Revolutionizing Feasibility Studies: A Proprietary Complex Model for Atmospheric API 650 Storage Tank Cost Estimation in National Oil Company [1, 2]

By Samuel Yonathan Montang

ABSTRACT

In the complex landscape of cost estimation for large-scale oil and gas projects, this study addresses the critical need for a precise and reliable model to estimate the cost of atmospheric API 650 storage tanks within a National Oil Company. The urgency of this issue is further emphasized in light of Hubbert's peak theory, which predicts a peak in oil production followed by a decline.

The paper introduces an innovative methodology, developing Company Developed Complex Models (CDCMs) using Solver for Excel. This approach is rigorously validated through statistical measures, including R-square, Mean Squared Error (MSE), F, and Significant F values, ensuring the model's accuracy and reliability.

An essential contribution of this research is the development of a Log-Linear Model, identified as the preferred solution among the CDCMs. This model is presented as a practical and robust tool for cost estimation, designed to adapt to the unique challenges of large-scale projects in the oil and gas sector.

Acknowledging the dynamic nature of cost estimation, the paper outlines a systematic approach for recalibrating the model, ensuring its responsiveness to changing conditions.
In conclusion, this paper contributes significantly to parametric cost estimation, presenting a comprehensive, validated, and adaptable model designed to meet the demanding standards of large-scale oil and gas projects, especially for Atmospheric API 650 storage tanks cost estimation.

Keywords: Parametric Model, Company Developed Complex Models, API 650, Atmospheric Tank, Cost Estimate, Estimation, AACE, Feasibility Study, National Oil Company, Hubbert's Peak Theory

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[2] This paper was originally prepared during a 6-month long Graduate-Level Competency Development/Capacity Building Program developed by PT Mitrata Citragraha and led by Dr. Paul D. Giammalvo to prepare candidates for AACE CCP or other Certifications. https://build-project-management-competency.com/our-faqs/

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INTRODUCTION

The global oil and gas industry is grappling with a significant concern known as the concept of Peak Oil, more famously known as "Hubbert's Peak Theory"[3]. This term refers to the hypothetical point at which global oil production will reach its maximum rate, after which production will gradually decline. As this peak approaches, the industry faces increasing pressure to optimize its operations and reduce costs. The implications of Peak Oil are far-reaching, affecting not only the oil and gas industry but also the broader global economy and environment. The decline in oil production signifies a transition towards more sustainable energy sources, but it also presents significant challenges, particularly for major oil and gas industry players.

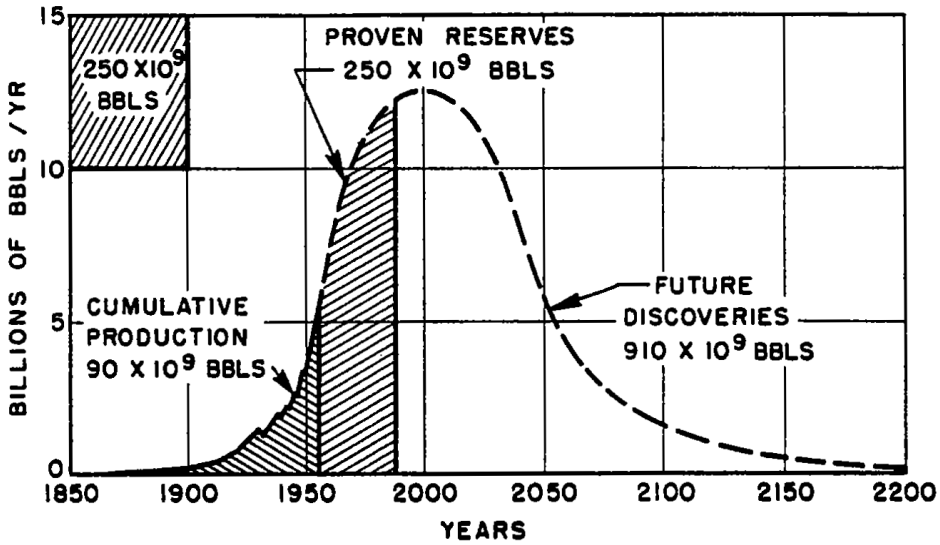

Figure 1 – Hubbert Curve[4]

Pertamina, with Pertamina Patra Niaga as its sub-holding (hereinafter referred to as National Oil Company), is a leading company in the oil and gas industry, the "nation's largest contributor to the state budget"[5] and "the most significant contributor to non-tax state revenue"[6], is one such player. As resources become scarcer and extraction costs rise, the need for accurate cost estimation and efficient operations becomes even more critical. The advent of Peak Oil adds an

[3] Investopedia. (2007). *Peak oil: Predictions and possible consequences*. https://www.investopedia.com/terms/p/peak_oil.asp
[4] Klemow, K. (n.d.). *Hubbert curve*. Welcome to Ken Klemow's. https://klemow.wilkes.edu/Hubbert.Curve.html
[5] Pertamina. (2019). *Peningkatan Kontribusi Pertamina Untuk Dukung APBN*. Retrieved July 6, 2023 from https://www.pertamina.com/id/news-room/news-release/peningkatan-kontribusi-pertamina-untuk-dukung-apbn
[6] Commission VI of the Indonesian Parliament. (2023). *Setoran ke Negara Rp307 triliun Buktikan Kontribusi Pertamina terhadap Pajak dan PNBP*. Retrieved July 6, 2023 from https://www.dpr.go.id/berita/detail/id/44364/t/Setoran+ke+Negara+Rp307+triliun+Buktikan+Kontribusi+Pertamina+terhadap+Pajak+dan+PNBP

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additional layer of complexity to the challenges National Oil Company faces. It underscores the need for more accurate cost estimation methods and tools to ensure financial sustainability and operational efficiency in a changing industry landscape.
The success of the oil and gas industry, and by extension, National Oil Company, is inextricably linked to the "iron triangle of cost, schedule, and quality/scope"[7].

These three factors form the cornerstone of effective project management in the industry. To maintain these three factors, the performance of oil and gas companies needs to be evaluated using specific metrics. According to a study by Rui et al.[8], five categories affect the performance of Oil & Gas companies: cost, schedule, safety, quantity, and production. Among these, cost performance metrics are of high practical importance as they are the primary output of cost estimation activities, which are vital to Project Cost Management (PCM)[9] or, more broadly, Energy Project Management.

Despite its importance, cost estimation evaluation is often underestimated in the oil and gas industry. Historical data reveals that oil and gas projects frequently experience cost and time overruns while delivering low-quality standards. Several factors contribute to this, such as the size of the project (the larger it is, the more likely it is to experience cost overrun), geographical conditions, the number of joint venture participants, differences in each company's ability to deliver project results, and variations in each project.

In addition to these factors, the cost estimation process often leads to cost overruns. "Traditionally, cost estimation has been conducted using single-point estimates"[10]. This is also compounded by National Oil Company's company policy and regulation for cost estimates, which requires cost estimates to be formed using the single-point and minimum price as the best estimate. While point estimates are helpful for PCM to control costs, stipulate contract terms, and assist in resource allocation, single point estimates can lead to managerial decision-making errors, resulting in project failure. "This is because cost estimation is a probabilistic activity that involves predicting future costs, which inherently includes uncertainty that must be considered in estimation and decision-making"[11].

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[7] Adlane, H. et al. (2021). The Project Management Triangle Assessment in Aeronautical Industries, Morocco: Focus on Eco-logistics. *Management Systems in Production Engineering*, 29(2), pp. 132–138. https://doi.org/10.2478/mspe-2021-0017

[8] Rui, Z., Li, C., Peng, F., Ling, K., Chen, G., Zhou, X., & Chang, H. (2017). Development of industry performance metrics for offshore oil and gas project. *Journal of Natural Gas Science and Engineering*, 39, 44-53. https://doi.org/10.1016/j.jngse.2017.01.022

[9] Mittas, N., & Mitropoulos, A. C. (2022). A Data-Driven Framework for Probabilistic Estimates in Oil and Gas Project Cost Management: A Benchmark Experiment on Natural Gas Pipeline Projects. *Computation*, 10(5), p. 75. https://doi.org/10.3390/computation10050075

[10] Zafar, S., & Mustafa, A. (2020). Risk Management in Oil and Gas Construction Projects in Pakistan. *International Journal of Construction Management*, 20(5), pp. 383-395. https://doi.org/10.1080/15623599.2018.1507787

[11] *Ibid*

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The risks associated with single-point estimation are manifold. Single-point estimates do not account for the uncertainty inherent in the data, leading to overconfidence in the results and potentially misguided decision-making. They do not capture the variability in the data, which can be problematic when dealing with complex systems where variability can have significant impacts on outcomes. Single-point estimates are sensitive to the input parameters, and small changes in the input parameters can lead to substantial changes in the estimate, making the results unstable and unreliable. They are not robust to changes in the data or the model; if the data or the model changes, the estimate can change dramatically. This lack of robustness can make single-point estimates unreliable in dynamic or changing environments. Lastly, single-point estimates are based on average or expected values and do not capture extreme events, which can be problematic in risk management, where the focus is often on the potential for extreme events[12].

Furthermore, empirical evidence suggests that the project estimation process often overlooks project-related risks, primarily due to a lack of experience and the absence of tools and methodologies to assist with future uncertainty-related cost estimation[13]. This lack of a comprehensive approach to cost estimation is particularly concerning in Peak Oil, as the industry needs to be prepared for the increasing costs and challenges of declining oil production.

Therefore, this paper will analyze and discuss how National Oil Company needs a tool to assist in project estimation and decision-making, namely a "parametric model to aid in business decision-making"[14], particularly in feasibility studies. For this paper, the author will limit the discussion to projects related to Atmospheric Storage Tanks, as National Oil Company operates in the downstream sector, where the main activities are Receipt, Storage, and Distribution—the 'Storage' activity results in frequent investment in Atmospheric Storage Tanks at National Oil Company.

The Parametric Model the author will create will utilize historical data from the construction of storage tanks at National Oil Company over the past five years. The result of this paper will be a parametric model for the construction of storage tanks, including foundations (piles), excluding instrumentation and piping systems. This parametric model will facilitate estimators in compiling the construction costs of storage tanks to prepare CAPEX Class 4 (feasibility study) with variables

[12] Flyvbjerg, B., Holm, M. S., & Buhl, S. (2002). Underestimating Costs in Public Works Projects: Error or Lie? *Journal of the American Planning Association*, 68(3), pp. 279-295. https://doi.org/10.1080/01944360208976273
[13] International Society of Parametric Analysts. (2008). *Parametric Estimating Handbook* (4th ed.). Vienna: ISPA/SCEA Joint Office. pp. 1-1 to 1-36
[14] Mittas, N., & Mitropoulos, A. C. (2022). A Data-Driven Framework for Probabilistic Estimates in Oil and Gas Project Cost Management: A Benchmark Experiment on Natural Gas Pipeline Projects. *Computation*, 10(5), p. 75. https://doi.org/10.3390/computation10050075

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of tank capacity and planned year of construction[15]. This approach will help address the challenges posed by Peak Oil and contribute to more sustainable and efficient operations in the oil and gas industry.

In conclusion, this paper aims to address the following research questions:

1. How can the traditional single-point estimation method be improved to better account for the inherent uncertainty and variability in cost estimation for oil and gas projects, particularly in the context of Peak Oil?

2. How can a parametric model be developed and implemented to assist the National Oil Company in project estimation and decision-making, particularly for feasibility studies related to constructing Atmospheric Storage Tanks?

3. How can the proposed parametric model facilitate the preparation of CAPEX Class 4 (feasibility study) with variables of capacity and planned year of construction, and how can this contribute to more sustainable and efficient operations in the oil and gas industry in the face of Peak Oil?

By addressing these questions, this paper aims to contribute to the body of knowledge on cost estimation in the oil and gas industry, particularly in Peak Oil, and provide practical insights for National Oil Company and other oil & gas industry players.

[15] International Society of Parametric Analysts. (2008). *Parametric Estimating Handbook* (4th ed.). Vienna : ISPA/SCEA Joint Office. pp. 1-1 to 1-36

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METHODOLOGY

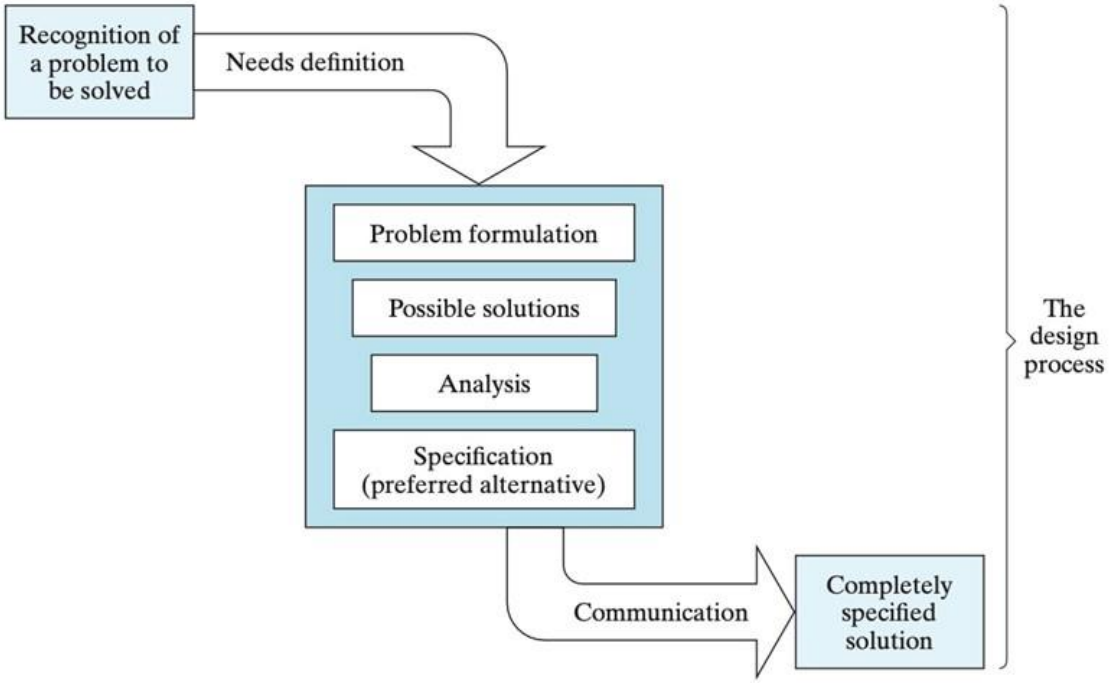

Figure 2 – Engineering Economic Analysis Procedure[16]

Step 1 - Problem Definition

The National Oil Company's Oil and Gas sector faces challenges in storage tank cost estimation, including:

a. **Over-reliance on Single-Point Estimates:** Current estimations mainly use single-point estimates, which don't account for industry-specific uncertainties. This can lead to cost overruns and project delays due to the absence of a range of potential outcomes.

b. **Absence of a Parametric Model:** The company lacks a parametric model for storage tank cost estimation. Such models, prevalent in various sectors, use project parameters to provide more accurate estimates than single-point methods.

c. **Requirement for a Reliable Decision-Making Tool:** Management needs a dependable tool for investment decisions, especially during feasibility studies. A parametric model can offer diverse cost estimates for different scenarios, enhancing risk management.

