



Development of A Parametric Cost Estimation Model for Landfill Construction Projects

Nurhayati Junaedi^{1*}, Ridho Bayuaji², Alfred Jonathan Susilo³

¹Civil Engineering Doctoral Program Universitas Tarumanagara, Jakarta Barat 11450, Indonesia

²Department of Civil Infrastructure Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111, Indonesia

³Civil Engineering Program, Faculty of Engineering, Universitas Tarumanagara, Jakarta Barat 11450, Indonesia

[*nurhayati.328182009@stu.untar.ac.id](mailto:nurhayati.328182009@stu.untar.ac.id)

Abstract. Indonesia's waste management system is still dominated by the collect–transport–dispose approach, making landfills crucial for environmental sustainability. Landfill construction is a complex process requiring accurate cost estimation to prevent overruns and delays. This study develops a landfill construction cost estimation model using the Cost Significant Model (CSM) approach. Data were obtained from landfill project budgets in Java, Indonesia (2013–2021) and analyzed using multiple linear regression in SPSS. Results show that landfill block, leachate treatment installation, and operational road are the most significant cost components, the estimation model is $Y = 3698103502.04 + 1.301X_3 + 0.371X_4 + 1.236X_5$. The model falls within the class 4 cost estimation accuracy range according to AACE International standards, making it suitable for feasibility study use. This study introduces a model, context-specific cost estimation model for landfill projects in Indonesia, supporting effective planning and sustainable infrastructure development.

Keywords: cost estimation, landfill construction, cost significant model

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1. Introduction

Rapid urban population growth increases the complexity of human activities and economic enterprises, resulting in higher volumes and more complex characteristics of municipal waste. Indonesia's waste management system is still dominated by the collect-transport-dispose paradigm, which relies heavily on direct transportation of waste to final disposal sites. Based on research, education, work and knowledge have a significant influence on the amount of waste generated [1]. As a result, landfills function primarily as waste storage sites rather than as final processing sites for residual waste and often exceed their designed capacity. Open dumping of waste without any treatment has the potential to pollute the

environment and have a negative impact on public health, where in one landfill it causes an increase in air pollution which is characterized by an increase in the concentration of NO₂, O₃, SO₂, dust and NH₃ [2]. The difficulty of managing landfill and the significant environmental impacts of landfill demand improved TPA management [3]. Selecting suitable landfill sites requires consideration not only of physical and environmental aspects but also of economic and social factors [4]. The intricate nature of waste management systems necessitates careful consideration of numerous options and evaluation criteria when selecting a suitable landfill site [5]. Law No. 18 of 2008 concerning Waste Management defines waste as the solid residue from daily human activities and/or natural processes. In principle, this Law also functions as a legal basis for the implementation of waste management, including as a guideline for central and regional governments in allocating budgets for waste management infrastructure, in this case the construction of landfills.

Effective construction management plays a crucial role in ensuring that landfill development projects are completed on time, within budget, and according to technical standards. The budget is crucial because it is closely tied to financing and has the potential to disrupt the work implementation process if the project's technical specifications are not met [6]. Regarding the project's financial budget, the lack of budget is 1 of the 10 main implementation obstacles that need to be mitigated [7]. The main factors causing cost overruns in building construction projects include poor cost estimation, poor material quality control, and failure to consider risk factors at the project site [8]. By comparing the budget plan and the Implementation Budget Plan, it can be seen what types of work experienced cost overruns, where in the types of work on school buildings and mess buildings, the work that experienced cost overruns were the lower structure work [9]. In many cases, lean construction is presented as a powerful tool to transform the construction industry towards a more efficient, sustainable, and value-focused model [10].

Cost estimation serves as a fundamental reference for project budgeting and control, defined by the National Estimating Society (USA) as "the art of estimating project costs based on available information". Before developing a cost estimate or Bill of Quantities, planning consultants typically conduct field surveys to assess site conditions and other important factors affecting costs. These initial considerations highlight the importance of reliable cost estimation in the early stages of project development, as it guides budget allocation and technical feasibility assessments [11]. The accuracy of cost estimation calculations depends heavily on the expertise of the consultant and the project owner, as the process requires assumptions, professional judgment, and knowledge [12]. However, these methods are time-consuming, highly dependent on professional experience, and limited by limited and sometimes unreliable price data. Consequently, there is an urgent need for cost estimation models that can provide rapid yet reliable predictions at the conceptual stage [13].

