Modifying The Lang Factor using Process Plant Project Data Cost in PERTAMINA for more Precision, Valid, & Reliable AACE Class 4 Estimation Purpose in Indonesia[1]

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Abstract

Lang Factor is Conceptual Estimating Method for estimating Total Plant Cost (TPC) by multiplying a Factor (f) by its Total Equipment Cost (TEC). Hans Lang introduced this Concept in 1947 (70+ years ago). Many things have changed since Hans Lang introduced this Concept, such as Modern construction techniques, computerized design practices, Etc. For its current implementation, the Author needs to research the correlation between TPC and TEC and the most appropriate lang factor range value to be applied in Class 4 Estimation. To address this issue, the Author Collected 92 of PERTAMINA's Project Data Costs from 2017 to 2022. The range of TPC Value starts from $12.2 million to $1.1 Billion and processes it using Cost Estimating Relationship (CER) and Monte Carlo Simulation. The study's findings show a very strong correlation between TPC and TEC. The authors chose the 3.00 to 5.33 range as a precise, valid, and reliable range to be utilized as an updated Lang factor that will be used to estimate Class 4 AACE for liquid processing plant costs in Indonesia.

Keywords: Lang Factor, Cost Estimating, Class IV Estimation, Equipment Factor, Top-Down Estimate, Project Screening, Concept Evaluation, Feasibility Study, Cost Estimating Relationship, Montecarlo Simulation.

Introduction

Cost Estimation Philosophy

"A cost estimate is a Compilation of all the potential costs related to the project or effort components that fall within a specified range. An investment choice, project, or activity's resources must be quantified, budgeted, and valued using the predictive process known as cost estimation. Cost estimation is a method for predicting ambiguous future costs. In that regard, cost estimating minimizes the estimate's uncertainty, given the scope definition level and quality. An expected and probabilistic cost distribution are desired

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outcomes of cost estimating. The accuracy of cost estimating is increased using previous reference cost data as a prediction procedure (where applicable)."[2]

"An estimate's scope and level of information are determined by its intended usage, which also defines its purpose. There are two general uses for cost estimates: (1) to support managers in analyzing projects performance and affordability and the choice of alternative systems and methods, and (2) to facilitate the budgeting process by presenting estimates of the funds required to implement a program. More specific applications for cost estimates include providing data for trade studies, independent reviews, and baseline changes."[3]

AACE Class Estimation

In the Recommended Practice 18R-97 document, AACE International has classified the Cost Estimate Matrix for Process Industries as shown in the table below:

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Table 1. Cost Estimate Classification Matrix for Process Industries[4]

[2] AACE International, Recommended Practice No. 46R-11. (2013). Required Skills And Knowledge of Project Cost Estimating, Page 1 of 21, AACE International, Morgantown, WV.
[3] United States Government Accountability Office (2020). GAO Cost Estimating and Assessment Guide, Best Practices for Developing and Managing Program Costs. Page 38.
[4] AACE International, Recommended Practice No. 18R-97. (2013). Cost Estimate Classification System, Page 3 of 10, AACE International, Morgantown, WV.

Table 1 illustrates typical ranges of accuracy ranges that are associated with the process industries. Depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall into the fields identified (although extreme risks can lead to more comprehensive ranges).[5]

Class 4 estimations typically have wide accuracy ranges and are developed with limited information. They are usually applied for project screening, feasibility analysis, concept assessment, and advanced budget approval. Typically, engineering is from 1% to 15% complete and would comprise, at a minimum, the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for central process systems, and preliminary engineered process and utility equipment lists. Class 4 estimates generally use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.[6]

Problem Statement

In the last four (4) years, there have been so many Feasibility Study activities for EPC Process Plant Projects in Indonesia. Below are some of the Study & EPC projects in Indonesia:

[5] AACE International, Recommended Practice No. 18R-97. (2013). Cost Estimate Classification System, Page 4 of 10, AACE International, Morgantown, WV.
[6] AACE International, Recommended Practice No. 18R-97. (2013). Cost Estimate Classification System, Page 6 of 10, AACE International, Morgantown, WV.

No	Project Name	Capacity	Year	Location
1	Synthetic Butadiene Rubber Plant	120 kTA	2018	West Java , Indonesia
2	Butadiene Expansion	137 kTA	2018	West Java , Indonesia
3	The New Polyethylene Plant	400 kTA	2019	West Java , Indonesia
4	Suban Compression Plant	100 MMSCFD	2019	South Sumatera, Indonesia
5	Kedung Keris Plant	3800 BOPD	2019	East Java , Indonesia
6	Methyl Tert-butyl Ether (MTBE) Plant	128 kTA	2020	West Java , Indonesia
7	CAP II Ethyene Plant	900 kTA	2021	West Java , Indonesia
8	CAP II Prophylene Plant	490 kTA	2021	West Java , Indonesia
9	CAP II Polyethylene Plant	736 kTA	2021	West Java , Indonesia
10	CAP II Polyprophylene Plant	590 kTA	2021	West Java , Indonesia
11	West Java Petrochemical Complex Megaproject	N/A	2022	West Java , Indonesia
12	TPPI Olefin Plant	1000 kTA	2022	East Java , Indonesia
13	TPPI Polyethylene Plant	270 kTA	2022	East Java , Indonesia
14	TPPI Polypropylene Plant	300 kTA	2022	East Java , Indonesia
15	Crude Distillation Unit Plant	300,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
16	Vacuum Distillation Unit Plant	81,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
17	LPG Recoverary Unit Plant	35,500 BPSD	2018 - 2023	East Kalimantan , Indonesia
18	Residue Fluid Catalytic Cracker Unit Plant	90,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
19	RFCC Naptha Hydrotraeting Unit Plant	48,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
20	Diesel Hydrotreating Unit Plant	160,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
21	CCR Platforming Unit Plant	33,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
22	RFCC LPG Treating Unit Plant	23,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
23	Propylene Recovery Unit Plant	23,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
24	Alkylation Plant	7,400 BPSD	2018 - 2023	East Kalimantan , Indonesia
25	Wet Gas Sulphuric Acid Plant	3,500 kg/h	2018 - 2023	East Kalimantan , Indonesia
26	Isomerization unit Plant	29,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
27	Naptha Hydrotreating Unit Plant	62,000 BPSD	2018 - 2023	East Kalimantan , Indonesia
28	Saturated Gas Concentration unit Plant	69,000 Nm3/h	2018 - 2023	East Kalimantan , Indonesia
29	Saturated LPG Treating Unit Plant	40,000 kg/h	2018 - 2023	East Kalimantan , Indonesia
30	Non-RFCC Sour Water Stripping Plant	100 m3/h	2018 - 2023	East Kalimantan , Indonesia
31	RFCC Sour Water Strippping Plant	76 m3/h	2018 - 2023	East Kalimantan , Indonesia
32	Hydrogen Maufacturing Unit Plant	120,000 Nm3/h	2018 - 2023	East Kalimantan , Indonesia
33	Ammine Regeneration Unit Train Plant	419,758 kg/h (409 m3/h) x 2 Train	2018 - 2023	East Kalimantan , Indonesia
34	Sulphur Plant SRU Plant	2 x 110 Tons/day	2018 - 2023	East Kalimantan , Indonesia
35	Water System Unit Plant	SWRO 3500 m3/hr	2018 - 2023	East Kalimantan , Indonesia
36	Cooling water System Plant	Utilities: 29,400 m3/h	2018 - 2023	East Kalimantan , Indonesia
37	Air System Plant	PA: 5,500 Nm3/h	2018 - 2023	East Kalimantan , Indonesia
38	Waste Water Treatment Plant	528 m3/h	2018 - 2023	East Kalimantan , Indonesia
39	Onshore Facilities Plant	New Storage Tank : 2.000.000 Bbl	2018 - 2023	East Kalimantan , Indonesia

Table 2. Study & EPC Process Plant Project List in Indonesia[7]

The above data relates to several Studies & EPC Process Plant Project Lists in Indonesia throughout 2018 - 2022. In Indonesia, so many Process Plant Assets were constructed and will be built by companies in Indonesia. It will pass through the Project Screening or Feasibility Studies to evaluate the project's success rate.

