Classification of Technical and Non-Technical Risk Parameters

No	Category	Parameter Description	Ready-Mix	Self-Managed
1	Cost	Cost incurred	4	3
2	Quality Control	Coarse aggregate gradation	3	2
3		Fine aggregate mud content	3	2
4		Water pH	3	2
5	Time	Truck mixer trip duration	4	1
6		Production continuity	3	3
7	Constraints	Power supply disruption	3	3
8		Component failure	3	3
9		Insufficient raw material	4	1
10		Inadequate slump value	4	2
11		Concrete setting before placement	3	1
12		Blocked concrete pumping pipe	2	2
13		Improper concreting stoppage	4	1
14		Insufficient casting volume	4	1
15		Social disturbance	4	1
Total Score			51	28

This study analyzes and compares risk levels and operational efficiency between the ready-mix and self-managed batching plant methods using a 15-parameter approach covering cost, quality control, time, and operational constraints. Each parameter is rated on an ordinal scale of 1–5, where higher values indicate greater risk and implementation difficulty. The assessment results for both concrete supply

methods are presented in Table 10.

Table 10. Risk Score Classification and Recommendation

Score Range	Recommendation Level	Description
1 – 15	Highly Recommended	
16 – 30	Recommended	Self-Managed
31 – 45	Considerable	
46 – 60	Not Recommended	Ready-Mix
61 – 75	Highly Not Recommended	

Table 10 presents the classification of concrete supply method recommendations based on total risk score ranges from 1 to 75. Scores of 1–15 indicate a highly recommended method with very low risk, while scores of 16–30 are classified as recommended, represented by the self-managed method in this study. Scores of 31–45 are considered acceptable with moderate risk, requiring closer control, whereas scores of 46–60 are not recommended due to high risk, as reflected by the ready-mix method. Scores of 61–75 indicate a very high-risk level and are therefore highly not recommended.

3.10. Concrete Quality Analysis

a. Testing Parameters

Concrete quality testing was conducted in accordance with SNI 03–2847–2019 to ensure compliance with strength and durability requirements. The evaluated parameters include compressive strength (fc'), coarse and fine aggregate gradation, fine aggregate mud content (maximum 2%), and mixing water pH (6.5–8.5).

b. Test Results

The concrete quality test results for both ready-mix and self-managed concrete are presented in Table 10, providing a direct comparison based on the selected parameters.

c. Evaluation and Interpretation

The results indicate that self-managed concrete exhibits more stable and consistent quality, meeting or exceeding the specified standards. In contrast, ready-mix concrete shows greater variability, particularly in slump and water content, mainly due to longer transportation distance and delivery time. Internal control of the batching plant in the self-managed method allows better regulation of materials and mixing processes.

d. Concrete Quality Comparison Chart

Figure 4.4 presents a graphical comparison of concrete quality between the two methods, highlighting differences in consistency and performance to facilitate clearer interpretation.

3.11. Interpretation of Findings

a. Cost Efficiency Interpretation

The cost analysis indicates that the self-managed method achieves lower total costs than the ready-mix method, demonstrating higher cost efficiency for large-volume and long-duration concrete works. This efficiency is mainly driven by better control over operational costs and greater flexibility in scheduling compared to the ready-mix method, which involves transportation costs and vendor dependency.

b. Project Risk Interpretation

The risk analysis based on 15 parameters shows that the ready-mix method carries higher risk, primarily due to reliance on external suppliers, delivery delays, and limited quality control during distribution. In contrast, the self-managed method offers lower and more controllable risks through direct on-site production and supervision.

c. Concrete Quality Interpretation

Both methods meet the required concrete strength; however, the self-managed method demonstrates more consistent concrete quality, indicating better mixing control and quality management. This consistency supports the observed cost efficiency and lower risk of the self-managed approach.

3.12. Discussion of Findings

This discussion confirms that the self-managed method provides superior performance in terms of cost efficiency, risk control, and concrete quality. A cost saving of 15.7% demonstrates its effectiveness for large-scale and long-duration bridge projects, supported by better operational flexibility and internal resource control. Risk assessment based on the 15-parameter matrix shows a lower cumulative risk score for the self-managed method compared to the ready-mix method, placing it in the recommended category, as shown in the tables above. Both methods meet the required concrete quality standards; however, the self-managed approach exhibits more consistent results, indicating that it represents not only a technical alternative but also a comprehensive project management strategy, while the ready-mix method remains appropriate under specific project constraints.