Existing research on landfill cost estimation remains limited, even though landfill facilities are essential infrastructure for effective waste management [14]. The complexity of early-stage landfill cost estimation lies in its conceptual nature. Conceptual estimates are produced before comprehensive design data becomes available, yet they play a critical role in evaluating feasibility, analyzing alternatives, and supporting decision-making [15]. Cost-determining criteria for landfills, such as facility size, operational duration, and biogas management, but the study was limited to variable identification without producing a cost estimation model [16]. Among the available methods, the Cost Significant Model (CSM) has been identified as a suitable approach for landfill cost estimation. CSM uses historical project data to identify the most significant cost drivers that affect total project costs and applies regression analysis to develop predictive models. The advantage of this approach is its ability to deliver rapid and reasonably accurate estimates, even in the absence of complete design details. This makes CSM particularly useful at the feasibility study and preliminary planning stages, where decision-makers require cost information under conditions of uncertainty. In project management literature, cost estimation is often classified based on the level of available information. Complementing this, international standards such as those from the Association for the Advancement of Cost Engineering (AACE) and the International Cost Engineering Council (ICEC) introduce five classes of cost estimates (Class 1 to Class 5), ranging from very rough conceptual estimates (Class 5) to highly accurate definitive estimates (Class 1). These classifications provide a structured framework for aligning estimation methods with project stages, improving consistency and transparency across projects [17].

Building on these frameworks, this study aims to develop a landfill construction cost estimation model based on the CSM approach, improving both accuracy and practicality in early project planning. This study incorporates international references to strengthen the theoretical foundation of cost estimation and project management, some of which are listed as follows: a) Cost estimation should be understood as a process that generally begins with the definition of a budget, which is based on the requirements and financial possibilities available by the owner [15]; b) One of the most important and impactful factors in the project management lifecycle is Cost. In addition to its proven vitality, it is not unusual to witness the failure to achieve project objectives within pre-set costs [17]; c) Proper selection of input variables is crucial for simulating a reasonably accurate model. Most developing countries have limited data records; therefore, selecting the most representative input variables to facilitate the modelling process in these countries is crucial [18]; d) Research on how to prevent cost overruns in construction projects, incorporating preventive, predictive, and corrective approaches to address cost drivers in construction projects. The cost performance of construction projects can also be examined from a value creation perspective [19]; e) Identifying the causes of uncertainty and designing strategies to manage risks are the objectives of project risk analysis at an early stage [20]; f) Inefficient management and incorrect analysis of two key project variables -cost and time- cannot be reliably measured, which can lead to project delays and incur additional costs [21].

Previous studies have primarily examined landfill planning and evaluation rather than construction cost modeling. Similarly, [22] applied a cost-benefit analysis (CBA) framework to evaluate landfill efficiency and propose system improvements, focusing more on operational aspects than capital expenditure. The Cost Significant Model (CSM) method for road improvement construction shows that the granular pavement and asphalt pavement work components have a significant effect on the total cost of road improvement construction [23]. In the reinforced concrete bridge construction analysis, the cost estimation using the CSM method is used to verify the estimated bids [24]. Collectively, previous studies have not developed or validated quantitative models specifically designed for landfill construction cost estimation, representing a clear research gap that this study aims to address. Therefore, this study introduces a new quantitative model to identify significant cost components that influence the total cost of landfill construction and to provide a rapid, practical, and accurate estimation tool.

Based on the description above, it is evident that research on landfill construction cost estimation remains limited. This research is expected to provide some novelty, aiming to achieve better results. Specifically, it seeks to determine the cost of work that significantly affects the total cost of landfill construction, as well as develop a landfill construction cost estimation model that can be used to quickly and easily determine the budget. Additionally, this study aims to improve the accuracy of the model and determine the stage at which the developed model can be applied, as referenced in the AACE classification table.