Below is one of the asset development processes in an energy company in Indonesia which is quite representative of the Asset Construction process in several companies in Indonesia:

[7] by Author

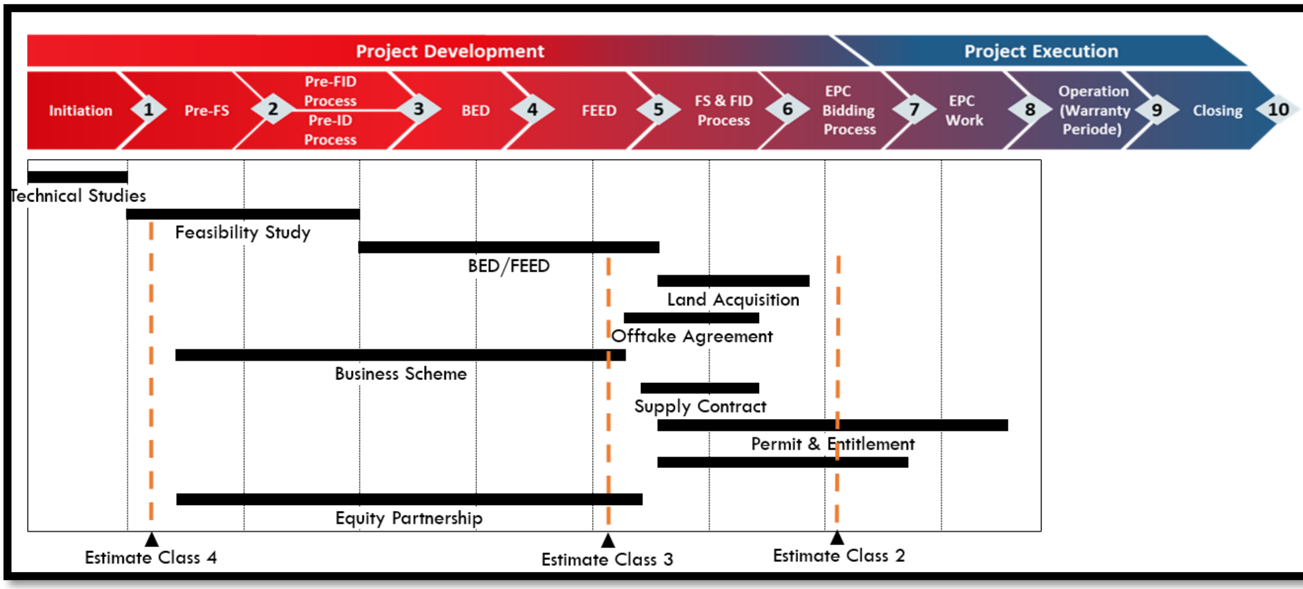

***Figure 1. Stages of Asset Process Plants in several companies in Indonesia*[8]**

Considering the importance of a Class 4 Estimation methodology to assist the Company in calculating the feasibility study, a precision, accurate, valid, and reliable class 4 estimate method is needed.
As stated before regarding Class 4 Estimate Methodology, Lang Factor is one of the estimation methods commonly used by several Oil & Gas companies to make Project Screening or Feasibility Studies with Class 4 AACE Estimation accuracy. "Hans Lang created the concept of estimating the entire cost of a plan by factoring in the cost of all the equipment"[9]:

Total plant cost (TPC) = Total equipment cost (TEC) x Equipment Factor (f) (Equation 1)

In 1947 (Over 70+ Years ago), Lang proposed three different factors based on the type of process plant. For solids, the factor is 3.10; for combined solids and fluids, 3.63; and for fluids alone, 4.74. These factors aim to cover all costs associated with the Total Plant Cost of a plant, including the ISBL and OSBL costs.[10]

Lang's method was modest, depending on a variable that only varies based on the process type. There are several equipment factoring methods available today. However,

[8] Wardhana,R. (2022). Knowledge Sharing Project Financing RDMP RU V Balikpapan Engineering Services PT. Kilang Pertamina Internasional.
[9] Lang, H.J. (1947). Cost Relationships in Preliminary Cost Estimation, Chem. Eng. October 1947.
[10] Dysert, L.R., (2003). Sharpen Your Cost Estimating Skills. Cost Engineering Vol. 45/No.6 June 2003, page 25.

the Lang factor is generally a catch-all for all equipment factors. Individuals have attempted to determine the Lang factor using their current data; some of these are shown in table 3 below,

Description	Solid	Solid - Fluid	Fluid
Original Lang Factor[11]	3.10	3.63	4.74
Peters & Timmerhaus[12]	3.90	4.10	4.80
AACE International RP 59R-10[13]	3.89	5.04	6.21
Perry's Chem. Eng. H.B.[14]	3.80	4.10	4.80
Dysert L.R.[15]	-	-	5.10
Wolf T.E.[16]	-	-	5.12
Wain, YA[17]	-	-	3.28 ± 1.123

***Table 3**. Lang Factor Data*

Many things had changed from when Hans Lang introduced the Lang Factor until now. Governmental rules and regulations that have been nonexistent in the 1940s and 1950s are now in effect. There are materials and construction methods that are different. There are digital process controls instead of pneumatic controls. The computer is used instead of the slide rule, and there is a three-dimensional computer design. Then there is material and labor cost inflation (escalation) over many decades[18]; Therefore, modifying the factors is necessary to adapt to current conditions.

Considering the importance of the Lang Factor to estimate Class 4 for Feasibility Study in Indonesia and as a method for reviewing the fairness of the Cost of an EPC Process Plant, In this paper, the Lang factor will be modified using Process Plant Project Data Cost in PERTAMINA to get more precision, valid, and reliable Lang Factor for AACE Class 4 Estimation Purpose in Indonesia Process Plant Project.

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[11] Dysert, L.R., (2003). Sharpen Your Cost Estimating Skills. Cost Engineering Vol. 45/No.6 June 2003, page 25.
[12] Peters & Timmerhaus, (1991). Plant Design and Economics for Chemical Engineers 4th edition Page 184
[13] AACE International. (2011). Recommended Practice No. 59R-10, Development of Factored Cost Estimates – As applied In Engineering, Procurement, And Construction for The Process Industries. AACE International. Morgantown, WV.
[14] Perry, Robert H, Don W. Green, and James O. Maloney. (1997). Perry's Chemical Engineers' Handbook, New York: McGraw-Hill, Seventh Edition April 1997, page 9-68.
[15] Dysert, L.R., (2003). Sharpen Your Cost Estimating Skills. Cost Engineering Vol. 45/No.6 June 2003, page 25.
[16] Wolf, T.E. (2013). Lang Factor Cost Estimates. Retrieved from http://prjmgrcap.com/langfactorestimating.html.
[17] Wain, Yosep Asro. (2014). Updating the Lang Factor and Testing its Accuracy, Reliability and Precision as a Stochastic Cost Estimating Method. Retrieved from https://pmworldlibrary.net/wp-content/uploads/2014/10/pmwj27-oct2014-Wain-updating-the-lang-factor-Featured-Paper.pdf
[18] Wolf, T.E. (2013). Lang Factor Cost Estimates. Retrieved from http://prjmgrcap.com/langfactorestimating.html.

The objective of this paper is intended to answer the following question:

1. What is the difference between the original Lang Factor issued in 1947 (Over 70+ Years Ago) and the current Lang Factor updated?
2. How is the correlation between Total Plant Cost (TPC) and its Total Equipment Cost (TEC) in forming the Lang Factor updated?
3. What is the most appropriate lang factor range value to be applied in a Concept Screening, Feasibility Study, and Class 4 AACE Estimation purpose for Fluid Process Plant Project in Indonesia?

