

Risk Probability of Time and Cost on Building Construction Project: A Monte Carlo Simulation

Hafnidar A. Rani^{1,*}, Jurisman Amin¹, Afizah Ayob², and Dekky Al Rahmatillah¹

¹Department of Civil Engineering, Faculty of Engineering, Universitas Muhammadiyah Aceh, Jl. Muhammadiyah No. 91, Banda Aceh 23245, Indonesia

²Faculty of Civil Engineering & Technology, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

*Corresponding author: hafnidar.ar@unmuha.ac.id

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Abstract

Construction project has never been avoided by not only low risk but also high risk. It can also occur in building and infrastructure construction project of Aceh Regional Intelligent Agency (BINDA) office complex. The complex structural works can impact the significant risk to the project construction process. To minimize the risk, it is required to review the risk analysis to the time and the cost. The problem of the research was how many probabilities of the highest risk by using Monte Carlo. The objective of the research was to analyze the highest risk probability percentage of time and cost in building construction project by using Monte Carlo simulation. Sampling technique used was census sampling by using 18 respondents. The variables used were contractual risk, construction risk, material and equipment risk, design and technology risk, and force majeure risk. The output of risk acceptability level analysis by using probability and impact found that the dominant risk in undesirable category is wrong implementation as the highest value of 7.50 risk value. The simulation output of Monte Carlo by using @risk software resulted that project duration time was 460 days on 99% probability. For probability distribution of cost estimation resulted that budget plan estimation was IDR 1,991,000,000 on 99% probability, so the project cost estimation can get the benefit as 1.00% by using @risk simulation. Therefore, the response provided is coordination to supervision consultant and owner.

Keywords: probability, risk, time, cost, Monte Carlo

1. Introduction

The fast construction development is found in the globalization era. There are several constraints in the implementation including time and cost problems. These problems can be detected as the

project target defined on time and at the proper cost [1]. A project requires a construction project management as a system or method in managing specific activities in project construction. Project construction is all activities to construct facility and infrastructure carried out in the limited time [2]. The implementation of a project construction in the

various conditions cannot be avoided from not only low risk but also high risk. The lower risk obtained, more benefits of the project can be achieved both time and cost [3].

The same condition also can occur in building and infrastructure construction project of Aceh Regional Intelligent Agency (BINDA) office complex constructed by CV. XYZ. The complex structural works can impact the significant risk to the project construction process. Each work construction requires monitoring and supervision. To minimize the risk in the project, it is required to review the risk analysis to the time and the cost.

Risk analysis used was Monte Carlo simulation. This method was carried out to identify the risk probability and evaluate the risk possibility, and find out how the effect of case study project activities. The problem found was how many probabilities of the highest risk by using Monte Carlo. The objective was to analyze the probability percentage to the highest risk in the project by using Monte Carlo simulation.

The respondent of the research was the contractor involved in building and infrastructure construction project of BINDA Aceh office complex. The variables used are contractual risk (A), construction risk (B), material and equipment risk (C), design and technology risk (D), and force majeure risk (E). The research method used was qualitative and quantitative methods approach by distributing questionnaire and interview. Risk analysis was used Monte Carlo simulation method by using @risk software in Ms. Excel.

2. Literature review

2.1 Project Management

Project management is the process of planning, organizing, leading, and controlling the company resources to achieve short term target determined. Project management grows since there is the requirement in finding the suitable management approach to the demand and project activity characteristic, and detecting dynamic and different activity to the routine operational activity [2].

2.2 Time and Cost

In the project construction, the time can impact the cost loss if delayed and cost profit if accelerated, the effort in optimizing the time become crucial in project design. The time is one of

the construction resources. The resource must be managed for the task effectiveness and efficiency [4].

Cost is cash or cash equivalence value spent to have material or service that expected providing current and future benefits to the organization. The main points must be considered in project cost managements are the planning of resources, cost estimation, budgeting, and cost control [5].

Project time scheduling is based on duration or normal time of the construction. Normal duration is the duration required in completing a construction project by using the experiences in the previous projects, and using the normal resources including: the limit human resources, general or normal equipment, and general or normal technologies. The delay effect occurring not only influences.

The effect of the delay that occurs does not only cause an increase in activity duration, but also construction cost improvement. The calculation of the cost by using Flash is explained as below [6].