2. Methods

This study develops an enhanced cost estimation model for landfill construction using the Cost Significant Model (CSM). The model aims to generate faster and more accurate estimates to support early budgeting and decision-making. Current estimation practices are manual and time-consuming, relying on expert judgment. By utilizing normalized historical contract data, this research seeks to produce a predictive model with improved accuracy and efficiency. The model is designed for practical use by project owners, consultants, and contractors in conceptual and feasibility study stages. The hypothesis posits that integrating CSM enhances the precision and applicability of landfill construction cost estimation. The research method to be carried out is presented in the form of a flow diagram shown in Figure 1.

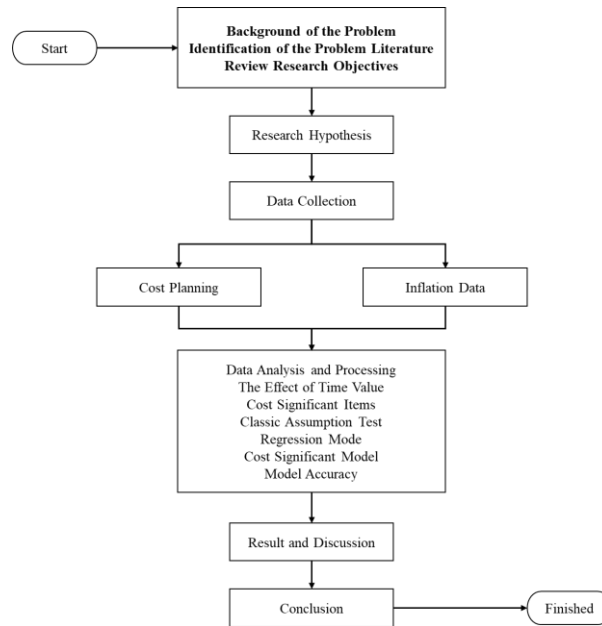


Figure 1. Research Flow Chart

The data used in this study are secondary in the form of historical data from similar jobs. The data is obtained from 12 detailed cost budgets of landfill construction work packages organized by the Work Unit of the Ministry of Public Works and Public Housing in several national regions from 2013 to 2021, with funding sources from the central government budget. The data is the cost without Value Added Tax (VAT). The research data is shown in Table 1.

Table 1. Research Data

No.	Work Name	Cost (IDR)	Year	Location
1	Landfill Construction 1 (LC1)	11,815,806,61.47	2013	Purworejo Regency
2	Landfill Construction 2 (LC2)	35,119,706,174.70	2015	Nganjuk Regency
3	Landfill Construction 3 (LC3)	13,617,490,070.65	2016	Pati Regency
4	Landfill Construction 4 (LC4)	14,471,200,826.53	2016	Wonogiri Regency 1
5	Landfill Construction 5 (LC5)	34,434,318,711.15	2018	Kediri District
6	Landfill Construction 6 (LC6)	20,767,012,417.44	2018	Rembang Regency
7	Landfill Construction 7 (LC7)	14,474,184,284.12	2018	Sukabumi City
8	Landfill Construction 8 (LC8)	18,181,848,871.95	2019	Lebak Regency
9	Landfill Construction 9 (LC9)	13,614,801,877.04	2020	Karimunjawa Regency
10	Landfill Construction 10 (LC10)	27,812,368,423.42	2020	Kendal Regency
11	Landfill Construction 11 (LC11)	41,907,500,000.00	2020	Banyumas Regency 1
12	Landfill Construction 12 (LC12)	20,000,000,000.00	2021	Wonogiri Regency 2

Source: E-monitoring Ministry of Public Works and Housing (2017-2021)

2.1 Research Variables

Research variables consist of dependent variables (Y) and independent variables (X). The dependent variable (Y) in this study is the total cost of work. In contrast, the independent variable (X) is the work cost component (X_1 to X_7) of each work package. The relationship between the research variables is shown in Figure 2. In general, in this study for planning the construction cost of landfill waste, there are 7 X variables (7 Sub-items of the Budget Plan for Landfill Construction Work) starting from variable X_1 is the preparation work, X_2 is the Occupational Safety and Health Management System cost, X_3 is the block landfill work, X_4 is the leachate treatment plant installation work, X_5 is the operational road work,

X₆ is the retaining wall work, X₇ is the monitoring well work which is total into variable Y, namely the total cost or real cost of implementing the construction of landfill waste.