Methodology

Research is a scientific activity, so in carrying out this activity, it must be carried out in systematic, rational, or reasonable ways and with valid data or following facts. Below Figure is an illustration of the developing methodology:

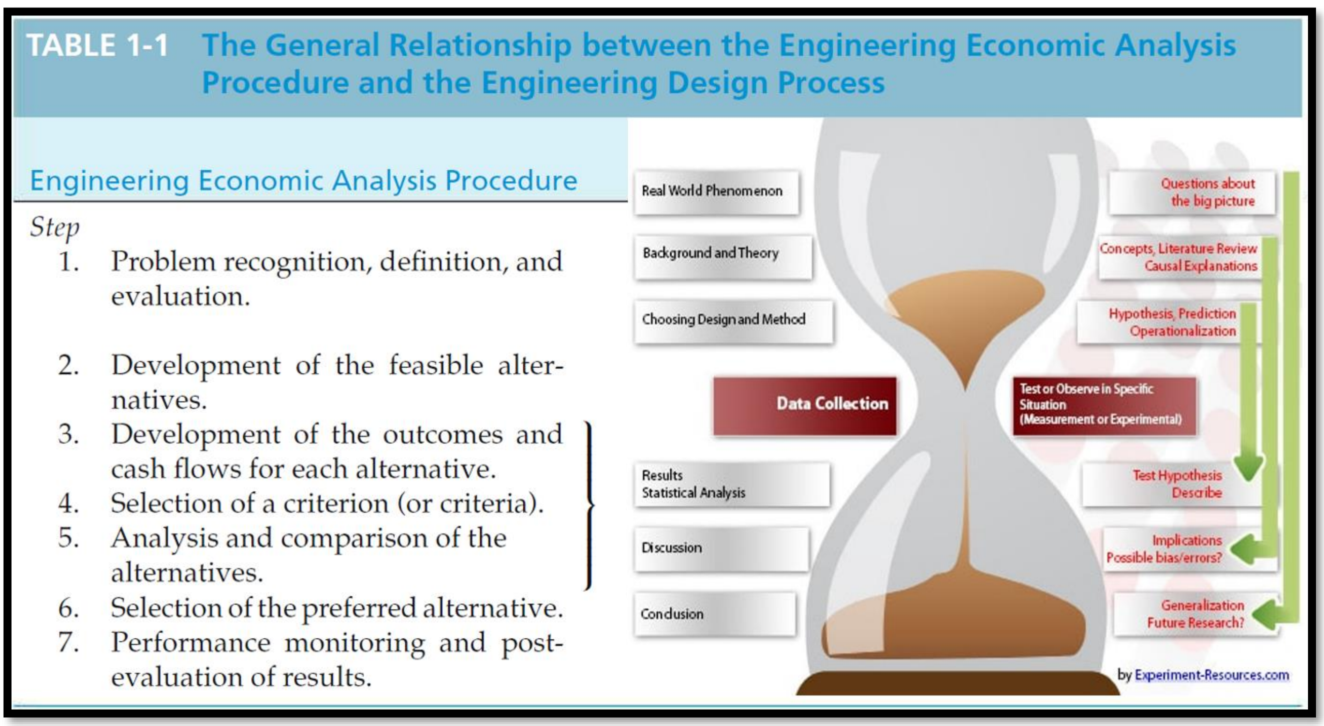
TABLE 1-1 The General Relationship between the Engineering Economic Analysis Procedure and the Engineering Design Process

Engineering Economic Analysis Procedure

Step
1. Problem recognition, definition, and evaluation.
2. Development of the feasible alternatives.
3. Development of the outcomes and cash flows for each alternative.
4. Selection of a criterion (or criteria).
5. Analysis and comparison of the alternatives.
6. Selection of the preferred alternative.
7. Performance monitoring and post-evaluation of results.

Figure 2. Engineering Economic Analysis Procedure[19] & Steps of the Scientific Process[20]

[19] Sullivan, G. W., Wicks, M. E., & Koelling, C. P. (2018). Engineering economy 16th Edition. Chapter 2 Cost Concepts and Design Economics,.page 31.
[20] Martyn Shuttleworth (2008). What is Research? Retrieved from: https://explorable.com/what-is-research

The methodology of scientific research must have 4 points item that needs to be elaborate on in detail:

1. Problem Recognition, Definition, & Evaluation: At this stage, a problem must be understood and stated explicitly before proceeding with other analyses. "Typically, internal or external organizational needs or requirements serve as the trigger for problem recognition."[21]

2. Development of the Feasible Alternatives: This stage will define alternative solutions that can solve the problem that has been determined. There are 2 (two) things need to be done at this stage, looking for alternative solutions and filtering them to choose a feasible solution for a more detailed analysis.

3. Development of the Outcomes: This stage will describe the techniques used to collect data to solve problems.

4. Selection of a Criterion (or Criteria): At this stage, the best alternative will be chosen to accommodate solutions in solving problems and explain how the raw Data is compiled and analyzed.

Step 1. Problem Recognition, Definition, and Evaluation

Lang Factor is one of the estimation methods commonly used by several Oil & Gas companies to make Project Screening or Feasibility studies with Class 4 AACE Estimation accuracy. In 1947 (Over 70+ Years ago), "Hans Lang introduced the concept of using the total cost of equipment to estimate the total cost of a plant".[22]

The problem is that many things have changed from the period Hans Lang introduced Lang Factor until now. There are now governmental rules and regulations which did not exist in the 1940s and 1950s. There are materials and construction methods that are different. There are digital process controls instead of pneumatic controls. The computer is used instead of the slide rule, and there is a three-dimensional computer design. The material and labor cost inflation (escalation) over many decades[23]. Therefore, modifying the factors is necessary to adapt to current conditions.

The objective of this paper is intended to answer the following question:

[21] Sullivan, G. W., Wicks, M. E., & Koelling, C. P. (2018). Engineering economy 16th Edition. Chapter 2 Cost Concepts and Design Economics, page 32.
[22] Lang, H.J. (1947). Cost Relationships in Preliminary Cost Estimation, Chem. Eng. October 1947.
[23] Wolf, T.E. (2013). Lang Factor Cost Estimates. Retrieved from http://prjmgrcap.com/langfactorestimating.html.

1. What is the difference between the original Lang Factor issued in 1947 (Over 70+ Years Ago) and the current Lang Factor updated?
2. How is the correlation between Total Plant Cost (TPC) and its Total Equipment Cost (TEC) in forming the Lang Factor updated?
3. What is the most appropriate lang factor range value to be applied in a Concept Screening, Feasibility Study, and Class 4 AACE Estimation purpose for Fluid Process Plant Project in Indonesia?

Step 2. Development of the Feasible Alternatives

alternative solutions that will be used to solve the problems and answer the three (3) questions above are:

1. Develop Cost Estimating Relationship (CER) using Regression Analysis from Data Collected to get an Equation of the Lang Factor Updated in a Line Fit Plot Graphic between Total Plant Cost (TPC) vs Total Equipment Cost (TEC) and The Correlation between TPC vs. TEC.
2. Develop Monte Carlo Simulation from Data Collected to get the range of Percentiles of the Lang factor updated.

Step 3. Development of the Outcomes

Cost Estimating Relationship (CER)

"Based on one or more design parameters, a CER is a mathematical model that estimates the cost of an engineering project. CERs are appropriate tools since they make it simple and quick for the estimator to create a cost estimate. Moreover, estimates can be made before complete information is available early in the design phase. Engineers also can utilize CERs to support them in making early design decisions that satisfy both technical criteria and budgetary constraints."[24]

CER is "Specific analogies depend upon the known cost of an item used in prior systems as the basis for the cost of a similar item in a new system. Adjustments are made to known costs to account for differences in relative complexities of performance, design, and operational characteristics. This is often developed, creating a regression model.

