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A Conceptual Study on the Monte Carlo Simulation for Cost Forecasting in the Green Building Project

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Abstract

Monte Carlo Simulation is a mathematical technique that generates random variables for modelling risk. This technique is suitable and benefits to the various client such as public and private sector to evaluate the realistic costing proposed by the Quantity Surveyor. Through this approach, quality of life received by the client in investing budget without waste of propose funding in the construction project. The methodology used is a qualitative approach consist of case study and document analysis. The result shows through Monte Carlo simulation, can predict the worst return from the accuracy of the estimation and given absolute confidence for project development.

Keywords: Monte Carlo, Risk Analysis, Cost Prediction, Qualitative Approach

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1.0 Introduction

Cost overruns commonly occur in the construction project; one of the factors contributes to the cost overrun the Quantity Surveyor unable to estimate accurately during the pre-contract stage. Ali Touran, (2006) elaborates on the many factors are responsible for these cost overruns such as underestimation of cost to make the project more viable, the addition of scope during later stages of project planning and even during construction, changed condition and others. Based on the factors also contribute to the project delay in the construction industry due to not enough budget allocation for the proposed construction. Therefore, an accurate model is crucial for the Quantity Surveyor to use monte Carlo software to test the accuracy of the cost estimate prepared in the client's project. In Malaysia, the use of software to predict the uncertainty of cost only based on the "5 to 10% rule". The percentage is used for the cost contingency from the total cost of the construction. Therefore, failure to predict the cost, the client will suffer to allocate further budget in the development. The needs of an appropriate probabilistic model to predict the accuracy of cost in the construction project. Therefore, the study aim is to analyse the concept of Monte Carlo practice in predicting the cost estimate in the Green Building Project. The objective of this research is to explore the concept of monte Carlo simulation used to evaluate the accuracy of the cost estimate prepare in the construction project.

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2.0 Literature Review

The literature review highlighted the concept of Monte Carlo method practice in the construction industry. It's cover the definition of monte Carlo, method of estimating using monte Carlo, types of a forecasting method, benefits of monte Carlo and process of monte Carlo to predict the cost estimate.

2.1 Definition of Monte Carlo

A formal definition of Monte Carlo Methods was given by Halton (1970). He defined Monte Carlo as a method of "representing the solution of a parameter of a hypothetical Population, and using a random sequence of numbers to construct a sample of the population, from which statistical estimates can be obtained". This subsection of the literature review covers the relevant studies on the Monte Carlo definition. Table 1.0 below shows the meaning of Monte Carlo simulation.

Table 1.0 Definitions of Monte Carlo simulation

| Author(s) | Year | Definition of Monte Carlo simulation |
|----------------------|------|---|
| Hertz | 1964 | "As a tool to estimate risk in capital markets, and employs the mode, spread, and skewness of probability distributions to describe/model uncertainty from various sources and produce a distribution of the possible outcomes by randomly selecting input values from the predetermined distributions." |
| Marquez et al. | 2005 | "Monte Carlo produces probability distributions of functions, including distribution and mean square deviation." |
| Faris and Patterson | 2007 | "Monte Carlo simulation is a technique that combines historical data with inputs from S.M.E.s to assign a weight or probability of the occurrence of a certain risk throughout a project." |
| El-Sadek | 2010 | "Monte Carlo simulation, like any other simulation model tries to approximate real-world processes and interactions at a mechanical level." |
| Jahangirian et al. | 2010 | "Monte Carlo simulation is one of the earliest simulation methods." |
| Palisade Corporation | 2010 | "Monte Carlo Simulation is a proven technique used to simulate costs and schedule. Monte Carlo Simulation makes use of probability distributions in place of deterministic values to model the uncertainty associated with a particular input and the possible outcomes that can occur, thus allowing for better decision-making abilities when dealing with such uncertainty." |
| Chou | 2011 | "A probabilistic technique that can be applied for cost estimation and decision making." |
| Liu and Zhang | 2012 | "Monte Carlo is a method that substitutes point estimates with random numbers obtained from probability density functions and then builds models of possible results." |