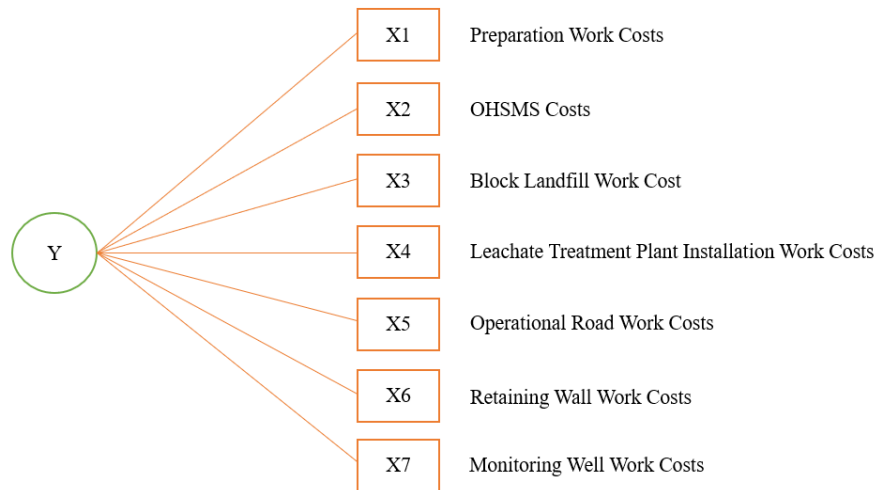


Figure 2. Relationship between independent variables and dependent variables

2.2 Data Analysis

Significant cost analysis was conducted through a structured modeling process to ensure transparency and reliability. Historical project costs were normalized to 2022 values using inflation-adjusted factors, followed by cost ratio analysis to identify key cost components influencing total construction costs. A multiple regression model was then developed to predict total project costs based on these components, and its accuracy was validated by comparing estimated and actual costs through error analysis. The statistical analysis was performed using SPSS version 26.0, which generated the regression coefficients and established the predictive equation. To ensure model validity, a classical assumption test was conducted, including normality tests (Kolmogorov–Smirnov and Shapiro–Wilk), multicollinearity test (Variance Inflation Factor), autocorrelation test (Durbin–Watson), and heteroscedasticity test (Breusch–Pagan).

3. Results and Discussion

3.1 Time Value

The implementation time of the work in the budget year for uniform data is then adjusted to account for the time value, namely by projecting the data to 2022.

Table 2. Effect of Time Value on Research Variables

Work Name	Preparation Work Cost (X ₁) in IDR	OHSMS Cost (X ₂) in IDR	Block landfill Work Cost (X ₃) in IDR	Leachate Treatment Plant Installation Work Cost (X ₄) in IDR	Operational Road Work Cost (X ₅) in IDR
LC 1	171,646,362.7	96,276,382.32	1,117,863,053	783,374,048.4	203,188,663.1
LC 2	305,342,568.6	108,310,923.1	1,665,476,767	571,415,689.4	307,947,100
LC 3	247,033,215.8	134,246,977.2	1,805,805,363	1,795,215,088	279,684,214.9
LC 4	31,889,394.02	57,416,551.29	2,503,127,062	3291,283,018	150,462,916.7
LC 5	163,191,013	181,048,195.8	2,334,736,745	763,108,763.1	309,346,592.8
LC 6	105,702,504.5	468,047,001.4	810,785,930	1,169,515,661	192,759,541.8
LC 7	160,622,075. 2	137,787,007	765,474,830.11	1,485,166,422	329,069,579.6
LC 8	194,555,365.6	161,149,536.8	1,841,447,227	1,090,378,338	307,029,611.9
LC 9	234,547,367.1	119,020,957.9	2,608,778,242	576,699,848.5	246,019,529.1
LC 10	303,583,293.8	160,603,646.6	2,563,664,741	775,852,256.4	345,989,492