[24] Sullivan, William G., Wicks, Elin M. & Koelling, C. Patrick (2014), Engineering Economy, 16th Edition, Chapter 3. Cost-Estimation Techniques. Page 113.

(Linear or "Best Fit"). Cost estimating relationships (CERs), also known as cost models, are developed from historical Data for similar systems or subsystems."[25]

"For a cost estimating relationship (CER), it is a best practice to use prediction interval statistical analysis to determine the bounds of the probability distribution because it is an objective method for determining variability. The prediction interval captures the error around a regression estimate and results in a wider variance for the CER. A CER input may also be uncertain and have a probability distribution that describes its range."[26]

Monte Carlo Simulation

Monte Carlo Simulation is a "Computation intensive forecasting technique applied where statistical analysis is extremely cumbersome due to the complexity of a problem (such as queuing or waiting for line probabilities, or inventories involving millions of items). Used only where the Problem has a chance (random) component and is subject to unpredictable influences, it simulates (models) a situation based on current and past (historical) data. In the simulation process, it computes an equation (mathematical model) thousands or millions of times, each time injecting random numbers to come up with a range of possibilities or outcomes of possible actions. The larger the number of computations, the greater the probability (according to the law of large numbers) approximating the future events to provide the maximum amount of known data incorporated into the model."[27]

"The variable with uncertainty is given a random value through a Monte Carlo simulation. After that, the model is run to get a result. While applying various diverse values to the variable in question, this process is repeated and again. Results are averaged after the Simulation is finished to get an estimate."[28]

"By creating models of potential outcomes by substituting a range of variables, the Monte Carlo simulation provides risk analysis— described as a probability distribution — for any parameter that has a built-in uncertainty. Then, it repeatedly calculates outcomes using a different set of random values drawn from the input probability distributions. Before it is finished, a Monte Carlo simulation may require thousands or even tens of thousands of recalculations, depending on the number of uncertainty and the ranges assigned to

[25] PTMC & Giammalvo, P. D. (2021). 1.4.1.10 unit 10 – Managing Cost Estimating & Budgeting. Retrieved from: https://build-project-management-competency.com/1-4-1-10-unit-10/
[26] GAO,U.S. (2020). Cost Estimating and Assessment Guide, Chapter 12: Step 9: Conduct Risk And Uncertainty Analysis , Page 147.
[27] PTMC, & Giammalvo, P. D. (2021). 1.4.1.6 Unit 6- Managing Risk and Opportunity. Retrieved from https://build-project-management-competency.com/1-4-1-6-unit-6/ . Page 41 of 70.
[28] Investopedia. (2003). What is a Monte Carlo simulation?. Retrieved October 14, 2022 from: https://www.investopedia.com/terms/m/montecarlosimulation.asp

them. A Monte Carlo simulation provides a distribution, or range, of potential outcome values. This information on possible results makes it feasible to estimate the probability of various outcomes in your projections and carry out a variety of other analyses."[29]

Step 4 Selection of a Criterion (or Criteria)

In this research, the amount of data collected and normalized are **92 (ninety-two) Data** on Fluid Process Plant Costs from 2017 up to 2022 located in Balikpapan, East Kalimantan, Indonesia **(See Appendix-1 Cost Data List of Process Plant)**. The range of Total Plant Cost Value collected starts from $12.2 million up to $1.1 Billion. This Data consists of Total Plant Cost (TPC), Total Equipment Cost (TEC), and Equipment Factor (f). The Ninety-two of these data will be processed using the Cost Estimating Relationship (CER) and Monte Carlo Simulation methods to obtain the appropriate Lang Factor Update.

In this research, the ninety-two data that have been collected and normalized consisting of Total Plant Cost (TPC) and Total Equipment Cost (TEC) will be simulated using Cost Estimating Relationship (CER) method with the Linear Regression using the Data Analysis feature in Microsoft Excel as shown below,

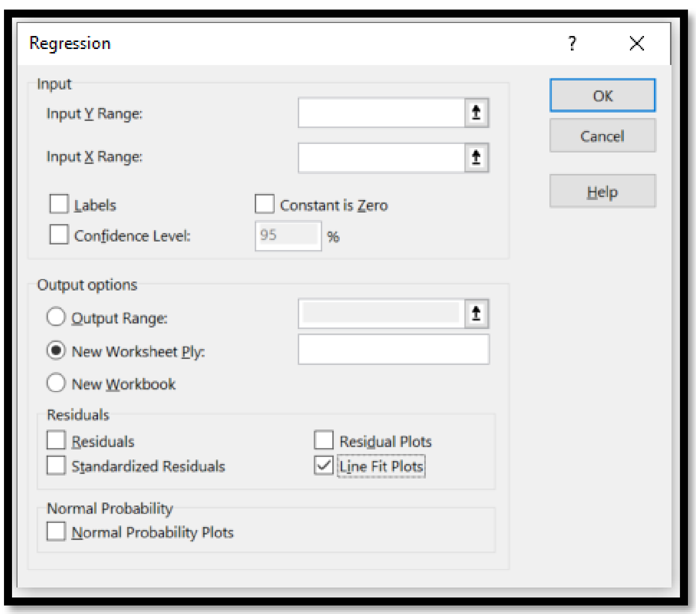

Figure 3. Regression Dialog Box

[29] Palisade. (2022). How Monte Carlo Simulation Works. Retrieved October 14, 2022 from: https://www.palisade.com/monte-carlo-simulation/

The Ninety-two data of Total Plant Cost ($) will be set as input Y range, and Total Equipment Cost ($) will be selected as input X Range. "Once the fundamental equation form for the CER has been established, Determining the coefficient values for the CER equation is the next step. The method of least squares is the most frequently used to determine the coefficient values. This technique aims to find a straight line through the Data that minimizes the overall variance of the observed data from the expected values. (The line itself represents the CER)."[30]

The next step is to process the **Monte Carlo Simulation** of the ninety-two Equipment Factor (f) data (See Appendix-1) using Tools @RISK 8.0 by Palisade with 100,000 iteration tests to generate the Probability Distribution of Equipment Factor (f), which will result in an appropriate lang factor range value to be applied in a Concept Screening, Feasibility Study, and Class 4 AACE Estimation purpose for Fluid Process Plant Project in Indonesia.

Findings

Step 5 Analysis and Comparison of the Alternatives

Before deciding what the Lang Factor update value is more Precision, Valid, and Reliable for AACE Class 4 Estimation Purpose in Indonesia, it is necessary to do further data analysis on the Data that has been collected. Below is the distribution from collected and normalized **ninety-two (92) Data (See Appendix-1)** of Fluid Process Plant Cost from 2017 to 2022 located in Balikpapan, East Kalimantan, Indonesia. The range of Total Plant Cost Value collected starts from **$12.2 million up to $1.1 Billion**.

[30] Sullivan, William G., Wicks, Elin M. &Koelling, C. Patrick (2014), Engineering Economy, 16th Edition, Chapter 3. Cost-Estimation Techniques. Page 114.

