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Utilizing the Monte Carlo Simulation for Estimating Construction Costs of Residential Buildings

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Abstract:- Cost risk in a residential construction project is one of the risks developers have to cope with. It is not unusual that the developer allocated a budget lower than what is needed to complete the project. This study aims to provide a practical way to estimate a more realistic cost of a construction project using the Monte Carlo Simulation method. A typical house type 36 construction activities and their respective costs were simulated with 5000 iterations to obtain the probability density function and the cumulative density function of the project cost. The study found that to avoid cost underestimation, which is a primary reason for cost overrun, the budget should be increased by 8.38% to attain a 95% probability of the project's successful completion.

Keywords:- *Monte Carlo Simulation; Residential Building; Cost Overrun.*

I. INTRODUCTION

Risks in construction projects are unavoidable. Cost/budget risk is one of the risks that residential building developers have to deal with [1]. It is not uncommon that the developer allocated an unrealistic budget for its residential project which could hinder the completion of the project [2].

The Monte Carlo Simulation method is frequently used in construction project schedule [2]–[5] and cost [6]–[9] risk analysis. Monte Carlo simulation is particularly advantageous in project management because it is a highly effective method for comprehending and measuring the possible impacts of project risks in both cost and schedule [10].

The objective of this study is to offer a feasible approach for utilizing the Monte Carlo Simulation method to estimate the cost of a residential building project by using the Microsoft Excel spreadsheet software.

II. LITERATURE REVIEW

Risk and uncertainty are two different situations that a decision-maker may face. Risk refers to a situation where the decision-maker knows the probabilities of potential outcomes, while uncertainty is a situation where the decision-maker lacks information about the probabilities of potential outcomes [11].

Cost overrun is a common risk in a construction project. According to Flyvbjerg [12] nine out of ten megaprojects had experienced cost overruns and concluded that overruns of up to 50 percent are common, and overruns of more than 50 percent are not unusual. According to Flyvbjerg et al. [13], the primary reason for cost overruns is the underestimation of costs.

III. METHODOLOGY

A. Data

Data of typical house type 36 construction activities and their respective costs, as shown in Table 1, were collected from residential building developers in Palu City, the capital of Central Sulawesi Province, Indonesia. The activity cost in Table 1 is the cost of labor and material and is in Indonesian Rupiah currency (IDR).

Table 1 Construction Activity and Cost

Activity	**Cost (In thousands of IDR)**	
	Expected	**Maximum**
1. Site clearance	100	200
2. Stake out and footing excavation	250	400
3. Footing	2650	3000
4. Plumbing	800	1000
5. Footing backfills	600	800
6. Steel fabrication	5100	6100
7. Lower tie beam	700	900
8. Wall, column, window, and door frame	8700	9500
9. Upper tie beam	650	900
10. Brick rafter	2000	2400
11. Steel Roof	7200	7700
12. Electrical rough-in	150	300
13. Wall plaster	4200	4600
14. Bathroom and toilet fixtures	1250	1400
15. Floor	4000	4400
16. Septic tank	620	750
17. Carport	420	550
18. Ceiling	3300	3800
19. Doors and windows installation	3780	4200
20. Painting	4850	5150
21. Electrical fitting	550	700
22. Cleaning	100	150
Total	51970	58900

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B. Monte Carlo Simulation Method

The Monte Carlo Simulation method involves repeatedly simulating the entire system by randomly selecting values for each variable from their respective probability distributions [10]. This is done numerous times, often thousands, resulting in a probability distribution of the system's overall value, which is calculated based on the iterations of the model [14].

➢ *The Monte Carlo Simulation Method follows the following Steps [15].*

- *Create a Quantitative Model of Y=F(X1, X2, …,Xn);*
- *Generate Random Variables X1, X2, …,Xn;*
- *Evaluate the Model and Output Stored in Yi;*
- *Repeat Steps 2 and 3 as Needed (for I=1 To K);*
- *Analyze the Results*

The Monte Carlo Simulation method assumed that the construction cost of house type 36 as in Table 1 was a random variable with a value between the expected and the maximum project cost i.e., between 51970 and 58900. Since the project cost is the sum of other random variables i.e., the cost of each activity, the project cost would be normally distributed.

The random cost of each activity in Table 1 was calculated using a Microsoft Excel function called RAND. For example, the random cost of the site clearance activity in Table 1 was computed by =RAND()*(200-100)+100. This computation generated a random number between 100 and 200.

C. Iteration Number

There is no definite answer on how many iterations should be run on Monte Carlo Simulation. Heijungs [16] states that 1000 or 10,000 iterations are typically needed. Burmaster and Anderson [17], and Xin [18]suggest that the iteration number should be more than 10,000, while Hongxiang and Wei [19] suggest that more than 2000 iterations should be performed.

Based on the above suggestions, the number of iterations of each activity cost in this study was set to 5000 iterations which should be sufficient for this study.

IV. RESULTS AND DISCUSSION

A. Simulation Results

After 5000 iterations, the standard deviation (σ) was obtained using (1).

$$\sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{N}} \qquad (1)$$

Where N = the population number; and $\bar{x}$ = population mean.

The true error (ε) was calculated using (2).

$$\varepsilon = \frac{3\sigma}{\sqrt{N}} \qquad (2)$$

The % true error was computed using (3).

$$\%\,\varepsilon = \frac{\varepsilon}{\bar{x}} \qquad (3)$$

Monte Carlo Simulation descriptive statistics result of 5000 iterations is shown in Table 2.