Work Name	Preparation Work Cost (X ₁) in IDR	OHSMS Cost (X ₂) in IDR	Block landfill Work Cost (X ₃) in IDR	Leachate Treatment Plant Installation Work Cost (X ₄) in IDR	Operational Road Work Cost (X ₅) in IDR
LC 11	234,547,367.1	218,975,935.9	2,760,692,340	514,543,329	292,024,690.9
LC 12	128,696,832	126,661,286.8	503,892,682.1	165,642,593.2	170,830,102.4

Work Name	Retaining Wall Work Cost (X ₆) in IDR	Monitoring Well Work Cost (X ₇) in IDR	Total Cost (Y) in IDR
LC 1	101,753,913.1	82,567,974.62	21,210,317,167
LC 2	150,091,688.6	16,412,082.23	21,424,460,108
LC 3	68,954,809.52	52,268,843.01	21,301,339,317
LC 4	74,306,025.88	44,205,395.45	21,003,984,891
LC 5	37,511,381.38	22,936,156.78	28,705,409,853
LC 6	59,975,618.37	33,322,789.74	21,679,748,942
LC 7	42,348,295.47	11,277,642.12	21,106,528,738
LC 8	110,261,616.3	12,302,932.63	20,454,659,849
LC 9	61,418,501.89	117,224,433.6	18,438,758,132
LC 10	58,077,594.55	26,861,533.62	28,702,410,794
LC 11	125,114,033.5	9,057,357.16	22,545,238,339
LC 12	149,028,694.7	4,468,409.43	18,687,975,069

3.2 Determining Cost-Significant Items

According to [13], the Cost Significant Model relies more on >80% of the most significant prices in influencing the total project cost as a basis for forecasting (estimation), which serves to estimate the magnitude or amount of something in the future.

Table 3. Cost Significant Items

Description	Symbol	Percentage of X to Y (%)	Cumulative Percentage of X to Y (%)	Analysis Results
Block Landfill Work	X ₃	53.7	53.7	Cost Significant Item
Leachate Treatment Plant Installation Work	X ₄	23.51	77.21	Cost Significant Item
Operational Road Work	X ₅	11.56	88.77	Cost Significant Item
Retaining Wall Work	X ₆	8.54	-	-
OHSMS Cost	X ₂	1.8	-	-
Preparation Work	X ₁	0.79	-	-
Monitoring Well Work	X ₇	0.1	-	-
Total		100	-	-

Based on Table 3, the Cost Significant Items percentage data is obtained in order from the largest, namely from variable X₃ (Block Landfill Work Cost) of 53.70%; variable X₄ (Leachate Treatment Plant Installation Work Costs) of 23.51%; variable X₅ (Operational Road Work Costs) of 11.56%; variable X₆ (Retaining Wall Work Costs) of 8.54%; variable X₂ (OHSMS work) of 1.80%; variable X₁ (Preparation Work Costs) of 0.79%; and the smallest value is variable X₇ (Monitoring Well Work Costs) of 0.10%.

3.3 Multiple Regression Analysis

This study considers interrelated factors that support construction work patterns that can be analyzed using several methods for determining the classification of variable values for landfill construction. The regression analysis used in the data analysis and discussion is described in several stages as outlined

below. The classical assumption test consists of normality test, multicollinearity test, heteroscedasticity test, and autocorrelation test. The classical assumption test was performed using SPSS version 26.

3.4 Classical Assumption Test

The classical assumption test consists of normality test, multicollinearity test, heteroscedasticity test, and autocorrelation test. The classical assumption test was performed using SPSS version 26.