[16] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). *Engineering Economy Global Edition* (17th ed.). Pearson UK.

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The study aims to create a parametric model for storage tank cost estimation at the National Oil Company. This model will use the Company Developed Complex Models approach, leveraging historical data and factors like tank capacity and investment year from storage tank constructions (AACE estimate Levels 3 and 2) over the previous five years.

Step 2 – Development of Alternatives

Parametric Estimating

Parametric estimating is a sophisticated technique that develops cost estimates by meticulously examining and validating the relationships between a project's technical, programmatic, and cost characteristics, as well as the resources consumed during its development, manufacture, maintenance, or modification. This method is rooted in understanding how various factors influence the overall cost. Parametric models can be classified into two main categories: simple and complex. Simple models consist of one cost driver, known as Cost Estimating Relationships (CERs). In contrast, complex models consist of multiple CERs or algorithms to derive cost estimates. Using historical data and statistical methods, parametric models can provide accurate and flexible cost estimates. This approach allows for creation of models that can adapt to various scenarios and requirements, making it a valuable tool for project planning and budgeting.

Cost Estimating Relationships (CERs) are mathematical models derived from historical cost data to predict future project expenses. Developed through regression analysis, they consider factors like timing, labor, overhead costs, and production rates. As the backbone of many cost estimation models, CERs provide a rapid and reliable method for forecasting costs across various industries and project types[17].

Company Developed Complex Models (CDCMs)

Company Developed Complex Models are advanced, tailored algorithms designed for bespoke business applications. Their strength lies in blending statistical methods, machine learning, and organizational expertise to address intricate challenges that off-the-shelf models might falter against. When applied to domains like finance, risk management, or cost estimation for projects like API 650 Storage Tanks, CDCMs are precise and adaptable.

The deliberate focus on 'storage tank capacity' and 'planned year-to-built' as primary variables in the CDCM for API 650 Storage Tank Cost. The capacity of a storage tank is paramount, influencing material requisites, construction complexity, and project timelines. Larger tanks invariably alter cost dynamics, accounting for specialized equipment needs, heightened labor hours, and potentially divergent methodologies. On the other hand, the 'planned year-to-built' variable encapsulates the industry's susceptibility to inflationary pressures, raw material price fluctuations, labor market shifts, and technological innovations. By forecasting the build year,

[17] Akintoye, A. (2000). Analysis of factors influencing project cost estimating practice. *Construction Management and Economics*, *18*(1), 77-89. https://doi.org/10.1080/014461900370979

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the model adapts its cost predictions to future market scenarios, be it rising steel prices or innovative, cost-saving construction techniques.

CDCMs offer several advantages over traditional CERs:

- Customization: Tailored to specific projects, CDCMs authentically represent unique project features.
- Accuracy: These models can achieve more precise estimates by emphasizing critical cost drivers, which is vital for superior project management.
- Flexibility: With a focus on crucial variables, CDCMs can evolve with changing requirements or market dynamics, ensuring persistent relevance.

CDCMs are not only technically feasible but also cost-effective. They allow for a more nuanced understanding of cost drivers and can be integrated with existing project management tools. Using software like Solver® for Excel can further enhance the efficiency and accuracy of CDCMs. By leveraging technology and expert knowledge, CDCMs provide a comprehensive and cost-effective solution for cost estimation. They enable organizations to create tailored models that reflect their specific needs and expertise, leading to more informed decision-making and successful project execution.

Constructing a CDCM involves:

1. Data Collection: Initiating with a robust foundation by gathering historical and project-centric data.
2. Model Formulation: Establishing the mathematical relationships between the selected pivotal variables.
3. Calibration: Using statistical methods like R-square and Mean Square Error to fine-tune the model ensures that it accurately represents the data. Refining the model iteratively using statistical measures, ensuring alignment with the data.
4. Validation: Testing the model against known data to ensure accuracy is a critical step in the development process. Validation assures the model is robust and reliable, providing confidence in its predictions.

The choice of a streamlined CDCM approach, emphasizing tank capacity and planned construction year, ensures a blend of simplicity, robustness, and clarity. By capturing the core cost drivers for API 650 Storage Tanks, the model becomes an invaluable tool for agile, informed decision-making.

Evaluation Criteria

Evaluating CDCMs requires considering factors like accuracy, reliability, and ease of use. Statistical methods such as R-square, Mean Square Error, and others can be used to assess the model's fit and predictive power. Data from the provided PDFs can be incorporated into this

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evaluation to ensure a comprehensive assessment. Evaluation is an ongoing process that involves continuous monitoring and refinement of the model. By regularly evaluating the model against real-world data and adjusting it as needed, organizations can ensure that it remains accurate and relevant.

To evaluate the CDCMs to ensure their accuracy, reliability, and effectiveness, the author will rely on R-square (R^2) and Mean Square Error (MSE) as those are two common statistical methods.

R-Square (R^2)

R-square, also known as the coefficient of determination, is a statistical measure representing the proportion of the variance in the dependent variable that is predictable from the independent variables. In the context of CDCM, it indicates how well the model's predictions match the actual data.
R-square is calculated as:

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

Eq. 1 R-Square

Where:
SS_{res} is the sum of the squared residuals (difference between actual and predicted values).
SS_{tot} is the total sum of squares (difference between actual values and the mean of actual values).

Interpretation:

- Value Range: R^2 ranges from 0 to 1.
- Higher Value: A higher R^2 value (closer to 1) indicates a better fit of the model, meaning that the independent variables explain a more significant proportion of the variance in the dependent variable.
- Lower Value: A lower R^2 value (closer to 0) suggests that the model does not explain much of the variability in the dependent variable.

In CDCMs, R^2 can be used to assess how well the model captures the underlying relationship between the variables. A high R^2 value indicates that the model effectively represents the cost dynamics and the influencing factors, providing confidence in its predictions.

Mean Square Error

Mean Square Error is a measure of the average squared differences between the predicted values and the actual values. It quantifies the difference between the model's predictions and the observed data, indicating its accuracy.

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MSE is calculated as follows:

$$MSE = \frac{1}{n} * \sum_{i=1}^{n} (y_i - \hat{y}_i)^2$$

Eq. 2 Mean Square Error

Where:

- y_i is the actual value.
- $\hat{y}_i$ is the predicted value.
- n is the number of observations.

Interpretation:

- Value Range: MSE can range from 0 to positive infinity.
- Lower Value: A lower MSE indicates that the model's predictions are close to the actual values, reflecting its accuracy.
- Higher Value: A higher MSE suggests that the model's predictions are far from the actual values, indicating a lack of accuracy.

In CDCMs, MSE can be used to quantify the model's accuracy in numerical terms. A low MSE value assures that the model accurately predicts costs, while a high MSE may signal the need for model refinement or reconsideration of the variables included.

R^2 and Mean Square Errors are valuable tools for evaluating the effectiveness of a CDCM. While R^2 provides insights into the model's ability to explain the variability in the dependent variable, MSE quantifies the accuracy of the predictions. Together, these metrics offer a comprehensive assessment of the model's performance, guiding further refinement and validation. In the context of cost estimation, particularly for complex projects like API 650 Storage Tank construction, the rigorous evaluation of CDCMs using these statistical methods ensures that the model is robust, reliable, and suitable for practical use.

Step 3 – Development of Prospective Outcomes

Data Collection

The data collection process is a critical step in developing prospective outcomes. In this study, the author collected data from 41 building costs of storage tanks for gasoline products. The data were gathered with specific constraints:

- **Standard:** The tanks were built using the API 650 standard, widely recognized for tank design and construction[18].
- **Time Frame:** The data were collected from 2018 to 2023, providing a comprehensive view of recent trends.

[18] American Petroleum Institute. (2020). *API Standard 650 : Welded Tanks for Oil Storage* (13th ed.).

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- **Material Specification:** Only tanks built using ASTM A283 Grade C steel plate material were considered, ensuring consistency in material quality[19][20].
- **Source of Data:** The data were exclusively collected from tanks constructed by the National Oil Company in Indonesia.

Below are the building costs of storage tanks for gasoline products, with each respective year and capacity. The costs displayed are Jakarta base in Million Rupiah before applying profit & risk.

[19] *Ibid*
[20] ASTM International. (2003). *ASTM A283/A283M-03: Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates*.

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NO	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	PROJECT COST (REGION BASE) (MAT+LABOR) (IN MILLION RUPIAH) BEFORE PROFIT & RISK	PROJECT COST (JAKARTA BASE) (MAT+LABOR) (IN MILLION RUPIAH) BEFORE PROFIT & RISK
1	PROJECT 1	JAWA TENGAH	20,000	2018	28,101	31,092
2	PROJECT 2	JAWA TENGAH	20,000	2018	35,829	39,643
3	PROJECT 3	JAWA TENGAH	40,000	2018	38,687	42,805
4	PROJECT 4	SULAWESI SELATAN	2,500	2018	4,070	4,368
5	PROJECT 5	SULAWESI TENGAH	2,500	2018	4,482	5,041
6	PROJECT 6	SULAWESI TENGAH	2,500	2018	4,549	5,116
7	PROJECT 7	SULAWESI TENGAH	2,500	2018	4,339	4,881
8	PROJECT 8	SULAWESI TENGGARA	2,500	2018	4,082	4,370
9	PROJECT 9	SULAWESI SELATAN	2,500	2018	4,609	4,946
10	PROJECT 10	MALUKU	5,000	2018	7,183	6,202
11	PROJECT 11	SUMATERA UTARA	5,000	2018	10,774	11,588
12	PROJECT 12	JAWA TIMUR	50,000	2018	36,172	38,011
13	PROJECT 13	JAWA TENGAH	40,000	2018	58,559	64,793
14	PROJECT 14	JAWA TENGAH	40,000	2018	58,273	64,476
15	PROJECT 15	JAWA BARAT	5,000	2019	7,183	7,951
16	PROJECT 16	NUSA TENGGARA TIMUR	1,500	2020	5,267	6,283
17	PROJECT 17	MALUKU	1,500	2020	3,891	3,655
18	PROJECT 18	MALUKU	1,500	2020	3,891	3,655
19	PROJECT 19	MALUKU	1,000	2020	4,040	3,795
20	PROJECT 20	MALUKU	2,000	2020	4,788	4,498
21	PROJECT 21	SUMATERA SELATAN	10,000	2020	16,217	20,442
22	PROJECT 22	JAWA BARAT	2,000	2020	5,387	6,056
23	PROJECT 23	NUSA TENGGARA TIMUR	1,000	2020	4,028	4,805
24	PROJECT 24	JAWA TIMUR	1,500	2020	2,712	3,093
25	PROJECT 25	KALIMANTAN TENGAH	3,000	2020	7,781	9,133
26	PROJECT 26	KALIMANTAN BARAT	2,500	2020	6,584	6,935
27	PROJECT 27	GORONTALO	1,000	2020	3,711	4,607
28	PROJECT 28	MALUKU	1,000	2020	3,301	3,101
29	PROJECT 29	MALUKU UTARA	1,000	2020	2,715	2,632
30	PROJECT 30	MALUKU	1,000	2020	2,558	2,402
31	PROJECT 31	KEP. RIAU	2,500	2021	6,528	6,786
32	PROJECT 32	ACEH	2,500	2021	8,505	10,428
33	PROJECT 33	SUMATERA UTARA	1,000	2021	4,543	5,428
34	PROJECT 34	JAWA TENGAH	8,000	2021	12,599	15,666
35	PROJECT 35	PAPUA BARAT	2,500	2021	5,161	4,798
36	PROJECT 36	SUMATERA UTARA	1,000	2021	4,543	5,428
37	PROJECT 37	NUSA TENGGARA BARAT	1,500	2022	4,729	5,500
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	2,492	3,231
39	PROJECT 39	SULAWESI TENGAH	1,500	2022	3,591	4,716
40	PROJECT 40	SULAWESI SELATAN	1,500	2022	3,292	4,200
41	PROJECT 41	PAPUA BARAT	2,500	2022	5,680	5,528
42	PROJECT 42	BALI	2,000	2023	5,088	5,901
43	PROJECT 43	JAWA TIMUR	700	2023	3,292	3,998

Table 1 – API 650 Storage Tank Building Projects and Costs in National Oil Company[21]

[21] By Author

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The collected data were normalized to July 31st, 2025, using the Gold Price Index. July 31st, 2025, is forecasted as the midpoint schedule for those projects[22], assuming that the tender starts at the end of 2023 at the earliest. "The Gold Price Index is a financial tool that tracks the value of gold over time and is often used as a hedge against inflation or currency fluctuations"[23]. Normalizing the data using this index involves adjusting the tank construction costs from 2018 to July 2023 to the equivalent value on July 31st, 2025, considering changes in the price of gold.