- a. Cost on optimistic condition

Project cost on optimistic condition =

$$Real\ service\ cost \times \left(\frac{optimistic\ time}{real\ time} \right) \quad (1)$$

- b. Cost on pessimistic condition

Project cost on pessimistic condition =

$$Real\ service\ cost \times \left(\frac{real\ time}{pessimistic\ time} \right) \quad (2)$$

2.3 Project Risk Management

Project risk is the effect of uncertainty probabilities accumulation influencing the project target and goal. The risk relates to the possibility of bad condition unexpected or uncertainty. The risk growth comes from the various activities affecting cost, schedule and project quality [7].

Risk management is defined as the process in identifying, measuring, and ensuring the risk and developing the strategy to manage the risk. In the project management, project risk management is the art and science in identifying, analyzing, and responding the risk during the project period and ensuring the project target achieved [8].

Based on the analysis, there were risks raised in project construction direct impacted to project construction time. The highest sensitivity value affected to total project time on FIA new building of phase II was CCTV work as 16%. While, for FEB and FH main building project of phase IV, FP new building of phase II, and PTIK new building of phase III was lift passenger work as 19%. After recognizing the dominant risk affected then it can be carried out the mitigation effort for the risk to reduce the impact [9].

2.4 Quantitative risk analysis

Quantitative risk analysis is the method used in prioritizing the risk variables identified in a project by managing the risk resources based on the impacts to the project target then estimating the risk level possible (high, moderate, low). The risk

assessment of the project can be divided into two factors [9].

- 1) Probability, the probability of the risk and the event frequency.
- 2) Impact, the impact of risk event.

Quantitative risk analysis can determine the most dominant risk by multiplying the frequency (likelihood) and impact (consequence) of the risk identified.

$$\text{Risk Index} = \text{Frequency} \times \text{Impact} \quad (3)$$

Based on the risk index calculated from the output of multiplying the frequency (likelihood) and impact (consequence), it is compiled the acceptability level as the previous table [10].

Table 1. Assessment of risk acceptability [9]

Probability Factor	<i>Frequent</i> (5)	25	20	15	10	5
	<i>Probable</i> (4)	20	16	12	8	4
	<i>Occasional</i> (3)	15	12	9	6	3
	<i>Remote</i> (2)	10	8	6	4	2
	<i>Improbable</i> (1)	5	4	3	2	1
	<i>Catastrophic</i> (5)	<i>Critical</i> (4)	<i>Serious</i> (3)	<i>Marginal</i> (2)	<i>Negligible</i> (1)	
Impact Factor						

Description:

Unacceptable
Undesirable
Acceptable
Negligible

From the matrix above, a risk rating can be made if the multiplication result is calculated as a unit indicator. For example, the value of the A1 indicator has an impact multiplied by the value of the A1 indicator frequency, which is 3x5, which means that the 3rd row (occasional) multiplied by the 5th column (catastrophic) has a resulting value of 15, where the value 15 is in the dark blue column, which is an unacceptable risk level and is an indicator of high risk or dominance. If the risk

rating is calculated using the results of the average value of the respondents' answers, then the preparation of the level of risk acceptance assessment can be seen through the table of risk level indicators as on Table 2 below.

Table 2. Risk level indicator

Risk acceptance	Scale
Unacceptable	$x \geq 15$
Undesirable	$5 \leq x < 15$
Acceptable	$3 \leq x < 5$
Negligible	$x < 3$

2.5 Monte Carlo Simulation

Monte Carlo is a method to solve the problem by using sampling technique of the random process involving probability distribution of a variable to produce an expected data, this method can be used when there is uncertainty variable or element in a system [10].

This simulation method involves random number user in modelling the system, in which the time does not have the role of static model substantive. The random number generating is capable in generating truly random number by using a computer algorithmic. In general, this method divides into several phases as below [11].

- 1) Creating the possibility distribution for important variable.
- 2) Generating cumulative possibility distribution for each variable in the first phase.
- 3) Determining random number interval.
- 4) Creating simulation of the test series.

The most possible total of project time resulted by Monte Carlo simulation was 104.479 days or 105 days. Meaning that the project probability success implemented was 50%. If the project time determined 112.807 days or 113 days meaning that that the project probability success implemented was 75% [12].

Random variable of total cost was normal distributed, so the median was not significant deviation compared to mean. Differentiate between median and mean was only 0.22%. The accuracy of Monte Carlo simulation was very high, the error percentage was only 0.56%. The other important information was kurtosis and skew. Kurtosis is relative curve size to the normal distribution curve size. Kurtosis of normal distribution was 0, but kurtosis of Monte Carlo simulation was -0.437 [13].

Monte Carlo simulation is running by using @risk software in Microsoft Excel. The software used I running this simulation is detailed explained as below.