3.5 Normality Test

Normality testing in regression analysis aims to determine whether the residuals generated by the model follow a normal distribution, as this is an important assumption for obtaining valid regression results. One commonly applied method for this purpose is the Kolmogorov-Smirnov test, which evaluates the distribution of the residuals against a normal curve. The interpretation of the test is based on its significance value: if the probability is greater than 0.05, the residuals can be considered normally distributed, whereas a value below 0.05 indicates that the residuals deviate from normality. The outcomes of this assessment are summarized in Table 4.

Table 4. Results of Normality Test with Kolmogorov-Smirnov		
One-Sample Kolmogorov-Smirnov Normal Test Summary		
Total N		12
Most Extreme Differences	Absolute	.125
	Positive	.078
	Negative	-.125
Test Statistic		.125
Asymptotic Sig. (2-sided test)		.200 ^{a,b}
a. Lilliefors Corrected		
b. This is a lower bound of the true significance.		

Based on Table 4, it is known that the significance value of 0.200 is greater than 0.05. This indicates that the data is normally distributed.

3.6 Multicollinearity Test

The purpose of conducting a multicollinearity test in regression analysis is to identify whether the independent variables exhibit a strong or near-perfect correlation with one another, which could distort the reliability of the model. The evaluation is generally carried out by examining two statistical indicators, namely the tolerance value and the Variance Inflation Factor (VIF). When the tolerance value exceeds 0.10, the dataset is considered free from multicollinearity issues, whereas a tolerance below 0.10 indicates the presence of multicollinearity. Similarly, the VIF provides an additional benchmark, where values under 10 suggest no significant multicollinearity, while values greater than 10 reflect problematic relationships among the predictors.

Table 5. Multicollinearity Test Results				
No.	Variabel	Tolerance VIF		Conclusion
1	Block Landfill Work Cost (X ₃)	0.606	1.649	No multicollinearity
2	Leachate Treatment Plant Installation Work Costs (X ₄)	0.606	1.649	No multicollinearity
3	Operational Road (X ₅)	1.000	1.000	No multicollinearity

3.7 Heteroscedasticity Test

In this research, heteroscedasticity was examined using the Glejser test to determine whether the variance of residuals remains constant across observations. The decision criteria for this test rely on the significance level obtained: a probability value greater than 0.05 indicates that heteroscedasticity is not

present, while a value below 0.05 suggests that heteroscedasticity exists within the model. The detailed results of this analysis are presented in Table 6.

Table 6. Heteroscedasticity Test Results

Variable	B	Std. Error	Beta	t	Sig.
(Constant)	2340901031	890116263.0	—	2.630	0.030
Block Landfill Work Cost (X ₃)	-0.125	0.093	-0.520	-1.342	0.216
Leachate Treatment Plant Installation Work Costs (X ₄)	0.238	0.184	0.502	1.293	0.232
Operational Road (X ₅)	0.290	0.318	0.275	0.911	0.389

From the results of the heteroscedasticity test in Table 6, it can be seen that the Sig value is > 0.05, which means that there is no heteroscedasticity.

3.8 Multiple Linear Regression Models

This regression test aims to obtain a model of the research, which is described in tabular form as follows:

Table 7. Model Coefficient Table

		Coefficient ^a				
	Model	B	Std. Error	Beta	t	Sig.
1	(Constant)	3698103502.04	1855250317.4		1.993	0.081
	Block landfill	1.301	0.195	0.858	6.677	< .001
	Leachate Treatment Plant Installation	0.371	0.384	0.124	0.967	0.362
	Operational Road	1.236	0.662	0.187	1.865	0.099
a. Dependent Variable: Total Cost						

Based on Table 7, the model coefficient equation can be described as follows:

$$Y = 3698103502.04 + 1.301X_3 + 0.371X_4 + 1.236X_5 \quad (1)$$

Where:

Y: Total Cost of Work

X₃: Block Landfill Work Cost

X₄: Leachate Treatment Plant Installation Work Costs

X₅: Operational Road Work Costs

3.9 Calculating Cost Model Factor (CMF)

The CMF is derived by measuring the deviation between the project's actual cost and the cost predicted through the regression model. This ratio is then applied to refine the cost estimation using the Cost Significant Model. The calculation process begins with generating the estimated cost by incorporating the identified cost-significant items into the established regression equation. Once the predicted cost (Y') is obtained, the CMF is determined by dividing Y' by the actual project cost (Y). The outcomes of this calculation are summarized in Table 8.