As mentioned by Chou (2012), Monte Carlo is a probabilistic technique that can be applied for cost estimation and decision making. The previous researcher mostly defined Monte Carlo simulation is a method or simulation or tool to describe various sources of probability distributions to model the uncertainty (El-Sadek, 2010;(Hertz, 1964); Jahangirian et al., 2010; Marquez et al., 2005; Palisade Corporation, 2010; Liu and Zhang, 2012). Whereas cited in Faris and Patterson (2007), Monte Carlo simulation is a technique that combines historical data with inputs from numerical data to assign a weight or probability of the occurrence of a particular risk throughout a project. Additionally, Monte Carlo Simulation is a proven technique used to simulate costs and schedule. Monte Carlo Simulation makes use of probability distributions in place of deterministic values to model the uncertainty associated with a particular input and the possible outcomes that can occur, thus allowing for better decision-making abilities when dealing with such uncertainty (Palisade Corporation, 2010). The further subsection of the literature review will cover the relevant studies on the Monte Carlo simulation definition. Even there are varies in terms of Monte Carlo simulation, but most of them focus on the probability distributions, cost estimate and decision making.

2.2 Method of Estimating for Cost Prediction using Monte Carlo Simulation

There are several methods used to estimate cost prediction; usually used cost contingency. At the simplest level, there is the "10% rule", where the Estimate is increased by 10% (Wilson, 2015). He describes a slightly better method is the "expert judgement" method. The percentage relies on the experience and knowledge of the expert and remains subjective and in truth, provides a "gut feel" amount for the contingency. The better methods rely on estimating the risks involved for sub-sections of the project and then using some way to combine the risks for the individual sections to get the risk and required contingency for the overall project. This uses the same divide-and-conquer procedure that is used to generate the total cost, i.e. divide the project up into manageable sections and estimate the costs piece by piece and then combine them. Various heuristic methods that have been developed by different institutions, but the most widely accepted and fundamentally sound way of combining the individual risks is Monte Carlo simulation. Describe by Mun, (2015) Monte Carlo simulation in its simplest form is a random numbers generator that useful for forecasting, estimation, and risk analysis. A simulation calculates numerous scenarios of a model by repeatedly picking values from a user-predefined probability distribution for the uncertain variables and using those values for the model. As all those scenarios produce associated results in a model, each scenario can have a forecast. Forecasting is the act of predicting the future. It can be based on historical data or speculation about the future when no history exists. When historical data exist, a quantitative or statistical approach is best, but if no historical data exist, then potentially a qualitative or judgement approach is usually the only recourse (Mun, 2015).

2.3 Types of Forecasting Method

Forecasting method is divided into the following; Refer Figure 1.2 Forecasting Methods.