1. @Risk, one of spreadsheet add-ins programs

located in Microsoft Excel software to analyze the risk. @Risk Program can run Monte Carlo simulation to get the output of the critical risk activity in percentage [10].

2. Microsoft Excel is the software general used for it simplify the data calculation automatically and fast. Many professionals recognize that MS Excel is beneficial in various problem solving. Starting from simple work to difficult work can be maximized the output. [14].

3. Methodology

3.1 Research Object

The object identified was the risk of time and cost in building construction project, carried out in Building and infrastructure of BINDA Aceh office complex located in Japakeh Street, Darul Imarah Sub District, Aceh Besar District, Aceh Province. This research was focused on contractor personals involved in the project. The method used was nonprobability sampling by using census sampling technique as 18 samples. The variables used are contractual risk (A), construction risk (B), material and equipment risk (C), design and technology risk (D), and force majeure risk (E). There were 30 indicators.

3.2 Data Processing

All questionnaire data collected is inputted by using SPSS version 25 software by number coding determined. It is carried out to simplify data analysis process. Data processing uses statistical analysis of factor analysis, probability and impact matrix analysis and descriptive analysis. Validity test is carried out by using SPSS version 25 software. Output of the software is Rcount. Then the value of Rcount of all indicators are compared to Rtable. If the indicator has Rcount > Rtable means that the indicator is valid, otherwise if If the indicator has Rcount < Rtable means that the indicator is not valid.

Risk factors of time and cost reliability test is carried out by using SPSS version 25 software. Output of the software is Cronbach Alpha value. If Cronbach Alpha value > 0.6 means that the variable is reliable, otherwise if Cronbach Alpha value < 0.6 means that the variable is not reliable.

3.3 Probability and Impact Matrix

The risk assessment is carried out based on the probability and the consequence or impact. It is carried out to assess the probability of each risk and impact. The next step is calculating risk interest level. After obtaining the probability scale, impact and risk interest level can be determined. The next step is mapping all three values to the matrix. Based on the matrix output, the low, medium, and high risk levels impacted and creating hazards can be determined.

3.4 Descriptive Analysis

This analysis is carried out to find out the data brief ad fast. This analysis uses SPSS version 25 software to find out the mean, median describing the respondents' answers of each research variable, and modus describing the most appearance of each research variable. The output of the descriptive analysis will be explained in each variable.

3.5 Risk Acceptability Level

The risk acceptability level is calculated after obtaining the risk index value, as the multiplying of frequency and impact (consequence) of the risk. Then it is compiled the risk acceptability value in the risk acceptability assessment matrix.

3.6 Data Analysis

Data analysis is the data simplification process to be easy read, comprehended, and interpreted. The data analysis uses Monte Carlo simulation. Monte Carlo simulation can be carried out by using @risk software in Microsoft Excel. The system developed only supports pert distribution by entering three time parameters, including the shortest time (optimistic), the most possible time (most likely), the slowest time (pessimistic). The selection of pert distribution is since the distribution use 3 estimations points represented uncertainty in the project determination.

4. Result and Discussion

4.1 Respondent's Characteristic

The respondents' characteristic in the research was contractor as 18 respondents. The characteristics were grouped into gender, age, educational background, work experience, and characteristic

percentage of work position as shown in table 3.

Table 3. Characteristics of respondents

No	Demographics	Amount	Percentage (%)
1	Gender		
	Male	16	88.89
	Female	2	11.11
2	Age		
	21-30 years	14	77.78
	31-40 years	2	11.11
	41-50 years	2	11.11
	> 50 years	0	0.00
3	Last education		
	Senior High School	1	5.56
	Diploma	4	22.22
	Bachelor degree	13	72.22
	Postgraduate (S2)	0	0.00
	Postgraduate (S3)	0	0.00
4	Work experience		
	0-2 years	7	38.89
	3-5 years	8	44.44
	6-8 years	3	16.67
	> 8 years	0	0.00
5	Position		
	Project Manager	1	5.56
	Quality Control	1	5.56
	Chief Manager	1	5.56
	Site Engineering	1	6.67
	Site Manager	1	5.56
	Site Administration Manager	1	5.56
	Quality Surveyor	2	11.11
	Engineering	3	16.67
	Logistic	2	11.11
	Administration	1	5.56
	Surveyor	1	5.56
	Assistant Surveyor	1	5.56
	Supervisor	1	5.56
	Foreman	1	5.56

4.2 Validity Test Output

Validity test was used to find out the validity of a question item in questionnaire. The samples were 15, so $= 15 - 2 = 13$. Rtable for 5% of significant rates was 0.514. The output of validity test in each question item of the variable processed by using SPSS program and Rcount used was the total value calculated. The validity test output of risk identification from 18 respondents resulted that all indicators got Rcount higher than Rtable (0.4683), meaning that all indicators were valid.