Table 8. Tabulation of Calculation of Y Value and CMF

Work Name	X ₃	X ₄	X ₅
	Block Landfill Work Cost	Leachate Treatment Plant Installation Work Costs	Operational Road
LC 1	11,778,363,053.5	7,833,743,048.95	203,188,683.11
LC 2	25,860,991,766.6	12,248,925,776.85	3,097,740,570.22
LC 3	8,305,825,073.24	1,795,501,218.92	2,796,864,401.33

Work Name	X ₃	X ₄	X ₅
	Block Landfill Work Cost	Leachate Treatment Plant Installation Work Costs	Operational Road
LC 4	2,604,843,246.46	3,344,731,824.53	1,530,462,916.28
LC 5	16,699,938,105.1	1,384,705,857.09	1,894,370,400.13
LC 6	8,431,283,998.69	4,199,872,541.68	2,160,517,441.99
LC 7	7,624,994,338.31	7,873,672,439.50	730,708,584.64
LC 8	5,452,448,484.06	4,765,262,880.51	4,016,398,220.72
LC 9	8,941,529,064.20	576,699,848.91	220,917,237.70
LC 10	12,483,386,982.1	4,052,394,157.05	1,718,964,815.73
LC 11	2,371,651,600.28	966,338,645.15	4,903,061,962.92
LC 12	4,957,487,829.06	1,630,981,974.37	1,708,130,202.44

Work Name	Cost Estimate	Total Cost	CMF
	Total (Y' Model)	Current (Y)	
LC 1	22,179,213,718.29	21,109,017,166.86	1.05
LC 2	45,716,412,598.96	44,881,810,813.75	1.02
LC 3	18,627,037,274.95	13,457,895,569.45	1.38
LC 4	10,145,569,183.79	8,210,830,113.51	1.24
LC 5	28,279,890,664.82	26,584,893,251.95	1.06
LC 6	18,895,756,255.96	15,652,142,346.03	1.21
LC 7	17,442,509,422.21	17,224,443,336.55	1.01
LC 8	17,523,919,709.64	15,433,518,009.10	1.14
LC 9	15,818,042,164.66	10,524,790,622.59	1.50
LC 10	24,296,912,808.80	20,312,004,083.69	1.20
LC 11	13,256,045,331.64	14,104,462,007.04	0.94
LC 12	12,974,193,071.97	8,689,299,718.75	1.49
Average			1.19

The CMF value obtained from calculating the average CMF value of all landfill models is 1.19, which will be used further in the calculation of the Cost Significant Model (CSM) and Model Accuracy.

3.10 Estimation of Cost Significant Model (CSM) & Model Accuracy

After knowing the average value of the Cost Model Factor (CMF), the next step is to calculate the CSM value. The CSM value (Y'CSM) is obtained by dividing the total cost estimate in (Y') by the average value of CMF. Meanwhile, to calculate the accuracy of the model, can use the following equation, where:

$$Y'CSM = \frac{Y'}{\text{Average CMF}} \text{ and Accuracy} = \frac{Y'CSM}{Y} \times 100 \quad (2)$$

The total initial cost, represented by Y, refers to the anticipated expenses at the beginning of the project or process. On the other hand, Y' stands for the total actual cost, which reflects the real expenses incurred throughout the execution of the project. Additionally, Y'CSM denotes the total cost associated with the modeling of the Cost Significant Model (CSM), a crucial element in understanding and forecasting the financial implications of the project. The results of the CSM calculation and Model Accuracy can be seen in Table 9.