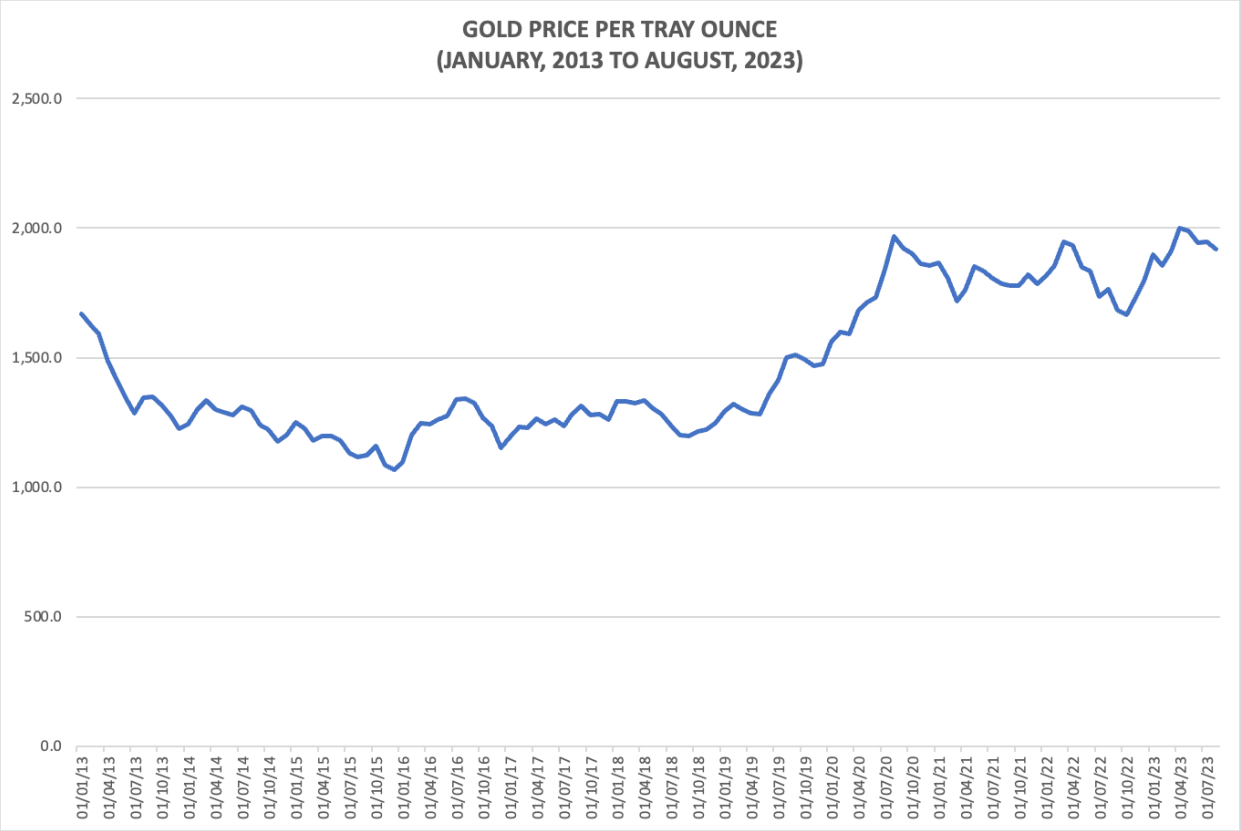

Figure 3 – Gold Price Per Tray Ounce (2013 - 2023)[24]

From the above chart, the author determined the average gold price for 2018 to July 2023 to become the baseline, as follows:

[22] NASA. (2015). NASA Cost Estimating Handbook Version 4.0. pp. 24-26
[23] *Gold as a Strategic Inflation Hedge*. (2021, April 21). World Gold Council. Retrieved August 3, 2023, from https://www.gold.org/goldhub/research/beyond-cpi-gold-as-a-strategic-inflation-hedge
[24] *Gold spot price and cost of gold*. (2023, September 14). World Gold Council. https://www.gold.org/goldhub/data/gold-prices#from-login=1&login-type=google

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Year	Average Gold Price per Year (in USD)
2018	$1,269
2019	$1,392
2020	$1,770
2021	$1,800
2022	$1,801
2023 upto August, 31st	$1,934

Table 2 – Average Gold Price Index for 2018 to August 2023[25] [26]

Subsequently, utilizing the same chart, the author plotted the regression using linear equations and polynomials of the 2nd, 3rd, 4th, 5th, and 6th orders, as follows:

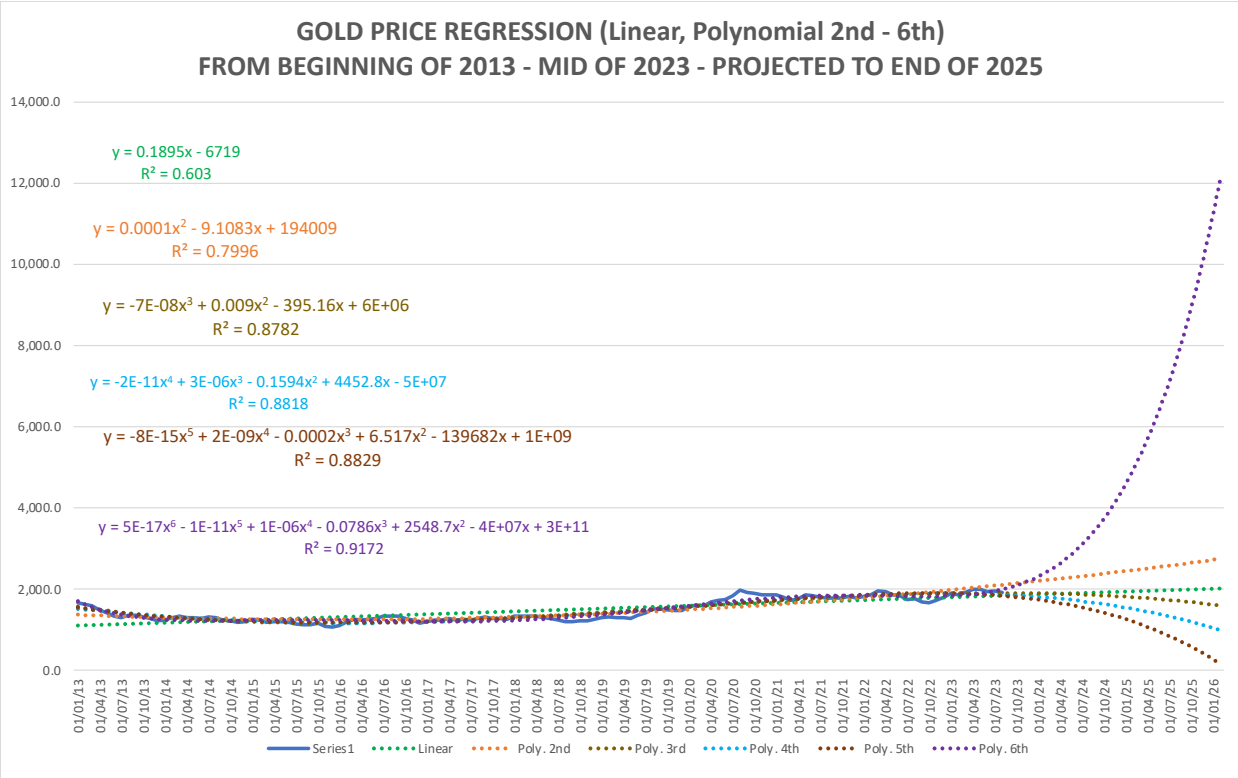

Figure 4 – Gold Price Regression Chart (2013 - 2025)[27]

[25] *Gold spot price and cost of gold*. (2023, September 14). World Gold Council https://www.gold.org/goldhub/data/gold-prices#from-login=1&login-type=google
[26] By Author
[27] By Author

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From the conducted regression analysis, we extract the value of R^2, which is displayed in the following table:

REGRESSION	Y (GOLD PRICE IN	R^2
LINEAR	1,993	0.6030
2ND POLY	2,723	0.7966
3RD POLY	1,634	0.8782
4TH POLY	1,013	0.8818
5TH POLY	981	0.8829
6TH POLY	949	0.9172

Table 3 – Gold Price R^2 Value

Beyond the R^2 value, the author also simulated the regression trend curve and the simulated Regression results for December 31st, 2023. The findings obtained are as follows:

REGRESSION	Y (GOLD PRICE IN DEC 31, 2025)	TREND	R^2
LINEAR	1,993	POSITIVE	0.603
2ND POLY	2,723	POSITIVE	0.7966
3RD POLY	1,634	NEGATIVE	0.8782
4TH POLY	1,013	NEGATIVE	0.8818
5TH POLY	981	NEGATIVE	0.8829
6TH POLY	949	NEGATIVE	0.9172

Table 4 – Gold Price Regression Value, R^2, and Trend

Even though the 3rd, 4th, 5th and 6th Polynomial provided a superior R^2, the author chose, based on the positive trend, compared to the last two-year gold price value on the baseline, as the foundation for the normalization. Based on the calculation results and analysis of the future gold price trend, the author established the regression that will be used for the normalization as follows:

LINEAR	=	$	1,993	(LOW)
AVERAGE	=	$	2,358	(MID)
POLYNOMIAL 2ND ORDER	=	$	2,723	(HIGH)

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Subsequently, based on the above prices, the author categorizes each output price into three classifications: Low, Medium, and High.

In performing the normalization, the author employed a Log-Normal analysis using Microsoft Excel, with a confidence level of P80. The P80 level was chosen following the Government Accountability Office (GAO) guidelines for the confidence level in cost estimation[28].

Based on the baseline presented in Table 2 and the cost predictions made using the Gold Price Index, the Author built projected Storage Tank Building Costs on July 31st, 2025, with a confidence level of P80, as displayed in **Appendices A**.

Step 4 – Selection of Decision Criterion

Model Formulation

After normalizing the data, the author formulated four distinct models to represent the relationship between Storage Tank Capacity and Year-to-Built:

Model 1 – Linear Model
The linear model is expressed as:

$$Cost = a + bx + c(y - 2018) + d\big(x * (y - 2018)\big)$$

Eq. 3 Linear Model

Where:
Cost = Storage Tank Cost
x = Storage Tank Capacity
y = Year-to-Construct (Midpoint)
a, b, c, d = coefficients to be estimated

This model assumes a linear relationship between the cost and the variables but includes an interaction term between Storage Tank Capacity and Year-To-Built. It's widely used for its simplicity and ease of interpretation, especially when the relationship between variables is expected to be directly proportional[29]. The transformation $(y - 2018)^f$ centers the year variable, which can improve numerical stability.

[28] Government Accountability Office. (2020). *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs*. Accessible Version GAO-20-195G.
[29] Chatterjee, S., & Hadi, A. S. (2015). *Regression analysis by example*. John Wiley & Sons.

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Model 2 – Combination of Polynomial and Power Model

The combination of polynomial and power model is expressed as:

$$Cost = ax + bx^c + d(y - 2018) + e(y - 2018)^f + g$$

Eq. 4 Combination of Polynomial and Power Model

Where:
Cost = Storage Tank Cost
x = Storage Tank Capacity
y = Year-to-Construct (Midpoint)
a, b, c, d, e, f, g = coefficients to be estimated

The model combines linear, polynomial, and power terms to capture complex relationships between the cost, Storage Tank Capacity, and Year-To-Built. Polynomial models can capture complex relationships and are particularly useful when linear models are inadequate[30]. The power terms x^c and $(y - 2018)^f$ allow for nonlinear relationships with Storage Tank Capacity and Year-To-Built, respectively.

Model 3 – Combination of Polynomial

The combination of the polynomial model is expressed as:

$$Cost = a + bx + cx^2 + d(y - 2018) + e(y - 2018)^2$$

Eq. 5 Polynomial Model

Where:
Cost = Storage Tank Cost
x = Storage Tank Capacity
y = Year-to-Construct (Midpoint)
a, b, c, d, e = coefficients to be estimated

The model includes linear and quadratic terms for Storage Tank Capacity and Year-To-Built, allowing for more complex relationships. Quadratic models are commonly used in cost estimation to capture nonlinearities.[31]

[30] James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An introduction to statistical learning: With applications in R*. Springer Science & Business Media.
[31] Niazi, Adnan & Dai, Jian & Balabani, Stavroula & Seneviratne, Lakmal. (2006). Product Cost Estimation: Technique Classification and Methodology Review. *Journal of Manufacturing Science and Engineering-transactions of The Asme - J MANUF SCI ENG. 128*. https://doi.org/10.1115/1.2137750.

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Model 4 – Log-linear Model

The log-linear model is expressed as follows:

$$\ln Cost = a * \ln x + b * (\mathrm{y} - 2018) + c$$

Eq. 6 Log-linear Model

Where:
Cost = Storage Tank Cost
x = Storage Tank Capacity
y = Year-to-Construct (Midpoint)
a, b, c = coefficients to be estimated

The model includes the natural logarithm of Storage Tank Capacity, allowing for a multiplicative relationship with cost. Log-linear models are commonly used in economics and cost estimation to capture elasticity[32]. The log transformation of Storage Tank Capacity allows for a nonlinear relationship with cost and year on the original scale.