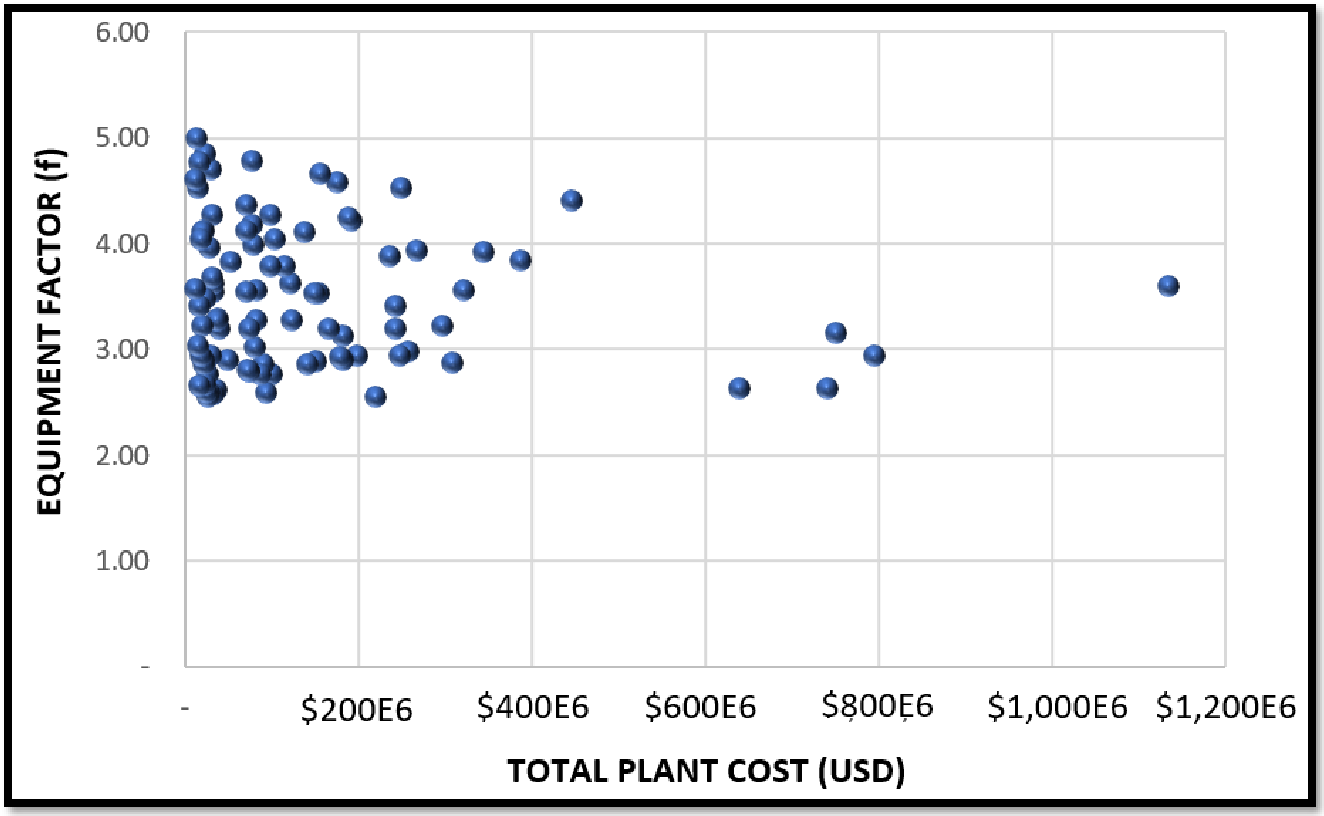

Figure 4. Scatter Plot of Total Plant Cost (USD) vs Equipment Factor (f)[31]

From Figure 4 above, from the Ninety-two (92) Total Plant Cost data collected, the majority of the Total Plant Cost value is below USD 500 million. There are only 5 data whose Total Plant Cost is above USD 500 million. Meanwhile, the Equipment Factor (Total Plant Cost / Total Equipment Cost) ranges being started from **2.55 up to 5.00.**

Cost Estimating Relationship (CER)

Cost Estimating Relationship (CER) between the Ninety-two (92) of Data Total Plant Cost (TPC) and Total Equipment Cost (TEC) was analyzed using the Data analysis feature in Microsoft Excel with Linear Regression Analysis. Below are the results of the Linear Regression analysis:

[31] By Author

Regression Statistics	
Multiple R	0.982599133
R Square	0.965501056
Adjusted R Square	0.965117734
Standard Error	35718408.36
Observations	92

Table 4. Summary Output of Regression Statistics[32]

The output Summary of table 4 reports the strength of the relationship between the independent variable (Total Equipment Cost) model and the dependent variable (Total Plant Cost).

Multiple R is a parameter to measure the level (closeness) of the linear relationship between the dependent variable (Total Plant Cost) and the independent variable (Total Equipment Cost). In this Simulation, the Multiple R-value of 0.9825 (close to the Value of 1) shows a very strong relationship.

"**R-squared (R^2)** is a statistical Evaluation that represents the amount of variance for a dependent variable in a regression model that is explained by one or more independent variables. Correlation explains how closely a dependent and independent variable are associated. R-squared explains to what extent one variable's variance explains the second variable's variance "[33]. R square is also known as the coefficient of determination which explains how far independent data can define the dependent data. R square has a value between 0 - 1 with the provision that the closer to the number one, the better. In this study, the **R Square value is 0.9655**, which means **96.55%** of the distribution of the dependent variable (Total Plant Cost) can be explained well (Best Fit) by the independent variable (Total Equipment Cost). The rest is only **3.45%** which cannot be explained by the independent variable or can be explained by variables outside the independent variable (error component).

The table below guides how to describe the strength of the correlation coefficient,

[32] By Author
[33] Fernando,J. (2021). R-Squared Formula, Regression, and Interpretations. Investopedia. https://www.investopedia.com/terms/r/r-squared.asp

Correlation Coefficient (r)	Description (Rough Guideline)
+1.0	Perfect positive + association
+0.8 to 1.0	Very strong + association
+0.6 to 0.8	Strong + association
+0.4 to 0.6	Moderate + association
+0.2 to 0.4	Weak + association
0.0 to +0.2	Very weak + or no association
0.0 to -0.2	Very weak - or no association
-0.2 to – 0.4	Weak - association
-0.4 to -0.6	Moderate - association
-0.6 to -0.8	Strong - association
-0.8 to -1.0	Very strong - association
-1.0	Perfect negative association

Table 5. The strength of the correlation coefficient[34]

based on table 5, the value of R Square obtained from this research is **0.9655 (+0.8 to 1.0)** in the **Very Strong + Association** category.

The other Report from Linear Regression Simulation is the Summary Output of ANOVA, as shown in Table 6 below :

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.21347E+18	3.2E+18	2518.78	1.35622E-67
Residual	90	1.14822E+17	1.3E+15		
Total	91	3.32829E+18			

Table 6. Summary Output of ANOVA[35]

"The observed total variability within a data set is divided into two parts using the statistical approach analysis of variance (ANOVA): systematic and random factors. The systematic factors statistically influence the given data set, while the random factors do not. Analysts use the ANOVA test to determine independent variables influence on the dependent variable in a regression study"[36]. The F test aims to determine whether the independent

[34] Lamorte, W. (2021). The Correlation Coefficient (r). PH717 Module 9 - Correlation and Regression. Retrieved from : https://sphweb.bumc.bu.edu/otlt/MPH-Modules/PH717-QuantCore/PH717-Module9-Correlation-Regression/PH717-Module9-Correlation-Regression4.html
[35] By Author
[36] Kenton, W. (2022). Analysis of Variance (ANOVA) Explanation, Formula, and Applications. Investopedia. https://www.investopedia.com/terms/a/anova.asp

variables (Total Equipment Cost) simultaneously affect the dependent variable (Total Plant Cost). The F test was conducted to see the effect of all independent variables simultaneously on the dependent variable. The level used is 0.05 or 5%. If the significant Value is F < 0.05, it can be interpreted that the independent variable simultaneously affects the dependent variable or vice versa. ANOVA statistical testing is a form of hypothesis testing which can draw conclusions based on data or statistical groups that are concluded. Decision-making seen from this test is done by looking at the F value contained in the ANOVA table. The significance level used is 0.05. In Table 6, it can be seen **that the Significance F value is 1.3562E67 (F < 0.05),** which means it can be accepted that independent variables (Total Equipment Cost) possess a substantial impact on the dependent variable (Total Plant Cost).