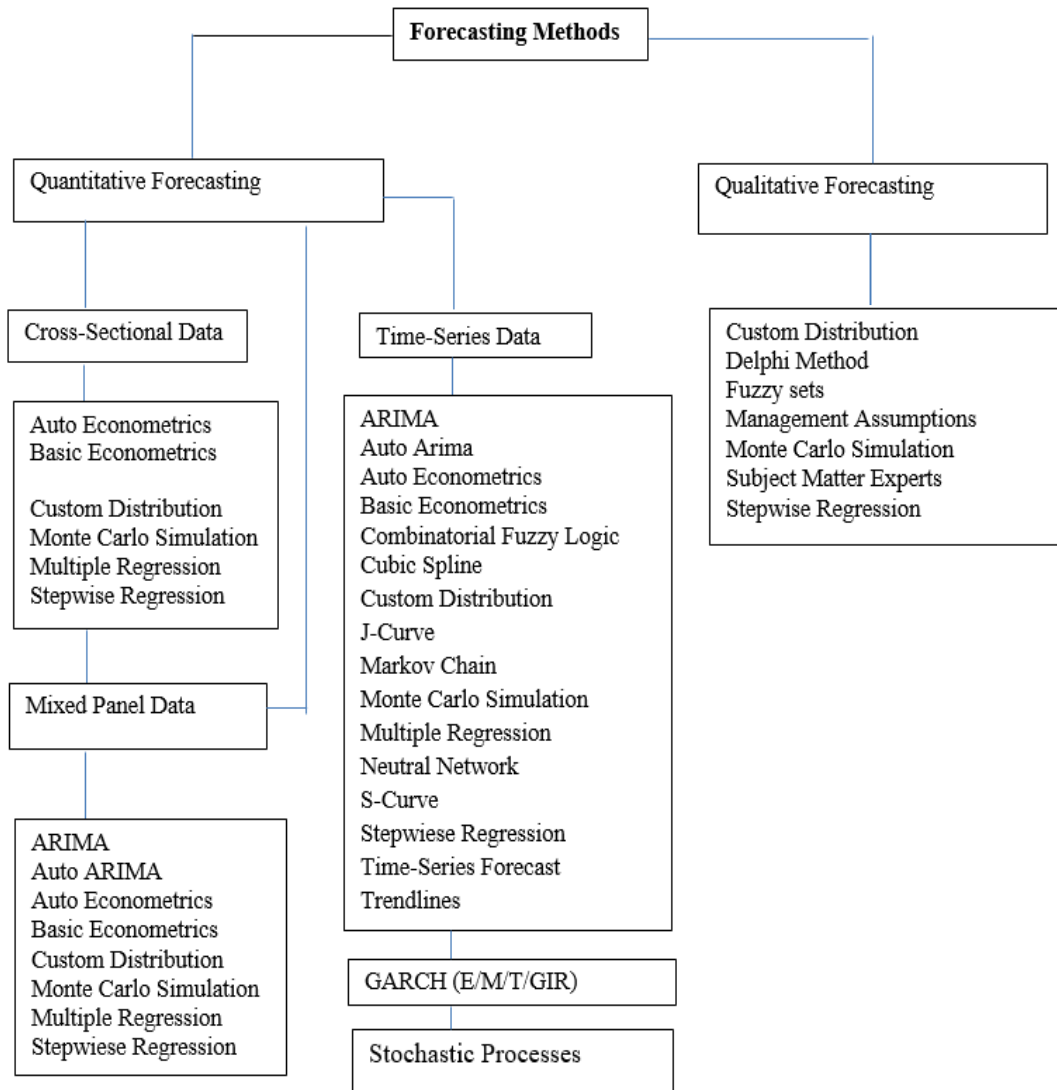


Figure 1.2 Forecasting Methods (Source : Mun, 2015)

Generally, forecasting can be divided into quantitative and qualitative approaches. In this research, a qualitative approach was used to identify the forecasting cost in the green project. The component of value and green building element cover the development cost during the feasibility study stage (Shukur, 2016). However, In Malaysia, different green building rating tools exist such as the Green Performance Assessment System, Penarafan Hijau, Green Real Estate, and GBI (Lim et al., 2016). GBI is Malaysia's first comprehensive rating system, developed by Malaysian Institute of Architects /Pertubuhan Arkitek Malaysia and the Association of Consulting Engineers Malaysia, to facilitate the accomplishment of sustainable development goals in Malaysia (GBI, 2018). GBI evaluates the environmental design and performance of green buildings in Malaysia based on six main criteria: sustainable site planning & management, materials & resources, water efficiency, indoor environment quality, innovation, and E.E. (GBI, 2018).

2.4 Benefits of Monte Carlo Simulation for Industry Players

Hongxiang and Wei (2013) highlighted that Monte Carlo simulation offers many advantages over other analysis:

- i) Correlation of input: M.C.s can model interdependent relationships between uncertainty variable. It is a vital feature to represent how and when the factors vary accurately
- ii) Scenarios Analysis: Deterministic model could hardly figure out the results of genuinely different scenarios under different combination of values generating from different input. M.C.s can quickly point out which information with value leads to a specific outcome.
- iii) Sensitivity Analysis: it is difficult to find the most relevant parameter in a particular result by deterministic analysis. However, M.C.s can easily and accurately seek the variable, which affects the result the most.