Coefficient Formulation Using Solver® for Excel

Solver® for Excel is an optimization tool that finds the best solution for a problem by changing the values of certain variables to minimize or maximize an objective function. In regression analysis, Solver can be used to estimate the coefficients that minimize the sum of squared residuals, a common objective in linear regression[33]. Solver® for Excel is a powerful tool for calculating regression coefficients, but it requires careful setup and interpretation, such as constraints, solution methods, and starting values. Using Solver® for Excel to estimate regression coefficients involves the following steps:

a. Define the objective function (e.g., the sum of squared residuals (SSR)).
b. Specify the cells containing the coefficients to be estimated.
c. Set constraints if necessary (e.g., allow negativity constraints).
d. Choose a solution method (e.g., GRG Nonlinear).
e. Run Solver® and interpret the results.

Residuals are the differences between observed and predicted values. Minimizing SSR is the standard objective in ordinary least squares regression[34]. Solver® estimates the coefficients that best fit the data by minimizing this objective to reduce the differences between observed and predicted values. The author then will use the R^2 method to evaluate the coefficient and model

[32] Wooldridge, J. M. (2013). *Introductory econometrics: A modern approach*. Cengage Learning.
[33] Winston, W. (2016). *Microsoft Excel data analysis and business modeling*. Microsoft Press.
[34] Montgomery, D. C., Peck, E. A., & Vining, G. G. (2015). *Introduction to linear regression analysis*. John Wiley & Sons.

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generated using a solver. Higher R^2 and lower MSE values generally indicate a better fit when comparing different models.

The Dataset

The dataset comprises 43 projects, each representing a unique year and tank capacity combination. This diversity in the data provides a rich basis for modelling, capturing variations in cost across different periods and tank sizes. The author will extract the actual project cost from each year and tank capacity. This approach ensures that the data reflects the real-world conditions and cost structures of each project, enhancing the validity of the analysis. The author has escalated all project costs to 2025 using a log-normal distribution with a P80 confidence level, a statistically robust method. The log-normal distribution is often used in cost estimation to model positively skewed data, where costs cannot be negative and may have a long right tail[35]. The P80 confidence level represents a conservative estimate, providing more certainty that the escalated costs will not exceed the estimated values. This approach aligns with industry best practices for risk management in cost estimation[36]. With the addition of escalated costs for 43 projects, the total dataset comprises 86 observations (**APPENDICES B**). This expanded dataset enhances the statistical power of the analysis, providing more information for estimating model coefficients.

FINDINGS

Step 5 – Analysis and Comparison Alternatives

After employing the Solver® for Excel tool on a dataset comprising 86 samples[37], the results from this modelling exercise are summarized as follows:

[35] Johnson, N. L., Kotz, S., & Balakrishnan, N. (2021). *Continuous univariate distributions*.
[36] AACE International. (2020). Cost Estimate Classification System. *AACE International Recommended Practice No. 18R-97.*
[37] Stuart, A., & Ord, K. (2010). *Kendall's advanced theory of statistics, distribution theory*. John Wiley & Sons.

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	MODEL 1	MODEL 2	MODEL 3	MODEL 4 (LOG)	MODEL 4 (EXP)
NUM OF SAMPLE	86	86	86	86	86
SUM OF SQUARE ERROR	9.41	30.61	25.80	0.07	5.92
SUM OF RESIDUAL ERROR	7,135,199,740	12,574,263,027	9,160,912,276	5.81	6,837,484,624
MEAN SQUARE ERROR	82,967,439	146,212,361	106,522,236	0.07	79,505,635
ROOT MSE	9,109	12,092	10,321	0.26	8,917
R^2	0.87	0.80	0.85	0.92	0.89
Adjusted R^2	0.87	0.79	0.85	0.92	0.89
F value	580.60	326.02	467.14	931.35	680.23
Significant F	3.2.E-39	1.8.E-30	7.7.E-36	7.0.E-47	9.5.E-42

Table 5 – Summary of Model Calculation and Analysis using ANOVA

COEFFICIENT	MODEL 1	MODEL 2	MODEL 3	MODEL 4
a	2397.627	-10.986	-12567.638	0.781
b	1.194	17.268	3.966	0.100
c	267.168	0.972	-0.0000479	2.473
d	0.191	-144.970	3651.965	
e		0.178	-200.745	
f		5.522		
g		0.929		

Table 6 – Coefficient for Each Model

Model 4 in its Logarithmic form, stands out from the models presented, boasting the smallest MSE, the highest R-square value, the largest F value, and the smallest Significant F value[38]. Drawing from existing theoretical frameworks, Model 4 emerges as the prime candidate for the Company Developed Complex Model tailored for constructing Atmospheric storage tanks in line with API 650 standards[39].

Diving deeper into the comparison between Model 4 and its predecessors, several distinct advantages become evident:

1. **Error Metrics**: The notably lower SSE and MSE for Model 4 (Logarithmic) signify a superior fit to the data, translating to enhanced prediction accuracy[40].

2. **R^2 Value**: The R^2 value of 0.92 for Model 4 underscores its capability to account for a more significant fraction of the variance in the dependent variable, thereby capturing more of the data's variability[41].

[38] *Ibid*
[39] Fox, J. (2015). *Applied regression analysis and generalized linear models*. SAGE Publications.
[40] Shrestha, N. (2020). Detecting multicollinearity in regression analysis. *American Journal of Applied Mathematics and Statistics*, 8(2), 39-42. https://doi.org/10.12691/ajams-8-2-1
[41] Austin, P. C., & Merlo, J. (2017). Intermediate and advanced topics in multilevel logistic regression analysis. *Statistics in Medicine*, 36(20), 3257-3277. https://doi.org/10.1002/sim.7336

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3. **ANOVA Analysis**: The F and Significant F values for Model 4 are the highest and lowest, respectively, among all models. This indicates that Model 4 is statistically the most significant and provides the best fit to the data[42].

4. **Model Transformation**: The logarithmic transformation inherent to Model 4 is pivotal to its standout performance[43]. Such transformations are renowned for stabilizing variances, linearizing relationships, and mitigating heteroscedasticity in regression models. This adaptability to data variations and bias reduction culminates in more precise and dependable predictions.

Step 6 – Selection of Preferred Alternative

Model 4 is the optimal choice based on its statistical metrics, notably its low MSE, high R-square, and significant F value, indicating its predictive accuracy. This model serves as the company's complex model for cost estimation in constructing an API 650 Atmospheric Storage Tank, represented by the equation:

$$\ln Cost = 0.781 * \ln StorageTankCapacity + 0.100 * (\text{Year} - 2018) + 2.473 \qquad \textbf{\textit{Eq. 7 CDCM}}$$

Here, the Storage Tank Capacity is denoted in kilolitres (KL).

At its core, Model 4's equation, Eq. 7 CDCMs, hinges on the Storage Tank Capacity (measured in kilolitres). It highlights the nuanced correlation between cost and two key predictors: the logarithm of storage tank capacity and the adjusted year of construction (Year-To-Construct minus 2018). The coefficient 0.781 of the storage tank capacity suggests that every logarithmic increase in capacity sees the cost logarithm rise by roughly 0.781 units[44]. Concurrently, the coefficient for the adjusted year-to-build marks the evolution of construction costs since 2018[45].

The model's strength lies in its logarithmic transformation, which stabilizes variances and rectifies inconsistencies in regression models. Model 4's adaptability and reduced bias make it the benchmark for accurate predictions[46].

Drawing from Hubbert's Peak Oil theory, which indicates a bell-curve trajectory for petroleum extraction leading to eventual decline, this cost model is crucial[47]. As the oil sector grapples with

[42] Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). Guilford Publications.
[43] *Ibid*
[44] Montgomery, D. C., Peck, E. A., & Vining, G. G. (2015). *Introduction to linear regression analysis*. John Wiley & Sons.
[45] Draper, N. R., & Smith, H. (2014). *Applied regression analysis*. John Wiley & Sons.
[46] Fox, J. (2015). *Applied regression analysis and generalized linear models*. SAGE Publications.
[47] Deffeyes, K. S. (2009). *Hubbert's peak: The impending world oil shortage*. Princeton University Press.

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diminishing resources, efficient cost management becomes pivotal. Model 4, with its precision, enables wise decision-making in storage tank construction, ensuring sound, cost-effective investments.

Step 7 – Performance Monitoring and Postevaluation of Results

To ensure the continued accuracy and relevance of Model 4, it is imperative to monitor its performance regularly. This can be achieved through the following steps:

1. **Data Collection**: Continuously gather new data on the actual costs of constructing API 650 Atmospheric Storage Tanks. This data should be collected annually or biannually, depending on the frequency of construction projects.
2. **Model Prediction**: Use Model 4 to predict the costs based on the new data's parameters, such as Storage Tank Capacity and Year-To-Built.
3. **Comparison**: Compare the predicted costs from Model 4 with the actual costs. This will help in identifying any discrepancies or deviations.
4. **Error Calculation**: Quantify the prediction error by subtracting the model's predicted cost from the actual cost. This provides a tangible measure of the model's accuracy[48].

A discrepancy threshold of, for instance, 5% between the predicted and actual costs can trigger model recalibration[49]. Calibration can be approached by:

1. **Re-Estimation**: Incorporate the new data to re-estimate the model's coefficients. This might necessitate rerunning the regression analysis by amalgamating old and new data.
2. **Validation**: Post recalibration, validate the model using a distinct data set to ascertain its accuracy[50].
3. **Update**: If improved accuracy is observed, supersede Model 4 with the recalibrated model.

[48] Wooldridge, J. M. (2013). *Introductory econometrics: A modern approach*. Cengage Learning.
[49] Hyndman, R. J., & Athanasopoulos, G. (2018). *Forecasting: Principles and practice*. OTexts.
[50] Hamilton, J.D. (1994). *Time Series Analysis*, *first edition*. Princeton University Press.

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CONCLUSION

While straightforward, the traditional single-point estimation method often fails to account for the inherent uncertainties and risks associated with project costs in the Oil and Gas industry[51]. This method can lead to erroneous managerial decisions and project failures due to its lack of probabilistic information, resulting in cost overruns and schedule delays. To address this, it's essential to move away from single-point estimates and adopt a more holistic approach that considers a range of possible outcomes or the likelihood of each outcome.

The National Oil Company currently lacks a parametric model for the cost estimation of storage tanks. A parametric model uses project characteristics (parameters) to estimate costs and is effective in various industries, including the Oil and Gas industry[52]. Such models allow for the consideration of multiple factors and uncertainties that can impact the cost and timeline of a project, providing a more accurate and reliable estimate than traditional single-point estimates. This study has proposed the development of a parametric model for the construction of storage tanks, which will facilitate estimators in compiling the construction costs of storage tanks for the preparation of CAPEX Class 4 (feasibility study) with variables of tank capacity and planned year of construction. This approach will help address the challenges posed by Peak Oil and contribute to more sustainable and efficient operations in the oil and gas industry.

The proposed parametric model, known as Model 4, elucidates the intricate relationship between the cost and two pivotal predictors: the logarithm of the storage tank capacity and the logarithm of the adjusted year of construction. This model's strength lies in its logarithmic transformation, stabilizes variances, linearizes relationships, and rectifies heteroscedasticity in regression models. In the context of Hubbert's Peak Oil theory, which posits a bell-shaped curve for petroleum extraction leading to a decline as resources wane, this model becomes indispensable. Cost optimization becomes crucial as the oil industry navigates the challenges of dwindling resources. Model 4, with its precision and adaptability, empowers companies to make informed decisions regarding the construction of storage tanks, ensuring judicious and cost-effective investments.

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[52] Tehrani, M., & Ahmadi, M. (2016). *On the Parametric Study of Lubricating Oil Production using an Artificial Neural Network (ANN) Approach*. arXiv:1701.06551 [cs.LG].

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APPENDICES I. API 650 STORAGE TANK COSTS, PROJECTED TO AUGUST 31ST 2025

NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	PROJECT COST (JAKARTA BASE) (MAT+LABOR) (IN MILLION RUPIAH) BEFORE PROFIT & RISK	*LOW*	*MID*	*HIGH*	PROJECT COST (JAKARTA BASE) (MAT+LABOR) (IN MILLION RUPIAH) BEFORE PROFIT & RISK PROJECTED TO 31 AUG 2025 (P80)
1	PROJECT 1	JAWA TENGAH	20,000	2018	31,092	*48,819*	*57,759*	*66,698*	65,342
2	PROJECT 2	JAWA TENGAH	20,000	2018	39,643	*62,246*	*73,644*	*85,041*	83,313
3	PROJECT 3	JAWA TENGAH	40,000	2018	42,805	*67,210*	*79,516*	*91,823*	89,956
4	PROJECT 4	SULAWESI SELATAN	2,500	2018	4,368	*6,859*	*8,115*	*9,371*	9,180
5	PROJECT 5	SULAWESI TENGAH	2,500	2018	5,041	*7,915*	*9,364*	*10,813*	10,593
6	PROJECT 6	SULAWESI TENGAH	2,500	2018	5,116	*8,033*	*9,504*	*10,975*	10,752
7	PROJECT 7	SULAWESI TENGAH	2,500	2018	4,881	*7,663*	*9,066*	*10,470*	10,257
8	PROJECT 8	SULAWESI TENGGARA	2,500	2018	4,370	*6,861*	*8,117*	*9,373*	9,183
9	PROJECT 9	SULAWESI SELATAN	2,500	2018	4,946	*7,767*	*9,189*	*10,611*	10,395
10	PROJECT 10	MALUKU	5,000	2018	6,202	*9,738*	*11,522*	*13,305*	13,034
11	PROJECT 11	SUMATERA UTARA	5,000	2018	11,588	*18,195*	*21,527*	*24,859*	24,353
12	PROJECT 12	JAWA TIMUR	50,000	2018	38,011	*59,682*	*70,611*	*81,539*	79,881
13	PROJECT 13	JAWA TENGAH	40,000	2018	64,793	*101,735*	*120,363*	*138,991*	136,166
14	PROJECT 14	JAWA TENGAH	40,000	2018	64,476	*101,237*	*119,774*	*138,311*	135,499
15	PROJECT 15	JAWA BARAT	5,000	2019	7,951	*11,382*	*13,466*	*15,550*	15,234
16	PROJECT 16	NUSA TENGGARA TIMUR	1,500	2020	6,283	*7,075*	*8,371*	*9,666*	9,470
17	PROJECT 17	MALUKU	1,500	2020	3,655	*4,116*	*4,869*	*5,623*	5,508
18	PROJECT 18	MALUKU	1,500	2020	3,655	*4,116*	*4,869*	*5,623*	5,508
19	PROJECT 19	MALUKU	1,000	2020	3,795	*4,274*	*5,056*	*5,839*	5,720
20	PROJECT 20	MALUKU	2,000	2020	4,498	*5,065*	*5,993*	*6,920*	6,780
21	PROJECT 21	SUMATERA SELATAN	10,000	2020	20,442	*23,020*	*27,236*	*31,451*	30,811
22	PROJECT 22	JAWA BARAT	2,000	2020	6,056	*6,820*	*8,069*	*9,317*	9,128
23	PROJECT 23	NUSA TENGGARA TIMUR	1,000	2020	4,805	*5,411*	*6,402*	*7,393*	7,242
24	PROJECT 24	JAWA TIMUR	1,500	2020	3,093	*3,483*	*4,121*	*4,759*	4,662
25	PROJECT 25	KALIMANTAN TENGAH	3,000	2020	9,133	*10,284*	*12,167*	*14,050*	13,765
26	PROJECT 26	KALIMANTAN BARAT	2,500	2020	6,935	*7,810*	*9,240*	*10,670*	10,453
27	PROJECT 27	GORONTALO	1,000	2020	4,607	*5,188*	*6,138*	*7,088*	6,943
28	PROJECT 28	MALUKU	1,000	2020	3,101	*3,492*	*4,131*	*4,771*	4,674
29	PROJECT 29	MALUKU UTARA	1,000	2020	2,632	*2,964*	*3,507*	*4,049*	3,967
30	PROJECT 30	MALUKU	1,000	2020	2,402	*2,705*	*3,201*	*3,696*	3,621
31	PROJECT 31	KEP. RIAU	2,500	2021	6,786	*7,514*	*8,890*	*10,266*	10,058
32	PROJECT 32	ACEH	2,500	2021	10,428	*11,548*	*13,662*	*15,777*	15,456
33	PROJECT 33	SUMATERA UTARA	1,000	2021	5,428	*6,010*	*7,111*	*8,211*	8,044
34	PROJECT 34	JAWA TENGAH	8,000	2021	15,666	*17,348*	*20,525*	*23,701*	23,219
35	PROJECT 35	PAPUA BARAT	2,500	2021	4,798	*5,313*	*6,286*	*7,259*	7,112
36	PROJECT 36	SUMATERA UTARA	1,000	2021	5,428	*6,010*	*7,111*	*8,211*	8,044
37	PROJECT 37	NUSA TENGGARA BARAT	1,500	2022	5,500	*6,086*	*7,201*	*8,315*	8,146
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	3,231	*3,576*	*4,231*	*4,885*	4,786
39	PROJECT 39	SULAWESI TENGAH	1,500	2022	4,716	*5,219*	*6,175*	*7,130*	6,985
40	PROJECT 40	SULAWESI SELATAN	1,500	2022	4,200	*4,648*	*5,499*	*6,350*	6,220
41	PROJECT 41	PAPUA BARAT	2,500	2022	5,528	*6,117*	*7,237*	*8,357*	8,187
42	PROJECT 42	BALI	2,000	2023	5,901	*6,081*	*7,195*	*8,309*	8,140
43	PROJECT 43	JAWA TIMUR	700	2023	3,998	*4,121*	*4,875*	*5,630*	5,515

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APPENDICES B. DATASET

NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	PROJECT COST (JAKARTA BASE) (MAT+LABOR) (IN MILLION RUPIAH) BEFORE PROFIT & RISK
1	PROJECT 1	JAWA TENGAH	20,000	2018	31,092
2	PROJECT 2	JAWA TENGAH	20,000	2018	39,643
3	PROJECT 3	JAWA TENGAH	40,000	2018	42,805
4	PROJECT 4	SULAWESI SELATAN	2,500	2018	4,368
5	PROJECT 5	SULAWESI TENGAH	2,500	2018	5,041
6	PROJECT 6	SULAWESI TENGAH	2,500	2018	5,116
7	PROJECT 7	SULAWESI TENGAH	2,500	2018	4,881
8	PROJECT 8	SULAWESI TENGGARA	2,500	2018	4,370
9	PROJECT 9	SULAWESI SELATAN	2,500	2018	4,946
10	PROJECT 10	MALUKU	5,000	2018	6,202
11	PROJECT 11	SUMATERA UTARA	5,000	2018	11,588
12	PROJECT 12	JAWA TIMUR	50,000	2018	38,011
13	PROJECT 13	JAWA TENGAH	40,000	2018	64,793
14	PROJECT 14	JAWA TENGAH	40,000	2018	64,476
15	PROJECT 15	JAWA BARAT	5,000	2019	7,951
16	PROJECT 16	NUSA TENGGARA TIMUR	1,500	2020	6,283
17	PROJECT 17	MALUKU	1,500	2020	3,655
18	PROJECT 18	MALUKU	1,500	2020	3,655
19	PROJECT 19	MALUKU	1,000	2020	3,795
20	PROJECT 20	MALUKU	2,000	2020	4,498
21	PROJECT 21	SUMATERA SELATAN	10,000	2020	20,442
22	PROJECT 22	JAWA BARAT	2,000	2020	6,056
23	PROJECT 23	NUSA TENGGARA TIMUR	1,000	2020	4,805
24	PROJECT 24	JAWA TIMUR	1,500	2020	3,093
25	PROJECT 25	KALIMANTAN TENGAH	3,000	2020	9,133
26	PROJECT 26	KALIMANTAN BARAT	2,500	2020	6,935
27	PROJECT 27	GORONTALO	1,000	2020	4,607
28	PROJECT 28	MALUKU	1,000	2020	3,101
29	PROJECT 29	MALUKU UTARA	1,000	2020	2,632
30	PROJECT 30	MALUKU	1,000	2020	2,402
31	PROJECT 31	KEP. RIAU	2,500	2021	6,786
32	PROJECT 32	ACEH	2,500	2021	10,428
33	PROJECT 33	SUMATERA UTARA	1,000	2021	5,428
34	PROJECT 34	JAWA TENGAH	8,000	2021	15,666
35	PROJECT 35	PAPUA BARAT	2,500	2021	4,798
36	PROJECT 36	SUMATERA UTARA	1,000	2021	5,428
37	PROJECT 37	NUSA TENGGARA BARAT	1,500	2022	5,500
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	3,231
39	PROJECT 39	SULAWESI TENGAH	1,500	2022	4,716
40	PROJECT 40	SULAWESI SELATAN	1,500	2022	4,200
41	PROJECT 41	PAPUA BARAT	2,500	2022	5,528
42	PROJECT 42	BALI	2,000	2023	5,901
43	PROJECT 43	JAWA TIMUR	700	2023	3,998

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NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	PROJECT COST (JAKARTA BASE) (MAT+LABOR) (IN MILLION RUPIAH) BEFORE PROFIT & RISK
44	PROJECT 1 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20,000	2025	65,342
45	PROJECT 2 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20,000	2025	83,313
46	PROJECT 3 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40,000	2025	89,956
47	PROJECT 4 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2,500	2025	9,180
48	PROJECT 5 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2,500	2025	10,593
49	PROJECT 6 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2,500	2025	10,752
50	PROJECT 7 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2,500	2025	10,257
51	PROJECT 8 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGGARA	2,500	2025	9,183
52	PROJECT 9 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2,500	2025	10,395
53	PROJECT 10 - WITH LOG-NORMAL ESCALATION	MALUKU	5,000	2025	13,034
54	PROJECT 11 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	5,000	2025	24,353
55	PROJECT 12 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	50,000	2025	79,881
56	PROJECT 13 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40,000	2025	136,166
57	PROJECT 14 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40,000	2025	135,499
58	PROJECT 15 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	5,000	2025	15,234
59	PROJECT 16 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1,500	2025	9,470
60	PROJECT 17 - WITH LOG-NORMAL ESCALATION	MALUKU	1,500	2025	5,508
61	PROJECT 18 - WITH LOG-NORMAL ESCALATION	MALUKU	1,500	2025	5,508
62	PROJECT 19 - WITH LOG-NORMAL ESCALATION	MALUKU	1,000	2025	5,720
63	PROJECT 20 - WITH LOG-NORMAL ESCALATION	MALUKU	2,000	2025	6,780
64	PROJECT 21 - WITH LOG-NORMAL ESCALATION	SUMATERA SELATAN	10,000	2025	30,811
65	PROJECT 22 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	2,000	2025	9,128
66	PROJECT 23 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1,000	2025	7,242
67	PROJECT 24 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	1,500	2025	4,662
68	PROJECT 25 - WITH LOG-NORMAL ESCALATION	KALIMANTAN TENGAH	3,000	2025	13,765
69	PROJECT 26 - WITH LOG-NORMAL ESCALATION	KALIMANTAN BARAT	2,500	2025	10,453
70	PROJECT 27 - WITH LOG-NORMAL ESCALATION	GORONTALO	1,000	2025	6,943
71	PROJECT 28 - WITH LOG-NORMAL ESCALATION	MALUKU	1,000	2025	4,674
72	PROJECT 29 - WITH LOG-NORMAL ESCALATION	MALUKU UTARA	1,000	2025	3,967
73	PROJECT 30 - WITH LOG-NORMAL ESCALATION	MALUKU	1,000	2025	3,621
74	PROJECT 31 - WITH LOG-NORMAL ESCALATION	KEP. RIAU	2,500	2025	10,058
75	PROJECT 32 - WITH LOG-NORMAL ESCALATION	ACEH	2,500	2025	15,456
76	PROJECT 33 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1,000	2025	8,044
77	PROJECT 34 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	8,000	2025	23,219
78	PROJECT 35 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2,500	2025	7,112
79	PROJECT 36 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1,000	2025	8,044
80	PROJECT 37 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA BARAT	1,500	2025	8,146
81	PROJECT 38 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	500	2025	4,786
82	PROJECT 39 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	1,500	2025	6,985
83	PROJECT 40 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	1,500	2025	6,220
84	PROJECT 41 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2,500	2025	8,187
85	PROJECT 42 - WITH LOG-NORMAL ESCALATION	BALI	2,000	2025	8,140
86	PROJECT 43 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	700	2025	5,515

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APPENDICES C. MODEL 1 BUILD AND ANOVA OUTPUT

NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	COST (ESTIMATED BY MODEL) 1	NORMALIZED ERROR	RESIDUAL SQUARE
1	PROJECT 1	JAWA TENGAH	20000	2018	31,092	26,280	0.024	23,155,006
2	PROJECT 2	JAWA TENGAH	20000	2018	39,643	26,280	0.114	178,572,654
3	PROJECT 3	JAWA TENGAH	40000	2018	42,805	50,163	0.030	54,141,966
4	PROJECT 4	SULAWESI SELATAN	2500	2018	4,368	5,383	0.054	1,029,530
5	PROJECT 5	SULAWESI TENGAH	2500	2018	5,041	5,383	0.005	117,094
6	PROJECT 6	SULAWESI TENGAH	2500	2018	5,116	5,383	0.003	71,179
7	PROJECT 7	SULAWESI TENGAH	2500	2018	4,881	5,383	0.011	252,412
8	PROJECT 8	SULAWESI TENGGARA	2500	2018	4,370	5,383	0.054	1,027,002
9	PROJECT 9	SULAWESI SELATAN	2500	2018	4,946	5,383	0.008	190,533
10	PROJECT 10	MALUKU	5000	2018	6,202	8,368	0.122	4,691,627
11	PROJECT 11	SUMATERA UTARA	5000	2018	11,588	8,368	0.077	10,367,903
12	PROJECT 12	JAWA TIMUR	50000	2018	38,011	62,104	0.402	580,495,189
13	PROJECT 13	JAWA TENGAH	40000	2018	64,793	50,163	0.051	214,039,432
14	PROJECT 14	JAWA TENGAH	40000	2018	64,476	50,163	0.049	204,857,655
15	PROJECT 15	JAWA BARAT	5000	2019	7,951	9,590	0.042	2,683,638
16	PROJECT 16	NUSA TENGGARA TIMUR	1500	2020	6,283	5,296	0.025	974,771
17	PROJECT 17	MALUKU	1500	2020	3,655	5,296	0.202	2,692,858
18	PROJECT 18	MALUKU	1500	2020	3,655	5,296	0.202	2,692,858
19	PROJECT 19	MALUKU	1000	2020	3,795	4,508	0.035	507,684
20	PROJECT 20	MALUKU	2000	2020	4,498	6,084	0.124	2,513,843
21	PROJECT 21	SUMATERA SELATAN	10000	2020	20,442	18,690	0.007	3,070,692
22	PROJECT 22	JAWA BARAT	2000	2020	6,056	6,084	0.000	758
23	PROJECT 23	NUSA TENGGARA TIMUR	1000	2020	4,805	4,508	0.004	88,377
24	PROJECT 24	JAWA TIMUR	1500	2020	3,093	5,296	0.507	4,850,529
25	PROJECT 25	KALIMANTAN TENGAH	3000	2020	9,133	7,659	0.026	2,170,031
26	PROJECT 26	KALIMANTAN BARAT	2500	2020	6,935	6,872	0.000	4,082
27	PROJECT 27	GORONTALO	1000	2020	4,607	4,508	0.000	9,802
28	PROJECT 28	MALUKU	1000	2020	3,101	4,508	0.206	1,979,400
29	PROJECT 29	MALUKU UTARA	1000	2020	2,632	4,508	0.508	3,518,177
30	PROJECT 30	MALUKU	1000	2020	2,402	4,508	0.768	4,432,334
31	PROJECT 31	KEP. RIAU	2500	2021	6,786	7,616	0.015	688,650
32	PROJECT 32	ACEH	2500	2021	10,428	7,616	0.073	7,910,355
33	PROJECT 33	SUMATERA UTARA	1000	2021	5,428	4,966	0.007	213,255
34	PROJECT 34	JAWA TENGAH	8000	2021	15,666	17,332	0.011	2,775,904
35	PROJECT 35	PAPUA BARAT	2500	2021	4,798	7,616	0.345	7,938,357
36	PROJECT 36	SUMATERA UTARA	1000	2021	5,428	4,966	0.007	213,255
37	PROJECT 37	NUSA TENGGARA BARAT	1500	2022	5,500	6,403	0.027	814,630
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	3,231	4,445	0.141	1,473,084
39	PROJECT 39	SULAWESI TENGAH	1500	2022	4,716	6,403	0.128	2,843,109
40	PROJECT 40	SULAWESI SELATAN	1500	2022	4,200	6,403	0.275	4,851,821
41	PROJECT 41	PAPUA BARAT	2500	2022	5,528	8,360	0.263	8,022,757
42	PROJECT 42	BALI	2000	2023	5,901	8,030	0.130	4,534,375
43	PROJECT 43	JAWA TIMUR	700	2023	3,998	5,237	0.096	1,535,104