3.13. Visualization of Research Findings

Figure 3. Photograph of the Self-Managed Batching Plant at the Musi V Bridge Project

Figure 4. Photograph of Traffic Congestion at Musi II Bridge Affecting Ready-Mix Distribution

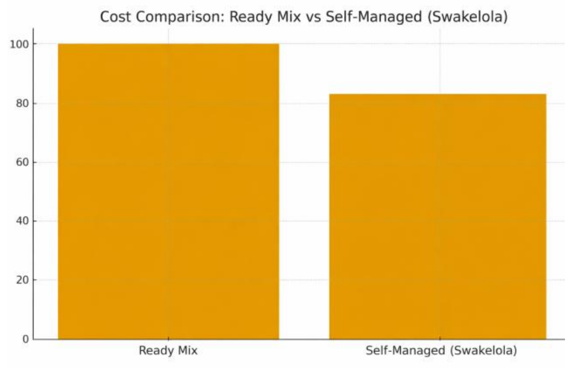

Figure 5. Comparison Graph of Total Cost: Ready Mix vs. Self-Managed

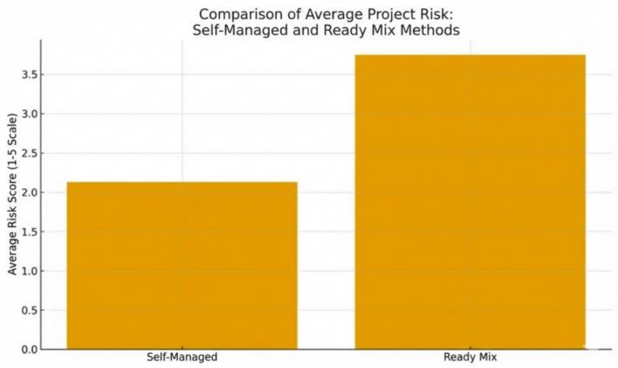

Figure 6. Comparison Graph of Risk Scores: Ready Mix vs. Self-Managed

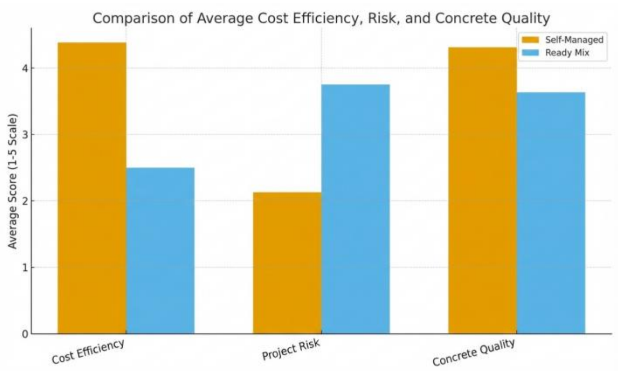

Figure 7. Average Cost Efficiency Chart Based on Respondent Assessmen

4. Conclusions

4.1. Author Contributions

Based on the analysis of the Musi Kayu Agung – Palembang – Betung Toll Bridge Project, the main conclusions of this study are as follows:

a. Cost Efficiency: The Self-Managed (Swakelola) method proved to be substantially more cost-effective, with a total cost of IDR 54.8 billion, representing a saving of IDR 10.2 billion (15.7%) compared to the Ready-Mix method (IDR 65 billion). This efficiency is attributed to more stringent operational control and the elimination of third-party distribution costs.

b. Risk Management: The Self-Managed method exhibits a significantly lower risk profile with a score of 28 (Category: Recommended), whereas the Ready-Mix method received a score of 51 (Category: Not Recommended). The primary risks associated with Ready-Mix are rooted in distribution uncertainties and uncontrollable traffic conditions.

c. Concrete Quality: Both methods comply with the SNI 03-2847-2019 standards. However, the Self-Managed method demonstrates greater quality consistency due to more intensive internal supervision of raw materials and the production process.

d. Strategic Recommendations: Utilizing a self-managed batching plant is highly effective for large-scale infrastructure projects, particularly when the contractor already owns the required equipment. If the project necessitates the procurement of new machinery, a comprehensive investment feasibility analysis is essential to ensure that expected efficiencies are maintained.

5. Declarations

5.1. Author Contributions

The following statements should be used:
Conceptualization, J.S., V.S.R. and A.K.; methodology, J.S. and V.S.R.; software, J.S.; validation, A.K., P.A.P. and J.S.; formal analysis, J.S. and V.S.R.; investigation, J.S. and V.S.R.; resources, J.S. and V.S.R.; data curation, V.S.R.; writing—original draft preparation, J.S. and V.S.R.; writing—review and editing, A.K. and P.A.P.; visualization, J.S. and V.S.R.; supervision, A.K. and P.A.P.; project administration, J.S. and V.S.R. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are contained within the article. Additional raw data regarding the project costs and risk matrices were obtained from PT Waskita Karya (Persero) Tbk and are available from the corresponding author upon reasonable request and with the permission of the involved third party.

5.3. Funding

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5.5. Conflicts of Interest

The authors declare no conflict of interest.

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