The Monte Carlo simulation method allows us (Marseguerra and Zio, 2000) to consider various relevant aspects of

systems operation that cannot be easily captured by analytical models (K-out-of-N, redundancies, stand-by nodes, etc.). With the advances of computer technology, the repetitiveness of the process and the handling of a huge amount of numerical information is no longer a barrier in implementing Monte Carlo simulation (Bennett and Ormerod, 1984). Monte Carlo became an alternative for the program evaluation and review technique for cost estimation (Balcombe and Smith, 1999; Khedr, 2006; Moselhi, 1997). Koo and Fischer (2000) reported that the simulation model could improve communication between project participants and safety by anticipating hazard in the construction site.

Specifically, Monte Carlo simulation helps project managers to quantify and justify project reserves based on the identified risk (Kwak and Ingall, 2007). Furthermore, this approach can be used to determine the final budget at project completion and contingencies estimation, which can be calculated based on the probability distribution of the final budget (Kwak and Ingall, 2007).

2.5 Process of Monte Carlo Simulation

The general processes of simulation include data collection, random number generation, formulation of the model, data analysis, and visual presentation (Chou, 2011). This approach uses a large number of simulated trials and sampling technique to approximate a solution to a problem (Ashworth, 2004; Grinstead and Snell, 2012), such as developing realistic cost estimate (Khedr, 2006).

Lorance and Robert (1999) list the various steps of carrying out a "Monte Carlo simulation". The first step is to define the capital resources by developing the deterministic model of the Estimate. The second step is to identify the uncertainty in the Estimate by specifying the possible values of the variables in the Estimate with probability ranges (distributions). The third step is to analyse the Estimate with the simulation. The model is run (iterated) repeatedly to determine the range and probabilities of all possible outcomes of the model.

Through a series of simulation, Monte Carlo can estimate the total cost by producing the distribution of cost component. Monte Carlo calculates the total cost of a project by independent sampling from the distribution of cost component. In this process, the optimistic and pessimistic value can be both created. The random value generator can select values for the interval (a, b) and then the frequency of data can be determined based on the distribution (Chen, 2013). The prediction shows based on Figure 1.3 below;

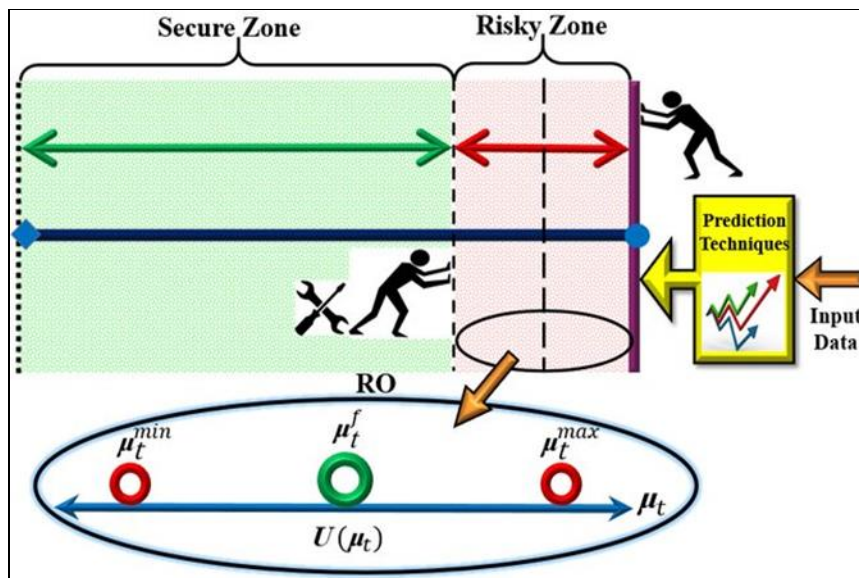


Figure 1.3 shows Prediction Techniques in Monte Carlo Simulation
(Source: "Robust Design of Microgrids with Reconfigurable Topology under Several Uncertainty," 2017)

This method can be applied while predicting the cost of development by the Quantity Surveyor in the green building project. The formula applies as follows:-

$$DC = PDC + CC + P + x\%C + y\%GBI$$

By using Monte Carlo, the Quantity Surveyor can convince the client either the justification of x% for contingency and Y% for Green Building is accurate for cost estimate proposes for the project. This simulation is crucial for the client to ensure the viability of the project

is worth for investment. Therefore, it can reduce the cost of overrun in the project and benefit received in term of quality of life for the client in the project development.