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NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	COST (ESTIMATED BY MODEL) 1	NORMALIZED ERROR	RESIDUAL SQUARE
44	PROJECT 1 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	65,342	54,869	0.026	109,688,795
45	PROJECT 2 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	83,313	54,869	0.117	809,057,031
46	PROJECT 3 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	89,956	105,469	0.030	240,657,814
47	PROJECT 4 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	9,180	10,593	0.024	1,995,736
48	PROJECT 5 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,593	10,593	0.000	0
49	PROJECT 6 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,752	10,593	0.000	25,272
50	PROJECT 7 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,257	10,593	0.001	113,018
51	PROJECT 8 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGGARA	2500	2025	9,183	10,593	0.024	1,988,343
52	PROJECT 9 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	10,395	10,593	0.000	39,077
53	PROJECT 10 - WITH LOG-NORMAL ESCALATION	MALUKU	5000	2025	13,034	16,918	0.089	15,082,625
54	PROJECT 11 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	5000	2025	24,353	16,918	0.093	55,282,272
55	PROJECT 12 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	50000	2025	79,881	130,770	0.406	2,589,642,070
56	PROJECT 13 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	136,166	105,469	0.051	942,259,855
57	PROJECT 14 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	135,499	105,469	0.049	901,774,500
58	PROJECT 15 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	5000	2025	15,234	16,918	0.012	2,836,964
59	PROJECT 16 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1500	2025	9,470	8,063	0.022	1,979,772
60	PROJECT 17 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,508	8,063	0.215	6,524,966
61	PROJECT 18 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,508	8,063	0.215	6,524,966
62	PROJECT 19 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	5,720	6,798	0.035	1,161,045
63	PROJECT 20 - WITH LOG-NORMAL ESCALATION	MALUKU	2000	2025	6,780	9,328	0.141	6,493,515
64	PROJECT 21 - WITH LOG-NORMAL ESCALATION	SUMATERA SELATAN	10000	2025	30,811	29,568	0.002	1,545,737
65	PROJECT 22 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	2000	2025	9,128	9,328	0.000	40,008
66	PROJECT 23 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1000	2025	7,242	6,798	0.004	197,565
67	PROJECT 24 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	1500	2025	4,662	8,063	0.532	11,563,788
68	PROJECT 25 - WITH LOG-NORMAL ESCALATION	KALIMANTAN TENGAH	3000	2025	13,765	11,858	0.019	3,636,140
69	PROJECT 26 - WITH LOG-NORMAL ESCALATION	KALIMANTAN BARAT	2500	2025	10,453	10,593	0.000	19,510
70	PROJECT 27 - WITH LOG-NORMAL ESCALATION	GORONTALO	1000	2025	6,943	6,798	0.000	21,210
71	PROJECT 28 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	4,674	6,798	0.207	4,511,909
72	PROJECT 29 - WITH LOG-NORMAL ESCALATION	MALUKU UTARA	1000	2025	3,967	6,798	0.509	8,012,676
73	PROJECT 30 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	3,621	6,798	0.770	10,091,885
74	PROJECT 31 - WITH LOG-NORMAL ESCALATION	KEP. RIAU	2500	2025	10,058	10,593	0.003	286,644
75	PROJECT 32 - WITH LOG-NORMAL ESCALATION	ACEH	2500	2025	15,456	10,593	0.099	23,649,026
76	PROJECT 33 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	8,044	6,798	0.024	1,553,628
77	PROJECT 34 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	8000	2025	23,219	24,508	0.003	1,661,251
78	PROJECT 35 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	7,112	10,593	0.240	12,119,618
79	PROJECT 36 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	8,044	6,798	0.024	1,553,628
80	PROJECT 37 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA BARAT	1500	2025	8,146	8,063	0.000	6,923
81	PROJECT 38 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	500	2025	4,786	5,533	0.024	557,796
82	PROJECT 39 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	1500	2025	6,985	8,063	0.024	1,160,714
83	PROJECT 40 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	1500	2025	6,220	8,063	0.088	3,394,453
84	PROJECT 41 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	8,187	10,593	0.086	5,788,422
85	PROJECT 42 - WITH LOG-NORMAL ESCALATION	BALI	2000	2025	8,140	9,328	0.021	1,411,896
86	PROJECT 43 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	700	2025	5,515	6,039	0.009	274,004

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.935374098
R Square	0.874924704
Adjusted R Square	0.873417773
Standard Error	8875.208824
Observations	85

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	45733495113	45733495113	580.6003	3.17687E-39
Residual	83	6537854528	78769331.67		
Total	84	52271349641			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	8.133602618	1166.475634	0.006972801	0.994453	-2311.939518	2328.206723	-2311.939518	2328.206723
52525.97995	0.992128971	0.041174612	24.09564833	3.18E-39	0.910234324	1.074023619	0.910234324	1.074023619

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APPENDICES D. MODEL 2 BUILD AND ANOVA OUTPUT

NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	COST (ESTIMATED BY MODEL) 2	NORMALIZED ERROR	RESIDUAL SQUARE
1	PROJECT 1	JAWA TENGAH	20000	2018	31,092	41,645	0.115	111,356,172
2	PROJECT 2	JAWA TENGAH	20000	2018	39,643	41,645	0.003	4,005,603
3	PROJECT 3	JAWA TENGAH	40000	2018	42,805	73,191	0.504	923,333,189
4	PROJECT 4	SULAWESI SELATAN	2500	2018	4,368	7,175	0.413	7,878,956
5	PROJECT 5	SULAWESI TENGAH	2500	2018	5,041	7,175	0.179	4,556,004
6	PROJECT 6	SULAWESI TENGAH	2500	2018	5,116	7,175	0.162	4,239,827
7	PROJECT 7	SULAWESI TENGAH	2500	2018	4,881	7,175	0.221	5,265,631
8	PROJECT 8	SULAWESI TENGGARA	2500	2018	4,370	7,175	0.412	7,871,961
9	PROJECT 9	SULAWESI SELATAN	2500	2018	4,946	7,175	0.203	4,967,513
10	PROJECT 10	MALUKU	5000	2018	6,202	13,011	1.205	46,363,204
11	PROJECT 11	SUMATERA UTARA	5000	2018	11,588	13,011	0.015	2,025,253
12	PROJECT 12	JAWA TIMUR	50000	2018	38,011	87,477	1.694	2,446,962,533
13	PROJECT 13	JAWA TENGAH	40000	2018	64,793	73,191	0.017	70,529,580
14	PROJECT 14	JAWA TENGAH	40000	2018	64,476	73,191	0.018	75,958,656
15	PROJECT 15	JAWA BARAT	5000	2019	7,951	12,867	0.382	24,157,583
16	PROJECT 16	NUSA TENGGARA TIMUR	1500	2020	6,283	4,325	0.097	3,834,938
17	PROJECT 17	MALUKU	1500	2020	3,655	4,325	0.034	448,898
18	PROJECT 18	MALUKU	1500	2020	3,655	4,325	0.034	448,898
19	PROJECT 19	MALUKU	1000	2020	3,795	2,951	0.050	713,067
20	PROJECT 20	MALUKU	2000	2020	4,498	5,633	0.064	1,288,464
21	PROJECT 21	SUMATERA SELATAN	10000	2020	20,442	23,115	0.017	7,143,214
22	PROJECT 22	JAWA BARAT	2000	2020	6,056	5,633	0.005	178,815
23	PROJECT 23	NUSA TENGGARA TIMUR	1000	2020	4,805	2,951	0.149	3,438,185
24	PROJECT 24	JAWA TIMUR	1500	2020	3,093	4,325	0.158	1,516,338
25	PROJECT 25	KALIMANTAN TENGAH	3000	2020	9,133	8,116	0.012	1,034,054
26	PROJECT 26	KALIMANTAN BARAT	2500	2020	6,935	6,893	0.000	1,756
27	PROJECT 27	GORONTALO	1000	2020	4,607	2,951	0.129	2,742,202
28	PROJECT 28	MALUKU	1000	2020	3,101	2,951	0.002	22,512
29	PROJECT 29	MALUKU UTARA	1000	2020	2,632	2,951	0.015	101,588
30	PROJECT 30	MALUKU	1000	2020	2,402	2,951	0.052	300,697
31	PROJECT 31	KEP. RIAU	2500	2021	6,786	6,817	0.000	980
32	PROJECT 32	ACEH	2500	2021	10,428	6,817	0.120	13,039,877
33	PROJECT 33	SUMATERA UTARA	1000	2021	5,428	2,875	0.221	6,517,864
34	PROJECT 34	JAWA TENGAH	8000	2021	15,666	19,031	0.046	11,322,674
35	PROJECT 35	PAPUA BARAT	2500	2021	4,798	6,817	0.177	4,076,229
36	PROJECT 36	SUMATERA UTARA	1000	2021	5,428	2,875	0.221	6,517,864
37	PROJECT 37	NUSA TENGGARA BARAT	1500	2022	5,500	4,403	0.040	1,202,843
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	3,231	1,554	0.270	2,814,882
39	PROJECT 39	SULAWESI TENGAH	1500	2022	4,716	4,403	0.004	98,068
40	PROJECT 40	SULAWESI SELATAN	1500	2022	4,200	4,403	0.002	41,361
41	PROJECT 41	PAPUA BARAT	2500	2022	5,528	6,972	0.068	2,086,379
42	PROJECT 42	BALI	2000	2023	5,901	6,482	0.010	337,610
43	PROJECT 43	JAWA TIMUR	700	2023	3,998	2,930	0.071	1,140,577

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NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	COST (ESTIMATED BY MODEL) 2	NORMALIZED ERROR	RESIDUAL SQUARE
44	PROJECT 1 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	62,538	48,912	0.063	269,928,721
45	PROJECT 2 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	79,738	48,912	0.170	1,183,373,319
46	PROJECT 3 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	86,097	80,459	0.011	90,203,789
47	PROJECT 4 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	8,786	14,443	0.329	27,695,622
48	PROJECT 5 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,139	14,443	0.132	14,818,155
49	PROJECT 6 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,291	14,443	0.118	13,623,385
50	PROJECT 7 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	9,817	14,443	0.167	17,523,759
51	PROJECT 8 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGGARA	2500	2025	8,789	14,443	0.328	27,668,062
52	PROJECT 9 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	9,949	14,443	0.152	16,383,367
53	PROJECT 10 - WITH LOG-NORMAL ESCALATION	MALUKU	5000	2025	12,475	20,279	0.309	52,483,682
54	PROJECT 11 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	5000	2025	23,308	20,279	0.028	16,599,743
55	PROJECT 12 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	50000	2025	76,454	94,745	0.035	220,930,706
56	PROJECT 13 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	130,323	80,459	0.167	3,103,266,366
57	PROJECT 14 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	129,685	80,459	0.165	3,029,432,169
58	PROJECT 15 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	5000	2025	14,580	20,279	0.110	25,454,605
59	PROJECT 16 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1500	2025	9,064	11,874	0.064	5,779,956
60	PROJECT 17 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,272	11,874	1.335	40,520,848
61	PROJECT 18 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,272	11,874	1.335	40,520,848
62	PROJECT 19 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	5,475	10,500	0.698	22,847,147
63	PROJECT 20 - WITH LOG-NORMAL ESCALATION	MALUKU	2000	2025	6,489	13,183	0.892	40,997,307
64	PROJECT 21 - WITH LOG-NORMAL ESCALATION	SUMATERA SELATAN	10000	2025	29,489	30,665	0.000	21,595
65	PROJECT 22 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	2000	2025	8,736	13,183	0.197	16,440,568
66	PROJECT 23 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1000	2025	6,932	10,500	0.202	10,613,702
67	PROJECT 24 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	1500	2025	4,462	11,874	2.393	52,009,404
68	PROJECT 25 - WITH LOG-NORMAL ESCALATION	KALIMANTAN TENGAH	3000	2025	13,174	15,665	0.019	3,610,801
69	PROJECT 26 - WITH LOG-NORMAL ESCALATION	KALIMANTAN BARAT	2500	2025	10,005	14,443	0.146	15,917,188
70	PROJECT 27 - WITH LOG-NORMAL ESCALATION	GORONTALO	1000	2025	6,646	10,500	0.262	12,650,209
71	PROJECT 28 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	4,473	10,500	1.554	33,947,826
72	PROJECT 29 - WITH LOG-NORMAL ESCALATION	MALUKU UTARA	1000	2025	3,797	10,500	2.712	42,680,325
73	PROJECT 30 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	3,466	10,500	3.609	47,322,343
74	PROJECT 31 - WITH LOG-NORMAL ESCALATION	KEP. RIAU	2500	2025	9,626	14,443	0.190	19,231,291
75	PROJECT 32 - WITH LOG-NORMAL ESCALATION	ACEH	2500	2025	14,793	14,443	0.004	1,026,308
76	PROJECT 33 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	7,699	10,500	0.093	6,031,469
77	PROJECT 34 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	8000	2025	22,223	26,657	0.022	11,817,307
78	PROJECT 35 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	6,806	14,443	1.063	53,747,695
79	PROJECT 36 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	7,699	10,500	0.093	6,031,469
80	PROJECT 37 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA BARAT	1500	2025	7,797	11,874	0.209	13,897,918
81	PROJECT 38 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	500	2025	4,581	9,024	0.784	17,964,294
82	PROJECT 39 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	1500	2025	6,686	11,874	0.490	23,898,038
83	PROJECT 40 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	1500	2025	5,954	11,874	0.826	31,963,212
84	PROJECT 41 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	7,836	14,443	0.584	39,135,932
85	PROJECT 42 - WITH LOG-NORMAL ESCALATION	BALI	2000	2025	7,783	13,183	0.384	25,430,925
86	PROJECT 43 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	700	2025	5,274	9,631	0.557	16,939,151