Table 2 Simulation Descriptive Statistics

Parameters	Results
Mean	55428.639
Median	55420.046
% Difference between Median and Mean	0.016%
Standard Deviation	529.788
True Error	50.260
% True Error	0.09%

Since random variables of the project cost were normally distributed, the difference between the mean and the median should be small which was 0.016%.

The true error of the simulation results was 50.260, with a percentage of only 0.09%, as shown in Table 2. This indicates that the simulation results were sufficiently accurate.

The probability density function and the cumulative density function of the simulation results after 5000 iterations are shown in Table 3 and Fig. 1.

Table 3 Probability and Cumulative Percentages

Upper bin	Frequency	Probability %	Cumulative %
54000	10	0.20%	0.10%
54250	43	0.86%	1.00%
54500	138	2.76%	3.10%
54750	314	6.28%	8.60%
55000	551	11.02%	19.50%
55250	828	16.56%	36.10%
55500	890	17.80%	52.80%
55750	858	17.16%	70.80%
56000	654	13.08%	85.10%
56250	401	8.02%	93.60%
56500	203	4.06%	98.20%
56750	76	1.52%	99.60%
57000	31	0.62%	99.90%
More	3	0.06%	100.00%

The cumulative density function in Table 3 can be used to find the probability of the project's success based on the available budget. If, for instance, the developer can only provide a budget of IDR 55,5000K then the probability of the project can be executed successfully is only 55.48% as depicted in the solid lines in Fig. 1.

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Likewise, if the developer wants to complete the project successfully with a 95% probability, by interpolating the numbers in Table 3, it was found that the developer needs to provide a budget of IDR 56,328K as depicted in the dotted lines in Fig. 1. In other words, the developer has to increase the project budget by 8.38% over its expected budget of IDR 51,970K to attain 95% probability of the project successful completion.

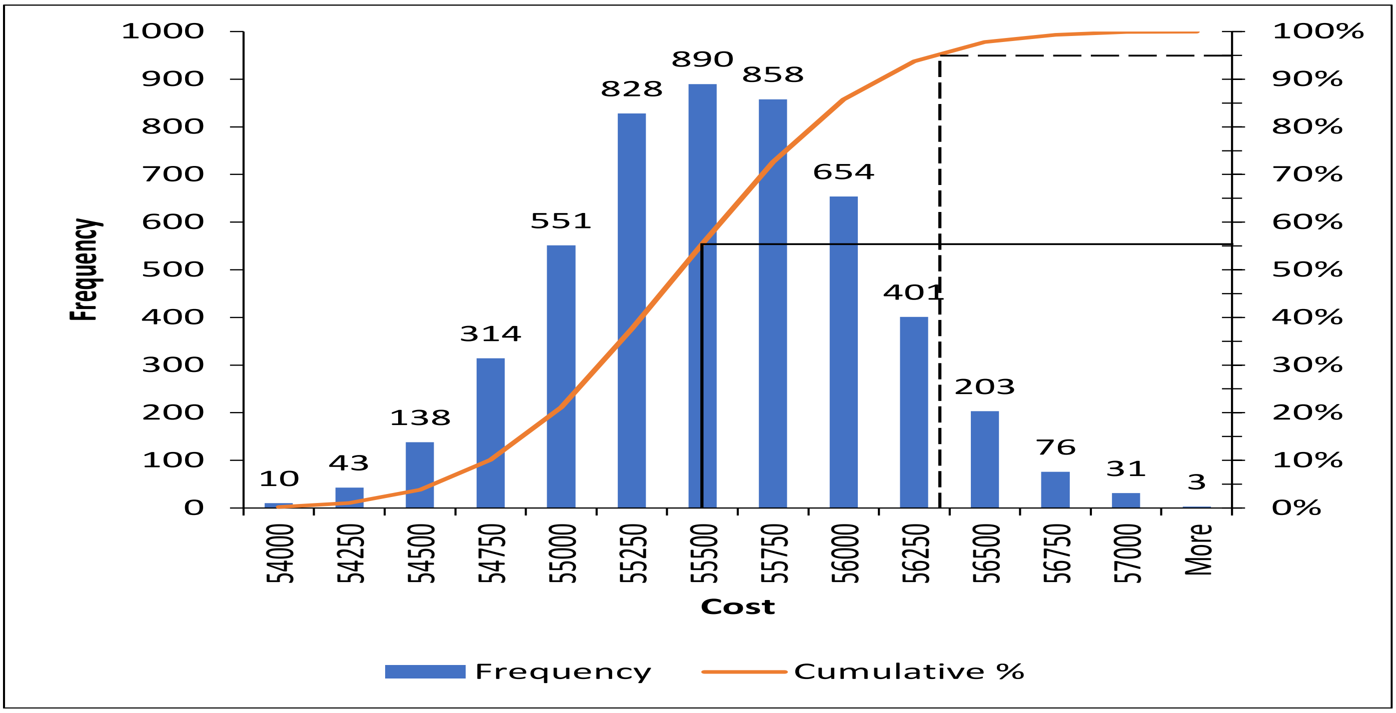

Fig 1 Probability and Cumulative Density Function

V. CONCLUSION

The Monte Carlo Simulation method can be a useful tool for residential construction developers or project managers to anticipate cost-related risk, which is not uncommon in a construction project. The results obtained from the Monte Carlo Simulation method can help residential construction developers to allocate a more realistic budget and successfully deliver the project.

However, the accuracy of the Monte Carlo Simulation method heavily relies on its input variables, which in this study are cost estimations. It should also be noted that the Monte Carlo Simulation method is not a solution provider, but rather a tool that helps predict system behavior by taking into account the risks inherent in construction project budgeting.

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