3.0 Methodology Approach

The research use a case study approach and document analysis. Three (3) projects of the case study were selected. Cost prediction was analysed using Monte Carlo simulation software. The methodology used to estimate the building cost in the green building project. The building cost is a critical element in the new development and needs to be appropriately evaluated by the Quantity Surveyor. For forecast statistics, a distribution's location or central tendency (expected returns) is calculated; the second tales describe its width or spread (risk); the third moment, its directional skew (most probable events); and the fourth moment, its peakedness or thickness in the tails (catastrophic losses or gains). The limitation of this research only concentrated on the green building project. All four events need to evaluate and interpreted to provide a more comprehensive view of the project under analysis. Steps of the study using the procedure explained by (Barreras, 2011) as follows;

- a. Compute initial Estimate (feasibility study stage)
- b. Determine correlations
 - i. Between Estimate Line Items
 - ii. Between Risk Drivers
 - iii. Between line items and risks
- c. Build a model
- d. Run Monte Carlo Simulation
- e. Analyse the result

3.1 Compute initial Estimate (feasibility study stage)

As the project defines the scope and prepares cost estimate for the various packages, it is crucial to capture the detail from the selected project. Cost estimate for prediction must include worst case, best case, and most likely values. This often referred to as a three-point estimate. As procurement activities take place on the project, it is helpful to remember that in the early phases of a project.

3.2 Determine correlations

Correlations can exist between any two or more items in the cost estimate, between risk events, and between risk event and cost estimate items. It is crucial to have a cross-discipline review of all correlations to ensure that all functional team leads agree with the correlations proposed for the Monte Carlo Simulation.

3.3 Build a Model

The Monte Carlo Simulation models should be structured to be able to demonstrate both the value of the risk treatments or response plans and the amount needed for contingency reserve. It is essential to carefully review the project assumptions and constraint at this point to ensure appropriate consideration is given when constructing the model.

3.4 Run Monte Carlo Simulation

The Monte Carlo Simulation software will have several sets to predict the cost estimate at the required level. What probability does management want to use to determine contingency for the proposed project either 80% or 90% for final project setting or need to reserve for management cost?

3.5 Analyse the result

The results are the most crucial step of the entire process. The results must well be understood by the Quantity Surveyor and Client. The results need to communicate on the amount of contingency element, distribution between one item is very tight or narrow and the deterministic value percentage at the area of baseline or below.

4.0 Findings

The findings show that by using software, capturing the data needed to build and simulate project risks and cost Estimate via a monte Carlo simulation is considered accurate. The client is more confident to make a decision making to proceed with the proposed project as compare using a conventional approach of the Estimate to predict the cost in the construction project.

5.0 Discussion

From this paper, Monte Carlo is a software used to predict the event of forecasting and Optimization software. The Software is written in Microsoft.NET C# and function together with Excel as the add-in. Therefore, this software is crucial to be used to predict the cost of estimation prepare by the Quantity Surveyor. From the literature review, the importance of this software to be used to avoid cost overrun

occurs in the construction project. The methodology used is a qualitative approach. The actual case study selected are Hospital projects which category as a Green Building Index. The review of a document such as a cost for development is crucial, and Monte Carlo simulation test will be conducted. The result from the Monte Carlo simulation will give the scenario to the client in terms of the accuracy of the proposed cost estimate.

6.0 Conclusion & Recommendations

This paper urges the need for research to help the industry players or practitioner to understand the importance of this software application for the process of decision making to identify risk and the worth for money during the preparation of the cost estimate. The Monte Carlo proved to be a vital tool to the clients, project manager and the Quantity Surveyor to predict the cost estimate and the uncertainty during the project undertaking. Through this approach, quality of life received by the client in investing budget without waste of propose funding in the construction project. The result shows through Monte Carlo simulation, and this method can predict the worst return from the accuracy of the estimation and given absolute confidence for project development in the construction project. Therefore, quality of life received by the client thorough successful implementation of the project according to time, cost and quality.

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