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.89279186
R Square	0.797077305
Adjusted R Square	0.794632453
Standard Error	11304.67605
Observations	85

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	41664306490	41664306490	326.0228	1.75094E-30
Residual	83	10607043151	127795700.6		
Total	84	52271349641			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2381.020902	1589.486143	-1.49798154	0.137932	-5542.444912	780.4031077	-5542.444912	780.4031077
47485.22323	1.04421305	0.057831594	18.05610024	1.75E-30	0.929188336	1.159237763	0.929188336	1.159237763

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APPENDICES E. MODEL 3 BUILD AND ANOVA OUTPUT

NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	COST (ESTIMATED BY MODEL) 3	NORMALIZED ERROR	RESIDUAL SQUARE
1	PROJECT 1	JAWA TENGAH	20000	2018	31,092	51,043	0.412	398,021,880
2	PROJECT 2	JAWA TENGAH	20000	2018	39,643	51,043	0.083	129,945,014
3	PROJECT 3	JAWA TENGAH	40000	2018	42,805	72,865	0.493	903,628,315
4	PROJECT 4	SULAWESI SELATAN	2500	2018	4,368	500	0.784	14,963,666
5	PROJECT 5	SULAWESI TENGAH	2500	2018	5,041	500	0.811	20,618,481
6	PROJECT 6	SULAWESI TENGAH	2500	2018	5,116	500	0.814	21,308,875
7	PROJECT 7	SULAWESI TENGAH	2500	2018	4,881	500	0.806	19,189,142
8	PROJECT 8	SULAWESI TENGGARA	2500	2018	4,370	500	0.784	14,973,309
9	PROJECT 9	SULAWESI SELATAN	2500	2018	4,946	500	0.808	19,770,880
10	PROJECT 10	MALUKU	5000	2018	6,202	9,517	0.286	10,990,265
11	PROJECT 11	SUMATERA UTARA	5000	2018	11,588	9,517	0.032	4,288,140
12	PROJECT 12	JAWA TIMUR	50000	2018	38,011	69,400	0.682	985,296,235
13	PROJECT 13	JAWA TENGAH	40000	2018	64,793	72,865	0.016	65,160,447
14	PROJECT 14	JAWA TENGAH	40000	2018	64,476	72,865	0.017	70,382,692
15	PROJECT 15	JAWA BARAT	5000	2019	7,951	12,567	0.337	21,304,334
16	PROJECT 16	NUSA TENGGARA TIMUR	1500	2020	6,283	2,423	0.377	14,897,358
17	PROJECT 17	MALUKU	1500	2020	3,655	2,423	0.114	1,516,375
18	PROJECT 18	MALUKU	1500	2020	3,655	2,423	0.114	1,516,375
19	PROJECT 19	MALUKU	1000	2020	3,795	500	0.754	10,858,741
20	PROJECT 20	MALUKU	2000	2020	4,498	4,323	0.002	30,793
21	PROJECT 21	SUMATERA SELATAN	10000	2020	20,442	31,453	0.290	121,235,325
22	PROJECT 22	JAWA BARAT	2000	2020	6,056	4,323	0.082	3,004,849
23	PROJECT 23	NUSA TENGGARA TIMUR	1000	2020	4,805	500	0.803	18,533,557
24	PROJECT 24	JAWA TIMUR	1500	2020	3,093	2,423	0.047	448,918
25	PROJECT 25	KALIMANTAN TENGAH	3000	2020	9,133	8,049	0.014	1,173,201
26	PROJECT 26	KALIMANTAN BARAT	2500	2020	6,935	6,198	0.011	543,796
27	PROJECT 27	GORONTALO	1000	2020	4,607	500	0.795	16,865,699
28	PROJECT 28	MALUKU	1000	2020	3,101	500	0.704	6,764,516
29	PROJECT 29	MALUKU UTARA	1000	2020	2,632	500	0.656	4,545,848
30	PROJECT 30	MALUKU	1000	2020	2,402	500	0.627	3,619,388
31	PROJECT 31	KEP. RIAU	2500	2021	6,786	8,445	0.060	2,751,565
32	PROJECT 32	ACEH	2500	2021	10,428	8,445	0.036	3,934,671
33	PROJECT 33	SUMATERA UTARA	1000	2021	5,428	2,747	0.244	7,186,896
34	PROJECT 34	JAWA TENGAH	8000	2021	15,666	27,492	0.570	139,854,414
35	PROJECT 35	PAPUA BARAT	2500	2021	4,798	8,445	0.578	13,296,553
36	PROJECT 36	SUMATERA UTARA	1000	2021	5,428	2,747	0.244	7,186,896
37	PROJECT 37	NUSA TENGGARA BARAT	1500	2022	5,500	6,515	0.034	1,030,841
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	3,231	2,645	0.033	344,076
39	PROJECT 39	SULAWESI TENGAH	1500	2022	4,716	6,515	0.145	3,235,995
40	PROJECT 40	SULAWESI SELATAN	1500	2022	4,200	6,515	0.304	5,361,169
41	PROJECT 41	PAPUA BARAT	2500	2022	5,528	10,290	0.742	22,680,095
42	PROJECT 42	BALI	2000	2023	5,901	9,858	0.450	15,662,794
43	PROJECT 43	JAWA TIMUR	700	2023	3,998	4,870	0.048	760,363

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NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	COST (ESTIMATED BY MODEL) 3	NORMALIZED ERROR	RESIDUAL SQUARE
44	PROJECT 1 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	62,538	63,959	0.000	1,910,948
45	PROJECT 2 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	79,738	63,959	0.054	374,540,794
46	PROJECT 3 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	86,097	85,782	0.002	17,425,279
47	PROJECT 4 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	8,786	13,417	0.213	17,948,951
48	PROJECT 5 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,139	13,417	0.071	7,971,547
49	PROJECT 6 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,291	13,417	0.061	7,101,928
50	PROJECT 7 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	9,817	13,417	0.095	9,986,208
51	PROJECT 8 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGGARA	2500	2025	8,789	13,417	0.213	17,926,766
52	PROJECT 9 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	9,949	13,417	0.084	9,130,033
53	PROJECT 10 - WITH LOG-NORMAL ESCALATION	MALUKU	5000	2025	12,475	22,434	0.520	88,357,385
54	PROJECT 11 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	5000	2025	23,308	22,434	0.006	3,682,483
55	PROJECT 12 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	50000	2025	76,454	82,317	0.001	5,932,047
56	PROJECT 13 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	130,323	85,782	0.137	2,538,523,364
57	PROJECT 14 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	129,685	85,782	0.135	2,471,787,037
58	PROJECT 15 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	5000	2025	14,580	22,434	0.223	51,847,982
59	PROJECT 16 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1500	2025	9,064	9,642	0.000	29,661
60	PROJECT 17 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,272	9,642	0.563	17,087,222
61	PROJECT 18 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,272	9,642	0.563	17,087,222
62	PROJECT 19 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	5,475	7,719	0.122	3,994,090
63	PROJECT 20 - WITH LOG-NORMAL ESCALATION	MALUKU	2000	2025	6,489	11,541	0.493	22,674,829
64	PROJECT 21 - WITH LOG-NORMAL ESCALATION	SUMATERA SELATAN	10000	2025	29,489	38,672	0.065	61,788,066
65	PROJECT 22 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	2000	2025	8,736	11,541	0.070	5,825,429
66	PROJECT 23 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1000	2025	6,932	7,719	0.004	227,072
67	PROJECT 24 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	1500	2025	4,462	9,642	1.141	24,798,658
68	PROJECT 25 - WITH LOG-NORMAL ESCALATION	KALIMANTAN TENGAH	3000	2025	13,174	15,268	0.012	2,260,306
69	PROJECT 26 - WITH LOG-NORMAL ESCALATION	KALIMANTAN BARAT	2500	2025	10,005	13,417	0.080	8,782,879
70	PROJECT 27 - WITH LOG-NORMAL ESCALATION	GORONTALO	1000	2025	6,646	7,719	0.012	601,193
71	PROJECT 28 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	4,473	7,719	0.425	9,272,812
72	PROJECT 29 - WITH LOG-NORMAL ESCALATION	MALUKU UTARA	1000	2025	3,797	7,719	0.894	14,075,036
73	PROJECT 30 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	3,466	7,719	1.281	16,791,774
74	PROJECT 31 - WITH LOG-NORMAL ESCALATION	KEP. RIAU	2500	2025	9,626	13,417	0.112	11,284,942
75	PROJECT 32 - WITH LOG-NORMAL ESCALATION	ACEH	2500	2025	14,793	13,417	0.017	4,157,975
76	PROJECT 33 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	7,699	7,719	0.002	105,913
77	PROJECT 34 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	8000	2025	22,223	32,464	0.159	85,473,713
78	PROJECT 35 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	6,806	13,417	0.786	39,756,041
79	PROJECT 36 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	7,699	7,719	0.002	105,913
80	PROJECT 37 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA BARAT	1500	2025	7,797	9,642	0.034	2,238,201
81	PROJECT 38 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	500	2025	4,581	5,772	0.042	971,480
82	PROJECT 39 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	1500	2025	6,686	9,642	0.145	7,057,696
83	PROJECT 40 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	1500	2025	5,954	9,642	0.303	11,707,841
84	PROJECT 41 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	7,836	13,417	0.408	27,351,112
85	PROJECT 42 - WITH LOG-NORMAL ESCALATION	BALI	2000	2025	7,783	11,541	0.175	11,572,269
86	PROJECT 43 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	700	2025	5,274	6,553	0.035	1,077,441

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.921482212
R Square	0.849129466
Adjusted R Square	0.847311749
Standard Error	9747.539948
Observations	85

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	44385143232	44385143232	467.1406	7.72301E-36
Residual	83	7886206409	95014535.05		
Total	84	52271349641			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1443.379293	1326.778861	-1.08788234	0.279796	-4082.289085	1195.530499	-4082.289085	1195.530499
62919.07819	1.030187034	0.047664198	21.61343474	7.72E-36	0.935384861	1.124989207	0.935384861	1.124989207

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APPENDICES F. MODEL 4 BUILD AND ANOVA OUTPUT