The other Report from Linear Regression Simulation is the Summary Output of the Coefficient, as shown in Table 7 below:

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	9,824,908.33	4,608,501.49	2.13191	0.03574	669,315.76	18,980,500.91
TOTAL EQUIPMENT COST (TEC)	3.071350939	0.061197645	50.1874	1.4E-67	2.949771135	3.192930742

***Table 7. Summary Output of Coefficient*[37]**

The concept of linear regression used here is to model the relationship between two variables with the equation as the slope formula. The formula for the equation is **Y= aX + b**, Y is the dependent variable (Total Plant Cost), the variable that moves on the Y axis, the X axis is the independent variable (Total Equipment Cost) where **"a"** is the line's gradient and **"b"** is the y-intercept. Below are the Equation and Line fit Plot with Default Intercept Regression Analysis report between Total Equipment Cost vs Total Plant Cost. From table 7 above and figure 5 Below, we get the equation:

$$Y = 3.071X + 9{,}824{,}908 \qquad \textbf{(Equation 2)}$$

Where:

Y = Total Plant Cost
X = Total Equipment Cost
a = 3.071
b = 9,824,908
$R^2 = 1$

[37] By Author

The Value of R2 is close to 1 from the Regression Line Fit Plot. It shows the model's ability to explain that the independent variable (Total Equipment Cost) simultaneously affects the dependent variable (Total Plant Cost). The coefficient of determination also shows that the contribution of the independent variable (Total Equipment Cost) in the regression model can explain and predict the Value of the dependent variable (Total Plant Cost) well.

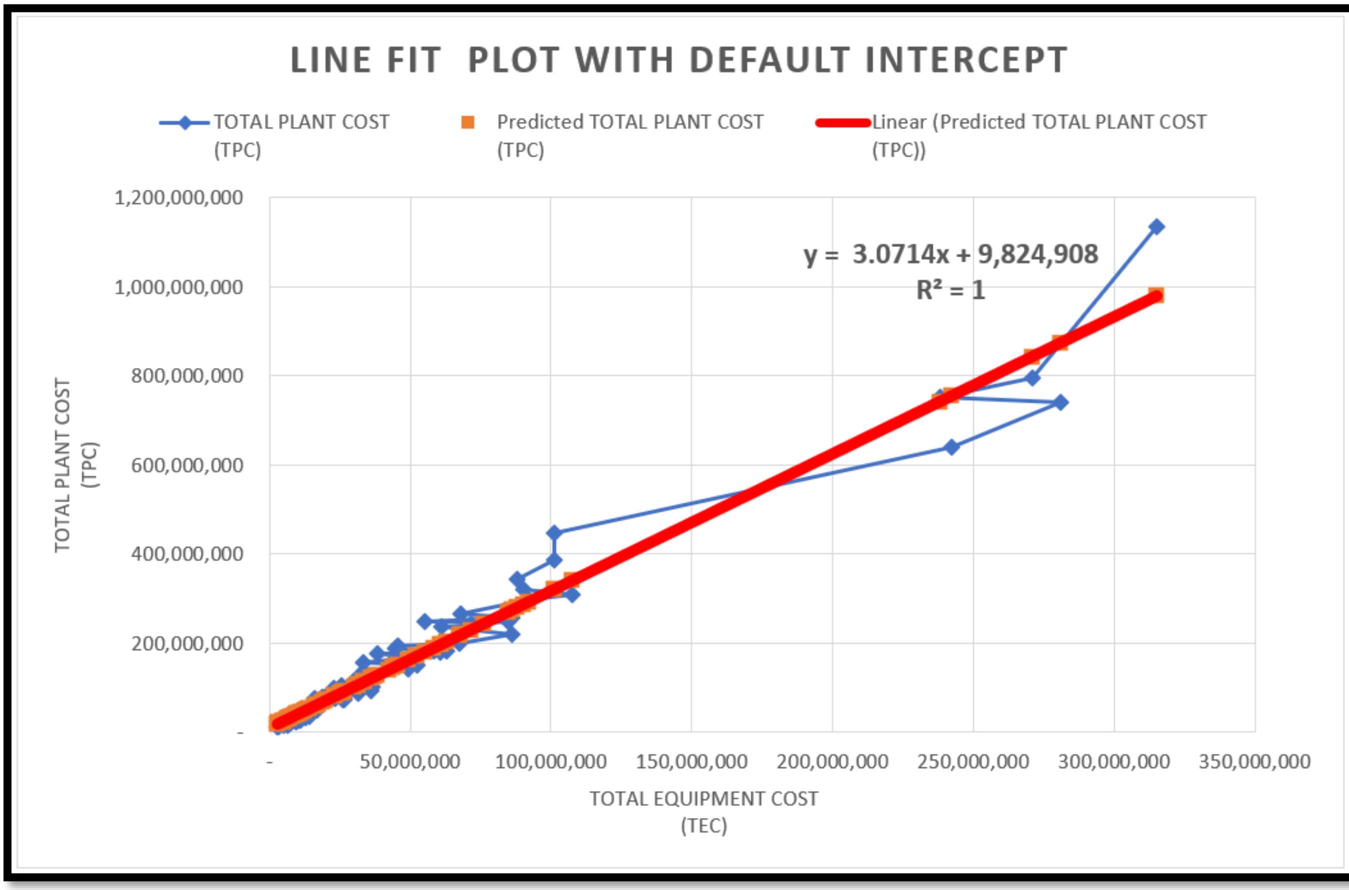

Figure 5. Line Fit Plot with Default intercept [38]

MONTE CARLO SIMULATION

The Next test uses Monte Carlo Simulation. The Data will be simulated using distribution from collected and normalized 92 (ninety-two) Data of Equipment Factor (f) as stated in Appendix 1. “It is essential to avoid the impact of stopping using a bell or normal

[38] By Author

distribution. Start using log-normal or "skewed right" distribution as the "worst-case" scenario is almost always way worse than we think it possibly could be."[39]

The Monte Carlo simulation at this stage uses the **RISK LOGNORM Formula with 100,000 iterations** from the @RISK Palisade Tools. Below are the outcomes of the simulation:

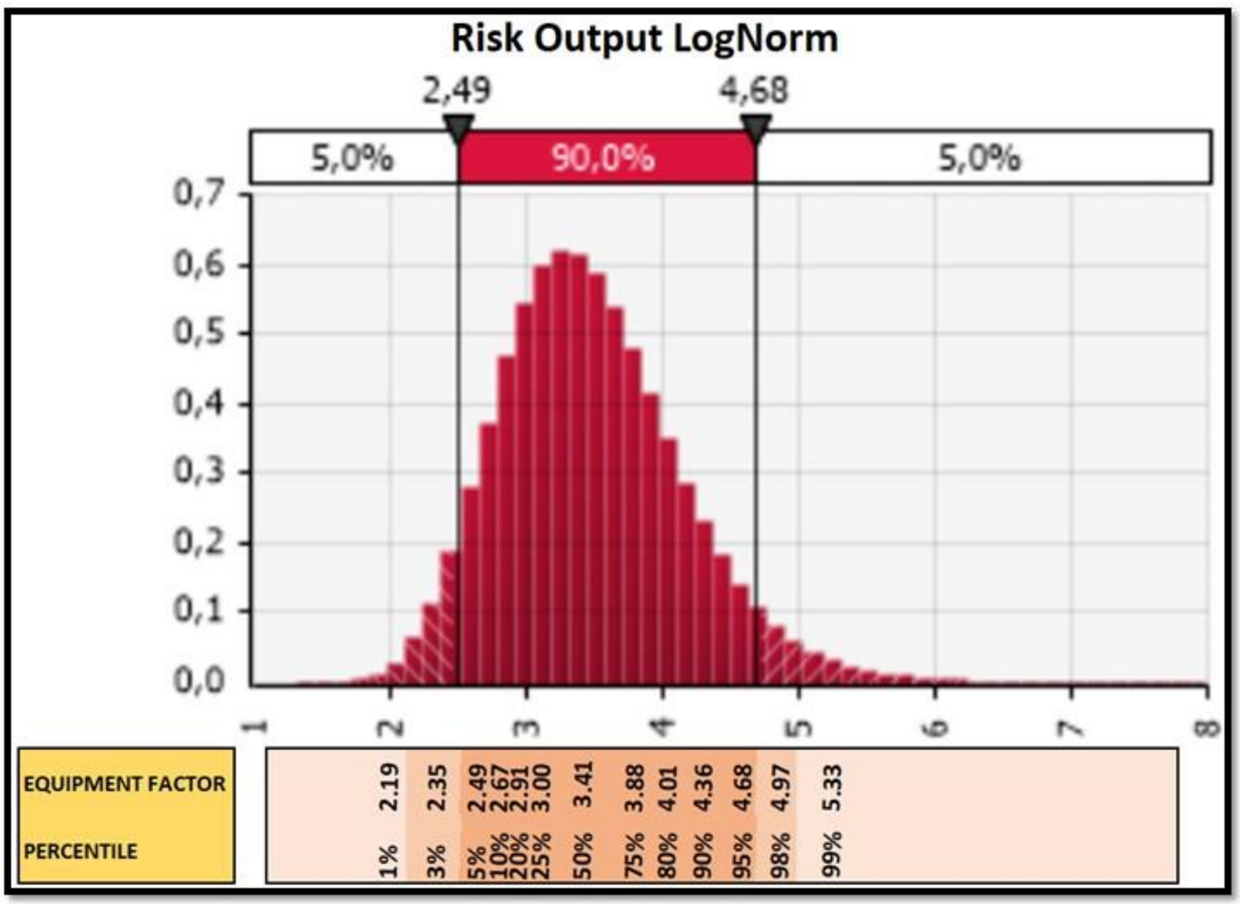

Figure 6. Risk Output: LOGNORMAL Distribution Curve of Equipment Factor Probability[40]

[39] PTMC, & Giammalvo, P. D. (2021). 1.4.1.10 unit 10 – Managing Cost Estimating & Budgeting. Retrieved from https://build-project-management-competency.com/1-4-1-10-unit-10/ .
[40] By Author

Summary Statistics	
Statistic	Value
Minimum	1.3187
Maximum	7.9612
Mean	3.4767
Std. Deviation	0.6709
Variance	00,000
Skewness	0.5858
Kurtosis	3.6146
Median	3.4137
Mode	3.2924
Left X	2.4924
Left P	5%
Right X	4.6754
Right P	95%

Table 8. Risk Output : Summary Statistic of Equipment Factor (f) LogNorm Distribution[41]

In Figure 6 and Table 8 above, from the simulation results of ninety-two (92) Data (see Appendix-1) to LOGNORM Simulation, the Equipment Factor (f) range value is 1.32 (Minimum) to 7.96 (Maximum) with a Mean value of 3.48.

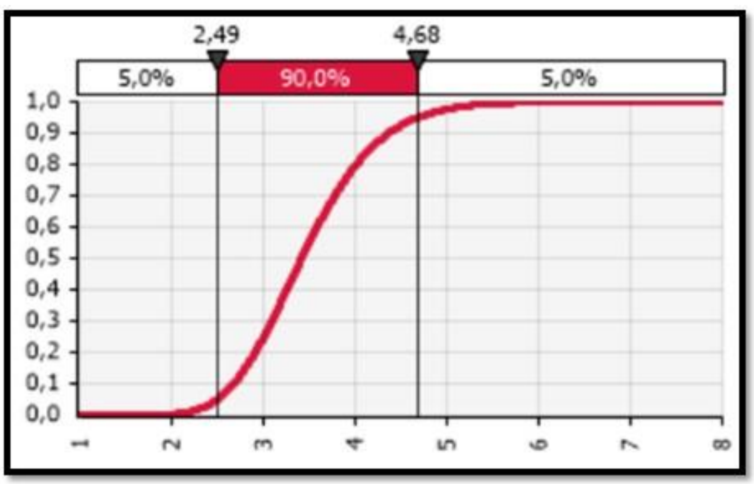

Figure 7. Risk Output: Percentile LogNorm Distribution Graph of Equipment Factor (f)[42]

[41] By Author
[42] By Author

Percentiles	
Percentile	Value
1%	2.19
3%	2.35
5%	2.49
10%	2.67
20%	2.91
25%	3.00
50%	3.41
75%	3.88
80%	4.01
90%	4.36
95%	4.68
98%	4.97
99%	5.33

***Table 9. Risk Output: Percentile Data of Equipment Factor of LogNorm Probability Distribution*[43]**

In Figure 6 and Table 9 above, from the simulation results of ninety-two (92) Data (see Appendix-1), the Percentile Data of Equipment Factor Probability Distribution is started **2.19 (P-1) up to 5.33 (P-99**).

Step 6 Selection of the Preferred Alternatives

Based on the Analysis and Comparison of the Alternatives that we did above, it can be seen that:

1. Based on the Cost Estimation Relationship Simulation using the Linear Regression method, there are very strong correlation (the value of R^2 is close to 1) between the dependent variable (Total Plant Cost) and its Independent Variable (Total Equipment Cost) which produces the equation as listed in Equation 2 **(Y = 3.071X + 9,824,908; R^2=1)** where "Y" is Total Plant Cost (TPC), and "X" is Total Equipment Cost (TEC).

[43] By Author

2. Based on Monte Carlo Simulation, the Percentile Data of Equipment Factor Probability Distribution is started with **2.19 (P-1) up to 5.33 (P-99).**

3. Commonly, "Company needs to develop a single number, usually a P-50 or Mean Value. However, because there is a danger that once a single number is published, it sticks in people's minds and eventually becomes fact"[44]. The authors decide to use the range of **values 3.00 (P-25) up to 5.33 (P-99)** as a range that is Precise, Valid, and reliable to be used as an Update Lang Factor which will be used as Class 4 AACE Estimating Method in estimating Liquid Process Plant Costs in Indonesia.

Step 7 Performance Monitoring and Post-Evaluation of Results

The above outcomes are obtained through ninety-two (92) Data (See Appendix-1) of Fluid Process Plant Costs from 2017 to 2022 located in Balikpapan, East Kalimantan, Indonesia. The total plant cost value range started from $12.2 million to $1.1 Billion. The more we can collect the Data, the more accurate and convincing the updated Lang Factor will be used as a Class 4 AACE Estimating Method in estimating Liquid Process Plant Costs in Indonesia.

Conclusion

The purpose of this research should find the answers to the questions below:

1. What is the difference between the original Lang Factor issued in 1947 (Over 70+ Years Ago) and the current Lang Factor updated? Below are the difference between the Original Lang Factor vs Current Updated Lang Factor:

[44] PTMC, & Giammalvo, P. D. (2021). 1.4.1.10 unit 10 – Managing Cost Estimating & Budgeting. Retrieved from https://build-project-management-competency.com/1-4-1-10-unit-10/ .

Original Lang Factor Fluid Process Plant (1947)	Updated Lang Factor Fluid Process Plant (2022)
4.74	**3.00 – 5.33**

Table 10. The difference between Original Lang Factor [45]vs Current Updated Lang Factor[46]

2. How are the correlation between Total Plant Cost (TPC) and its Total Equipment Cost (TEC) in forming the Lang Factor updated?

   There are very strong correlation (the value of R^2 is close to 1) between the dependent variable (Total Plant Cost) and its Independent Variable (Total Equipment Cost) which produces the equation as listed in Equation 2 **(Y = 3.071X + 9,824,908; R^2=1)** where "Y" is Total Plant Cost (TPC), and "X" is Total Equipment Cost (TEC).

3. What is the most appropriate lang factor range value to be applied in a Concept Screening, Feasibility Study, and Class 4 AACE Estimation purpose for Fluid Process Plant Project in Indonesia?

   The authors decide to use the range of values **3.00 (P-25) up to 5.33 (P-99)** as a range that is Precise, Valid, and reliable to be used as an Update Lang Factor which will be used as Class 4 AACE Estimating Method in estimating Liquid Process Plant Costs in Indonesia.