Table 9. Tabulation of CSM Calculation and Model Accuracy

Location	Cost Estimate	Cost Estimate	Cost Estimate CSM	Accuracy
	Total (Y)	Total (Y')	(Y"CSM)	
Purworejo Regency	21,109,017,166.86	22,179,213,718.29	18,690,077,786.87	-11.46

Location	Cost Estimate Total (Y)	Cost Estimate Total (Y')	Cost Estimate CSM (Y"CSM)	Accuracy
Nganjuk Regency	44,881,810,813.75	45,716,412,598.96	38,524,508,508.92	-14.16
Pati Regency	13,457,895,569.45	18,627,037,274.95	15,696,714,050.81	16.64
Wonogiri 1 Regency	8,210,830,113.51	10,145,569,183.79	8,549,513,055.13	4.12
Kediri Regency	26,584,893,251.95	28,279,890,664.82	23,831,023,184.28	-10.36
Rembang Regency	15,652,142,346.03	18,895,756,255.96	15,923,159,348.72	1.73
Sukabumi City	17,224,443,336.55	17,442,509,422.21	14,698,530,887.52	-14.66
Lebak Regency	15,433,518,009.10	17,523,919,709.64	14,767,134,068.15	-4.32
Karimunjawa Regency	10,524,790,622.59	15,818,042,164.66	13,329,617,643.28	26.65
Kendal Regency	20,312,004,083.69	24,296,912,808.80	20,474,629,810.83	0.80
Banyumas 1 Regency	14,104,462,007.04	13,256,045,331.64	11,170,662,835.,10	-20.80
Wonogiri 2 Regency	8,689,299,718.75	12,974,193,071.97	10,933,150,327.91	25.82
			Min	-20.80
			Max	26.65

Referring to the AACE cost estimation classification table, the accuracy of the lowest modelling results is -20.80% and the highest accuracy value is 26.65%, including class 4 (Study or Feasibility), which means that it can be used at the Initial Study Preparation Stage or Feasibility Study of Landfill Development so that the modelling results can be used as described in Table 10 below.

Table 10. Cost Estimation According to AACE International

Estimation class	End usage (typical purpose of estimate)	Methodology (typical estimating method)	Expected accuracy range typical o wand high range)
Class 5	Concept screening	Capacity factored, Parametric models, Judgment, or Analogy	Low: -20% to -50% High: +30% to +100%
Class 4	Study or Feasibility	Equipment factored or	Low: -15% to -30%
Class 3	Budget, authorization, or Control	Parametric models Semi-detailed unit cost with assembly-level line items	High: +20% to +50% Low: -10% to -20% High: +10% to +30%
Class 2	Control bid / Tender	Detailed unit cost with forced detailed take-off	Low: -5% to -15% High: +5% to +20%
Class 1	Check estimate or bid /Tender	Detailed unit cost with detailed take-off	Low: -3% to -10% High: +3% to +15%

Source: Christensen and Dysert (2005)

The model provides technical insights for decision-making in planning and design stages by identifying the most cost-significant components, thus allowing project managers and designers to prioritize resources effectively. When compared to international cost estimation tools such as RSMeans or CostWorks, which rely heavily on standardized cost databases and regional adjustment factors [25], the developed model offers a more context-specific approach tailored to Indonesian construction conditions. Moreover, highlight that variability in construction costs is often driven by factors such as soil conditions, regional market dynamics, and inflation rates, all of which can be systematically incorporated into parametric models to improve robustness [26]. By accounting for these variabilities, the model not only aligns with international best practices but also provides a scalable framework for enhancing accuracy across diverse project environments.

4. Conclusion

The development of a parametric cost estimation model for landfill construction using the Cost Significant Model (CSM) identified three dominant cost factors—block landfill work (X_3), leachate treatment plant installation (X_4), and operational road construction (X_5)—which together represent over 80% of total project costs. The resulting regression model achieved an average Cost Model Factor (CMF) of 1.19 with an accuracy range of -20.80% to 26.65% , classified as AACE Class 4, suitable for feasibility study applications. This model can be integrated with planning software or BIM systems for automated, real-time cost forecasting, enhancing project efficiency. Future work should explore AI-based predictive models to continuously improve cost estimation and support sustainable lifecycle cost management in landfill development.

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