4.3 Reliability Test Output

The test was carried out to find out the reliability of the variable in questionnaire prepared. The calculation used Cronbach Alpha formula. The reliability test output of each variable found that Cronbach Alpha is higher than 0.6, the mean of the total variables was $0.928 > 0.6$ meaning reliable.

4.4 Descriptive Analysis

Descriptive analysis was used to identify the frequency of respondents' questionnaire answers in problem solving based on respondents' data. Descriptive analysis was carried out to present the specific characteristic in the data of the specific sample.

Based on the overall mean calculated, the lowest mean was E2 (flood) question item as 1.56, and the highest mean was B8 (material quality was not suitable to the specification) question item as 2.61. It explained that material damage or loss increase 2.61%. Deviation standard was 0.978 meaning that mean was higher than standard indicating that data deviation is low so the distribution is equal.

4.5 Risk Acceptability Level Analysis

Descriptive analysis is carried out based on questionnaire output to obtain the mean of frequency and the mean of impact. Then the mean of frequency and the mean of impact is multiplied to get risk for each variable, as on Table 4.

Table 4. Analysis of risk acceptability level

No.	Indicator	Frequency (F)	Impact (D)	Risk (F x D)	Risk Level
1	A1	2.33	2.17	5.06	Undesirable
2	A2	2.22	1.89	4.22	Acceptable
3	A3	1.94	1.89	3.61	Acceptable
4	B1	2.39	2.56	6.56	Undesirable
5	B2	2.06	2.33	4.72	Acceptable
6	B3	2.28	2.39	5.61	Undesirable
7	B4	1.89	1.89	3.39	Acceptable
8	B5	2.28	2.17	5.06	Undesirable
9	B6	2.00	1.89	3.44	Acceptable
10	B7	1.94	2.50	5.11	Undesirable
11	B8	2.06	2.61	5.61	Undesirable
12	B9	2.28	2.06	4.67	Acceptable

13	B10	2.11	2.56	5.33	Undesirable
14	C1	2.06	2.00	4.17	Acceptable
15	C2	2.33	1.83	4.33	Acceptable
16	C3	1.94	2.22	4.50	Acceptable
17	C4	2.39	2.56	5.94	Undesirable
18	C5	2.61	2.56	6.56	Undesirable
19	C6	2.44	1.89	4.83	Acceptable
20	D1	2.28	2.06	4.50	Acceptable
21	D2	2.17	2.22	5.00	Undesirable
22	D3	2.61	2.44	6.50	Undesirable
23	D4	2.33	2.44	5.89	Undesirable
24	D5	2.89	2.22	7.22	Undesirable
25	D6	2.94	2.56	7.50	Undesirable
26	E1	2.67	1.83	5.56	Undesirable
27	E2	2.33	1.56	3.83	Acceptable
28	E3	2.06	1.78	3.22	Acceptable
29	E4	2.50	1.78	4.33	Acceptable
30	E5	2.00	1.94	4.11	Acceptable

Based on Table 4, the results were obtained from the data processing of the distribution of questionnaires which used an assessment scale for frequency and impact. From the results assessment, a multiplication between the frequency and the impact is carried out, so that the level of risk acceptance can be determined according to Table 2.

That of all variables consisting 30 indicators, 15 indicators (50%) were undesirable risks and 15 indicators (50%) were acceptable risks, because the risk value obtained is greater than 3, and less than 15. The output of risk acceptability level can be summarized in figure 1 below.

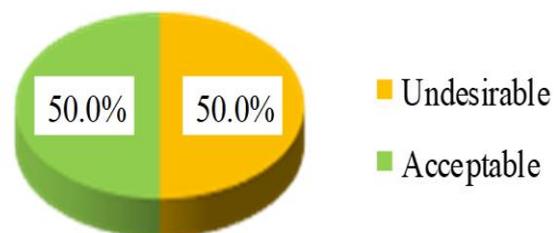


Figure 1. Percentage of risk acceptance level

Acceptable and undesirable risks are dominant (major) risks highly influencing in the project construction. There were 50% of undesirable risk in this research. It described that dominant risks were high in the project assessed and it gave the impact to the project construction. The dominant risks must get special attention from the involved parties in the project and respond the risk in reducing and solving the impacts occurred. The dominant risks table and responses is presented on Table 5.