[45] Dysert, L.R., (2003). Sharpen Your Cost Estimating Skills. Cost Engineering Vol. 45/No.6 June 2003, page 25.
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APPENDICES

APPENDIX 1: COST DATA LIST OF PROCESS PLANT

NO	FLUID PROCESS PLANT	TOTAL PLANT COST (TPC)	TOTAL EQUIPMENT COST (TEC)	EQUIPMENT FACTOR (F)
1	PROCESS PLANT-1	1,134,199,000	315,347,000	3.60
2	PROCESS PLANT-2	795,947,000	270,759,000	2.94
3	PROCESS PLANT-3	751,614,000	238,042,000	3.16
4	PROCESS PLANT-4	740,948,000	280,943,000	2.64
5	PROCESS PLANT-5	638,813,000	242,402,000	2.64
6	PROCESS PLANT-6	446,176,000	101,110,000	4.41
7	PROCESS PLANT-7	387,364,000	100,970,000	3.84
8	PROCESS PLANT-8	343,973,000	87,813,000	3.92
9	PROCESS PLANT-9	320,768,000	90,100,000	3.56
10	PROCESS PLANT-10	309,077,000	107,687,000	2.87
11	PROCESS PLANT-11	297,521,000	92,154,000	3.23
12	PROCESS PLANT-12	267,003,000	67,885,000	3.93
13	PROCESS PLANT-13	256,907,000	86,236,000	2.98
14	PROCESS PLANT-14	249,438,000	55,160,000	4.52
15	PROCESS PLANT-15	248,571,000	84,633,000	2.94
16	PROCESS PLANT-16	243,364,000	71,400,000	3.41
17	PROCESS PLANT-17	242,926,000	76,035,000	3.19
18	PROCESS PLANT-18	236,569,000	61,039,000	3.88

NO	FLUID PROCESS PLANT	TOTAL PLANT COST (TPC)	TOTAL EQUIPMENT COST (TEC)	EQUIPMENT FACTOR (F)
19	PROCESS PLANT-19	219,503,000	86,236,000	2.55
20	PROCESS PLANT-20	198,209,000	67,315,000	2.94
21	PROCESS PLANT-21	192,296,000	45,521,000	4.22
22	PROCESS PLANT-22	189,350,000	44,665,000	4.24
23	PROCESS PLANT-23	182,308,000	62,815,000	2.90
24	PROCESS PLANT-24	182,231,000	58,285,000	3.13
25	PROCESS PLANT-25	178,238,000	60,795,000	2.93
26	PROCESS PLANT-26	175,757,000	38,393,000	4.58
27	PROCESS PLANT-27	166,454,000	52,062,000	3.20
28	PROCESS PLANT-28	155,259,000	33,318,000	4.66
29	PROCESS PLANT-29	154,476,000	43,725,000	3.53
30	PROCESS PLANT-30	151,605,000	52,570,000	2.88
31	PROCESS PLANT-31	149,458,000	42,377,000	3.53
32	PROCESS PLANT-32	140,776,000	49,247,000	2.86
33	PROCESS PLANT-33	137,611,000	33,507,000	4.11
34	PROCESS PLANT-34	122,606,000	37,344,000	3.28
35	PROCESS PLANT-35	121,711,000	33,530,000	3.63
36	PROCESS PLANT-36	114,624,000	30,223,000	3.79
37	PROCESS PLANT-37	103,297,000	25,537,000	4.04

NO	FLUID PROCESS PLANT	TOTAL PLANT COST (TPC)	TOTAL EQUIPMENT COST (TEC)	EQUIPMENT FACTOR (F)
38	PROCESS PLANT-38	100,621,000	36,339,000	2.77
39	PROCESS PLANT-39	99,231,000	26,194,000	3.79
40	PROCESS PLANT-40	98,389,000	23,053,000	4.27
41	PROCESS PLANT-41	93,303,000	36,083,000	2.59
42	PROCESS PLANT-42	89,714,000	31,302,000	2.87
43	PROCESS PLANT-43	87,473,000	31,635,000	2.77
44	PROCESS PLANT-44	82,121,000	23,072,000	3.56
45	PROCESS PLANT-45	81,755,000	24,994,000	3.27
46	PROCESS PLANT-46	80,247,000	26,540,000	3.02
47	PROCESS PLANT-47	78,594,000	19,711,000	3.99
48	PROCESS PLANT-48	78,003,000	18,681,000	4.18
49	PROCESS PLANT-49	77,161,000	16,122,000	4.79
50	PROCESS PLANT-50	74,512,000	23,343,000	3.19
51	PROCESS PLANT-51	74,446,000	26,600,000	2.80
52	PROCESS PLANT-52	73,864,000	26,406,000	2.80
53	PROCESS PLANT-53	73,077,000	26,014,000	2.81
54	PROCESS PLANT-54	71,452,000	20,153,000	3.55
55	PROCESS PLANT-55	71,157,000	17,237,000	4.13
56	PROCESS PLANT-56	70,498,000	16,165,000	4.36
57	PROCESS PLANT-57	52,810,000	13,773,000	3.83

NO	FLUID PROCESS PLANT	TOTAL PLANT COST (TPC)	TOTAL EQUIPMENT COST (TEC)	EQUIPMENT FACTOR (F)
58	PROCESS PLANT-58	48,690,000	16,801,000	2.90
59	PROCESS PLANT-59	39,593,000	12,372,000	3.20
60	PROCESS PLANT-60	37,586,000	11,410,000	3.29
61	PROCESS PLANT-61	36,708,000	13,991,000	2.62
62	PROCESS PLANT-62	36,198,000	11,051,000	3.28
63	PROCESS PLANT-63	33,466,000	9,448,000	3.54
64	PROCESS PLANT-64	32,792,000	9,030,000	3.63
65	PROCESS PLANT-65	32,589,000	12,660,000	2.57
66	PROCESS PLANT-66	31,386,000	7,357,000	4.27
67	PROCESS PLANT-67	31,133,000	8,457,000	3.68
68	PROCESS PLANT-68	30,601,000	6,505,000	4.70
69	PROCESS PLANT-69	29,230,000	9,936,000	2.94
70	PROCESS PLANT-70	28,841,000	7,274,000	3.96
71	PROCESS PLANT-71	27,906,000	10,763,000	2.59
72	PROCESS PLANT-72	27,167,000	9,811,000	2.77
73	PROCESS PLANT-73	26,427,000	10,380,000	2.55
74	PROCESS PLANT-74	25,330,000	9,766,000	2.59
75	PROCESS PLANT-75	23,971,000	8,978,000	2.67
76	PROCESS PLANT-76	22,707,000	6,531,000	3.48
77	PROCESS PLANT-77	22,454,000	4,634,000	4.85

NO	FLUID PROCESS PLANT	TOTAL PLANT COST (TPC)	TOTAL EQUIPMENT COST (TEC)	EQUIPMENT FACTOR (F)
78	PROCESS PLANT-78	21,504,000	7,416,000	2.90
79	PROCESS PLANT-79	21,169,000	7,402,000	2.86
80	PROCESS PLANT-80	20,933,000	5,072,000	4.13
81	PROCESS PLANT-81	20,740,000	5,048,000	4.11
82	PROCESS PLANT-82	20,368,000	6,315,000	3.23
83	PROCESS PLANT-83	18,287,000	6,211,000	2.94
84	PROCESS PLANT-84	17,775,000	4,391,000	4.05
85	PROCESS PLANT-85	16,868,000	4,950,000	3.41
86	PROCESS PLANT-86	16,521,000	6,211,000	2.66
87	PROCESS PLANT-87	16,220,000	3,397,000	4.77
88	PROCESS PLANT-88	15,334,000	5,043,000	3.04
89	PROCESS PLANT-89	15,089,000	3,333,000	4.53
90	PROCESS PLANT-90	13,819,000	2,765,000	5.00
91	PROCESS PLANT-91	12,336,000	3,459,000	3.57
92	PROCESS PLANT-92	12,264,000	2,659,000	4.61

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