NO.	PROJECT NAME	REGION	CAPACITY (KL)	YEAR	COST (MAT+LABOR) (IN MILLION)	LN (COST ACTUAL)	LN (CAPACITY)	LN (YEAR)	LN COST (ESTIMATED BY MODEL) 4	NORMALIZED ERROR	RESIDUAL SQUARE	COST (ESTIMATED BY MODEL) 4 (EXP)	NORMALIZED ERROR	RESIDUAL SQUARE
1	PROJECT 1	JAWA TENGAH	20000	2018	31,092	10.345	9.903	0.000	10.211	0.000	0.018	27,189	0.016	15,234,003
2	PROJECT 2	JAWA TENGAH	20000	2018	39,643	10.588	9.903	0.000	10.211	0.001	0.142	27,189	0.099	155,107,574
3	PROJECT 3	JAWA TENGAH	40000	2018	42,805	10.664	10.597	0.000	10.752	0.000	0.008	46,731	0.008	15,414,302
4	PROJECT 4	SULAWESI SELATAN	2500	2018	4,368	8.382	7.824	0.000	8.586	0.001	0.041	5,355	0.051	973,856
5	PROJECT 5	SULAWESI TENGAH	2500	2018	5,041	8.525	7.824	0.000	8.586	0.000	0.004	5,355	0.004	98,831
6	PROJECT 6	SULAWESI TENGAH	2500	2018	5,116	8.540	7.824	0.000	8.586	0.000	0.002	5,355	0.002	57,110
7	PROJECT 7	SULAWESI TENGAH	2500	2018	4,881	8.493	7.824	0.000	8.586	0.000	0.009	5,355	0.009	225,236
8	PROJECT 8	SULAWESI TENGGARA	2500	2018	4,370	8.382	7.824	0.000	8.586	0.001	0.041	5,355	0.051	971,398
9	PROJECT 9	SULAWESI SELATAN	2500	2018	4,946	8.506	7.824	0.000	8.586	0.000	0.006	5,355	0.007	167,024
10	PROJECT 10	MALUKU	5000	2018	6,202	8.733	8.517	0.000	9.127	0.002	0.156	9,204	0.234	9,010,704
11	PROJECT 11	SUMATERA UTARA	5000	2018	11,588	9.358	8.517	0.000	9.127	0.001	0.053	9,204	0.042	5,684,199
12	PROJECT 12	JAWA TIMUR	50000	2018	38,011	10.546	10.820	0.000	10.927	0.001	0.145	55,632	0.215	310,506,102
13	PROJECT 13	JAWA TENGAH	40000	2018	64,793	11.079	10.597	0.000	10.752	0.001	0.107	46,731	0.078	326,239,594
14	PROJECT 14	JAWA TENGAH	40000	2018	64,476	11.074	10.597	0.000	10.752	0.001	0.104	46,731	0.076	314,880,291
15	PROJECT 15	JAWA BARAT	5000	2019	7,951	8.981	8.517	1.000	9.228	0.001	0.061	10,177	0.078	4,952,335
16	PROJECT 16	NUSA TENGGARA TIMUR	1500	2020	6,283	8.746	7.313	2.000	8.388	0.002	0.128	4,392	0.091	3,574,377
17	PROJECT 17	MALUKU	1500	2020	3,655	8.204	7.313	2.000	8.388	0.001	0.034	4,392	0.041	544,195
18	PROJECT 18	MALUKU	1500	2020	3,655	8.204	7.313	2.000	8.388	0.001	0.034	4,392	0.041	544,195
19	PROJECT 19	MALUKU	1000	2020	3,795	8.242	6.908	2.000	8.071	0.000	0.029	3,200	0.025	354,659
20	PROJECT 20	MALUKU	2000	2020	4,498	8.411	7.601	2.000	8.612	0.001	0.040	5,499	0.050	1,002,777
21	PROJECT 21	SUMATERA SELATAN	10000	2020	20,442	9.925	9.210	2.000	9.870	0.000	0.003	19,340	0.003	1,215,340
22	PROJECT 22	JAWA BARAT	2000	2020	6,056	8.709	7.601	2.000	8.612	0.000	0.009	5,499	0.008	309,784
23	PROJECT 23	NUSA TENGGARA TIMUR	1000	2020	4,805	8.477	6.908	2.000	8.071	0.002	0.165	3,200	0.112	2,577,097
24	PROJECT 24	JAWA TIMUR	1500	2020	3,093	8.037	7.313	2.000	8.388	0.002	0.123	4,392	0.176	1,687,646
25	PROJECT 25	KALIMANTAN TENGAH	3000	2020	9,133	9.120	8.006	2.000	8.929	0.000	0.036	7,549	0.030	2,506,440
26	PROJECT 26	KALIMANTAN BARAT	2500	2020	6,935	8.844	7.824	2.000	8.787	0.000	0.003	6,547	0.003	150,863
27	PROJECT 27	GORONTALO	1000	2020	4,607	8.435	6.908	2.000	8.071	0.002	0.133	3,200	0.093	1,979,815
28	PROJECT 28	MALUKU	1000	2020	3,101	8.039	6.908	2.000	8.071	0.000	0.001	3,200	0.001	9,773
29	PROJECT 29	MALUKU UTARA	1000	2020	2,632	7.876	6.908	2.000	8.071	0.001	0.038	3,200	0.047	322,202
30	PROJECT 30	MALUKU	1000	2020	2,402	7.784	6.908	2.000	8.071	0.001	0.082	3,200	0.110	635,622
31	PROJECT 31	KEP. RIAU	2500	2021	6,786	8.823	7.824	3.000	8.887	0.000	0.004	7,239	0.004	205,242
32	PROJECT 32	ACEH	2500	2021	10,428	9.252	7.824	3.000	8.887	0.002	0.133	7,239	0.094	10,171,943
33	PROJECT 33	SUMATERA UTARA	1000	2021	5,428	8.599	6.908	3.000	8.171	0.002	0.183	3,538	0.121	3,570,826
34	PROJECT 34	JAWA TENGAH	8000	2021	15,666	9.659	8.987	3.000	9.796	0.000	0.019	17,963	0.021	5,273,635
35	PROJECT 35	PAPUA BARAT	2500	2021	4,798	8.476	7.824	3.000	8.887	0.002	0.169	7,239	0.259	5,956,997
36	PROJECT 36	SUMATERA UTARA	1000	2021	5,428	8.599	6.908	3.000	8.171	0.002	0.183	3,538	0.121	3,570,826
37	PROJECT 37	NUSA TENGGARA BARAT	1500	2022	5,500	8.613	7.313	4.000	8.589	0.000	0.001	5,370	0.001	16,904
38	PROJECT 38	NUSA TENGGARA TIMUR	500	2022	3,231	8.081	6.215	4.000	7.730	0.002	0.123	2,276	0.087	912,645
39	PROJECT 39	SULAWESI TENGAH	1500	2022	4,716	8.459	7.313	4.000	8.589	0.000	0.017	5,370	0.019	427,152
40	PROJECT 40	SULAWESI SELATAN	1500	2022	4,200	8.343	7.313	4.000	8.589	0.001	0.060	5,370	0.078	1,369,136
41	PROJECT 41	PAPUA BARAT	2500	2022	5,528	8.618	7.824	4.000	8.988	0.002	0.137	8,004	0.201	6,132,966
42	PROJECT 42	BALI	2000	2023	5,901	8.683	7.601	5.000	8.914	0.001	0.053	7,434	0.068	2,351,106
43	PROJECT 43	JAWA TIMUR	700	2023	3,998	8.294	6.551	5.000	8.094	0.001	0.040	3,273	0.033	525,628
44	PROJECT 1 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	62,538	11.087	9.903	7.000	10.914	0.000	0.030	54,934	0.025	108,316,774
45	PROJECT 2 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	20000	2025	79,738	11.330	9.903	7.000	10.914	0.001	0.173	54,934	0.116	805,323,396
46	PROJECT 3 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	86,097	11.407	10.597	7.000	11.455	0.000	0.002	94,417	0.002	19,901,403
47	PROJECT 4 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	8,786	9.125	7.824	7.000	9.289	0.000	0.027	10,820	0.032	2,688,300
48	PROJECT 5 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,139	9.268	7.824	7.000	9.289	0.000	0.000	10,820	0.000	51,246
49	PROJECT 6 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	10,291	9.283	7.824	7.000	9.289	0.000	0.000	10,820	0.000	4,614
50	PROJECT 7 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	2500	2025	9,817	9.236	7.824	7.000	9.289	0.000	0.003	10,820	0.003	317,059
51	PROJECT 8 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGGARA	2500	2025	8,789	9.125	7.824	7.000	9.289	0.000	0.027	10,820	0.032	2,679,718
52	PROJECT 9 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	2500	2025	9,949	9.249	7.824	7.000	9.289	0.000	0.002	10,820	0.002	180,266
53	PROJECT 10 - WITH LOG-NORMAL ESCALATION	MALUKU	5000	2025	12,475	9.475	8.517	7.000	9.831	0.001	0.126	18,596	0.182	30,935,507
54	PROJECT 11 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	5000	2025	23,308	10.100	8.517	7.000	9.831	0.001	0.073	18,596	0.056	33,141,561
55	PROJECT 12 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	50000	2025	76,454	11.288	10.820	7.000	11.630	0.001	0.117	112,401	0.166	1,057,561,859
56	PROJECT 13 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	130,323	11.822	10.597	7.000	11.455	0.001	0.134	94,417	0.094	1,742,920,747
57	PROJECT 14 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	40000	2025	129,685	11.817	10.597	7.000	11.455	0.001	0.130	94,417	0.092	1,687,698,786
58	PROJECT 15 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	5000	2025	14,580	9.631	8.517	7.000	9.831	0.000	0.040	18,596	0.049	11,307,503
59	PROJECT 16 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1500	2025	9,064	9.156	7.313	7.000	8.890	0.001	0.071	7,259	0.055	4,887,946
60	PROJECT 17 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,272	8.614	7.313	7.000	8.890	0.001	0.076	7,259	0.101	3,064,513
61	PROJECT 18 - WITH LOG-NORMAL ESCALATION	MALUKU	1500	2025	5,272	8.614	7.313	7.000	8.890	0.001	0.076	7,259	0.101	3,064,513
62	PROJECT 19 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	5,475	8.652	6.908	7.000	8.573	0.000	0.006	5,288	0.006	186,909
63	PROJECT 20 - WITH LOG-NORMAL ESCALATION	MALUKU	2000	2025	6,489	8.822	7.601	7.000	9.115	0.001	0.086	9,089	0.116	5,331,484
64	PROJECT 21 - WITH LOG-NORMAL ESCALATION	SUMATERA SELATAN	10000	2025	29,489	10.336	9.210	7.000	10.372	0.000	0.001	31,962	0.001	1,323,967
65	PROJECT 22 - WITH LOG-NORMAL ESCALATION	JAWA BARAT	2000	2025	8,736	9.119	7.601	7.000	9.115	0.000	0.000	9,089	0.000	1,538
66	PROJECT 23 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	1000	2025	6,932	8.888	6.908	7.000	8.573	0.001	0.099	5,288	0.073	3,819,409
67	PROJECT 24 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	1500	2025	4,462	8.447	7.313	7.000	8.890	0.003	0.196	7,259	0.310	6,743,011
68	PROJECT 25 - WITH LOG-NORMAL ESCALATION	KALIMANTAN TENGAH	3000	2025	13,174	9.530	8.006	7.000	9.432	0.000	0.010	12,476	0.009	1,660,109
69	PROJECT 26 - WITH LOG-NORMAL ESCALATION	KALIMANTAN BARAT	2500	2025	10,005	9.255	7.824	7.000	9.289	0.000	0.001	10,820	0.001	134,378
70	PROJECT 27 - WITH LOG-NORMAL ESCALATION	GORONTALO	1000	2025	6,646	8.846	6.908	7.000	8.573	0.001	0.074	5,288	0.057	2,740,632
71	PROJECT 28 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	4,473	8.450	6.908	7.000	8.573	0.000	0.015	5,288	0.017	377,337
72	PROJECT 29 - WITH LOG-NORMAL ESCALATION	MALUKU UTARA	1000	2025	3,797	8.286	6.908	7.000	8.573	0.001	0.083	5,288	0.111	1,744,564
73	PROJECT 30 - WITH LOG-NORMAL ESCALATION	MALUKU	1000	2025	3,466	8.195	6.908	7.000	8.573	0.002	0.143	5,288	0.212	2,778,639
74	PROJECT 31 - WITH LOG-NORMAL ESCALATION	KEP. RIAU	2500	2025	9,626	9.216	7.824	7.000	9.289	0.000	0.005	10,820	0.006	581,086
75	PROJECT 32 - WITH LOG-NORMAL ESCALATION	ACEH	2500	2025	14,793	9.646	7.824	7.000	9.289	0.001	0.127	10,820	0.090	21,493,684
76	PROJECT 33 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	7,699	8.993	6.908	7.000	8.573	0.002	0.176	5,288	0.117	7,597,155
77	PROJECT 34 - WITH LOG-NORMAL ESCALATION	JAWA TENGAH	8000	2025	22,223	10.053	8.987	7.000	10.198	0.000	0.021	26,848	0.024	13,169,558
78	PROJECT 35 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	6,806	8.869	7.824	7.000	9.289	0.002	0.176	10,820	0.272	13,750,914
79	PROJECT 36 - WITH LOG-NORMAL ESCALATION	SUMATERA UTARA	1000	2025	7,699	8.993	6.908	7.000	8.573	0.002	0.176	5,288	0.117	7,597,155
80	PROJECT 37 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA BARAT	1500	2025	7,797	9.005	7.313	7.000	8.890	0.000	0.013	7,259	0.012	786,827
81	PROJECT 38 - WITH LOG-NORMAL ESCALATION	NUSA TENGGARA TIMUR	500	2025	4,581	8.473	6.215	7.000	8.032	0.003	0.195	3,077	0.128	2,921,642
82	PROJECT 39 - WITH LOG-NORMAL ESCALATION	SULAWESI TENGAH	1500	2025	6,686	8.852	7.313	7.000	8.890	0.000	0.001	7,259	0.002	74,823
83	PROJECT 40 - WITH LOG-NORMAL ESCALATION	SULAWESI SELATAN	1500	2025	5,954	8.736	7.313	7.000	8.890	0.000	0.024	7,259	0.028	1,078,644
84	PROJECT 41 - WITH LOG-NORMAL ESCALATION	PAPUA BARAT	2500	2025	7,836	9.010	7.824	7.000	9.289	0.001	0.078	10,820	0.103	6,931,701
85	PROJECT 42 - WITH LOG-NORMAL ESCALATION	BALI	2000	2025	7,783	9.005	7.601	7.000	9.115	0.000	0.012	9,089	0.014	900,592
86	PROJECT 43 - WITH LOG-NORMAL ESCALATION	JAWA TIMUR	700	2025	5,274	8.615	6.551	7.000	8.295	0.001	0.103	4,002	0.075	2,290,807

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SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.958214274
R Square	0.918174594
Adjusted R Square	0.917188746
Standard Error	0.26479206
Observations	85

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	65.30179424	65.30179424	931.3548853	6.98289E-47
Residual	83	5.819531317	0.070114835		
Total	84	71.12132555			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.100120891	0.302534865	-0.330940009	0.741523831	-0.701850569	0.501608787	-0.701850569	0.501608787
10.97731302	0.999230285	0.03274221	30.5181075	6.98289E-47	0.934107346	1.064353224	0.934107346	1.064353224

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About the Author

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Samuel Yonathan Montang is an engineer with 8 (eight) years of professional experience in the oil and gas sectors. He works as an engineer at Indonesia's largest National Oil Company. During his career, he has an experience as a Design Engineer and Cost Estimator. He has been involved in several projects, including Fuel Terminal Facilities, Aviation Fuel Supply Facilities, Piping/Pipeline Construction, and Jetty Facilities throughout South Sumatera, Java, Bali, and Nusa Tenggara Island.

He holds a bachelor's degree in Engineering Physics from Bandung Institute of Technology (ITB), a master's degree in Master of Business Administration (MBA) from Gadjah Mada University (UGM), and a certified engineer from The Institution of Engineers Indonesia (PII).

He is attending a distance learning mentoring course under the tutorage of Dr. Paul D. Giammalvo, CDT, CCE, MScPM, MRICS, Senior Technical Advisor to PT. Mitratata Citragraha (PTMC), to attain Certified Cost Professional certification from AACE International.

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