Table 5. The dominant risk analysis

No	Risk Factor/Variable	Response
A1	Delay payment by the owner	Direct coordination to the owner
B1	Traffic jam in the project location	The alternative to avoid the traffic jam is construction material loading in the project only carried out at night.
B3	Differentiate of unstable soil condition	Doing feasibility study before construction
B5	Concrete quality is not suitable to the specification	Reviewing BQ and construction specification
B7	Change of construction schedule	The project team will complete the report and legal document of the schedule change as the effect of the differentiate of initial data of the design given by the owner to the service provider, and ensure the schedule change agreed by the supervision consultant before being implemented to avoid the future <i>dispute</i>
B8	Material quality is not suitable to the specification	Looking forr the material alternatif which is suitable with the specification and cheching and testing before material sent to the project location.
B10	Security intervention in the project location	Security post and the security in the project location
C4	Material price increase	Have contract with the supplier/vendor in the early of the project construction by using the project cost.
C5	Lacking of material waste disposal place	Waste disposal was carried out uotside the project location, by getting the permission from

D2	The design change	supervision and owner Coordinaton and consultation with the supervision and owner
D3	Incomplete design data	Looking for the information and complete design data to the design consultant
D4	Safety role is not implemented in the field	Briefing K3 before starting each activity in the project location. If there is the violation, warning to be given to K3 team to carry out as the requirement.
D5	Mistake in structure calculation and analysis	Direct coordination with engineering team
D6	The wrong implementation	Coordinaton and consultation with the supervision and owner
E1	Earthquake	Building protection

4.6 Monte Carlo Simulation

The risk analysis process was quantitative by using Monte Carlo simulation. The first phase of the simulation was rearranging every project schedule and finding out the total of three time (duration). They were optimistic, most likely and pessimistic by using Ms. excel.

The simulation provided significant impact to the company in considering the real field compared to the project management itself. By using the simulation, the company can plan the schedule more efficient since it has considered the delay factors in the field, the company also can minimize the cost affected by the delay. The output of Monte Carlo by using @risk program resulted time and cost risk for all work items and it can be explained detail as below table.

Table 6. The output of Monte Carlo simulation by using @risk program for time

No	Working Time Schedule	Duration (day)
1	The shortest time can be completed (min) of the total project time	391
2	The longest time can be completed (max) of the total project time	472
3	The mean time can be completed (<i>mean</i>) of the total project time	432
4	The time can be 50% success implemented	432

The output of Monte Carlo simulation by using @risk software resulted each project time activity. The minimal time was 391 days, the maximal time was 472 days, and the mean time was 432 days. It required 460 days for 99% success implemented. It was carried out the analysis of minimum unit price and maximum unit price. Then the Monte Carlo Simulation was conducted by using @risk software, it resulted probability distribution of more realistic cost estimation. The simulation output can be explained as below.

Table 7. The output of Monte Carlo simulation to probability distribution of cost estimation by using @risk program

No	Description	Simulation Output
1	Maximum of total project cost	IDR 2,031,000,000
2	Minimum of total project cost	IDR 1,670,000,000
3	Mean of total project cost	IDR 1,869,000,000
4	Deviation Standard of total project cost	IDR 55,668,342
5	Percentage of 50%	IDR 1,870,000,000
6	Percentage of 75%	IDR 1,907,000,000
7	Percentage of 95%	IDR 1,954,000,000
8	Percentage of 99%	IDR 1,991,000,000

Based on the above table, it is resulted that the actual cost of the project construction in RAB was IDR 1,998,515,254. The minimum cost as the simulation output was IDR 1,670,000,000, the minimum cost as the simulation output was IDR 2,031,000,000. It required IDR 1,991,000,000 for 99% success implemented.

5. Conclusion

The risk factors influencing the time and the cost are contractual risk, construction risk, material and equipment risk, design and technology risk, and force majeure risk. Based on risk acceptability level analysis by using probability and impact, the dominant risk having the highest value was indicator the wrong implementation as 7.50 and the response given was coordination and consultation with the supervision and owner. The quantitative risk analysis was carried out by using Monte Carlo

simulation using @risk software. For statistical distribution of project time, it resulted that probability time for 99% was 460 days, so the project time can get the benefit as 1.35%. For probability distribution of cost estimation, it resulted that probability for 99% was IDR 1,991,000,000, so the project cost estimation can get the benefit as 1.00% by using @risk simulation.

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