Journal of
Entrepreneurship and
Project Management
(JEPM)

MONTE-CARLO APPROACH FOR MEASURING ADJUSTING COST RISKS VALUES OF RESIDENTIAL BUILDING PROJECT'S WHOLE LIFE CYCLE FROM CLIENTS' PERSPECTIVE IN THE UNITED ARAB EMIRATES

Journal of Entrepreneurship and Project Management, Vol. 6 No. 1 (2021), 72–89.

CARI
Journals

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021 www.carijournals.org

MONTE-CARLO APPROACH FOR MEASURING ADJUSTING COST RISKS VALUES OF RESIDENTIAL BUILDING PROJECT'S WHOLE LIFE CYCLE FROM CLIENTS' PERSPECTIVE IN THE UNITED ARAB EMIRATES

Ahmed Sadek

The British University in Dubai
2015132021@student.buid.ac.ae

Abstract

Purpose – Although projects' experts always take into consideration the related cost-risks. They are experiencing the challenge of not being able to finish the project within the estimated budget. Latest cost-risks studies concentrated on modelling and estimating risks at the preconstruction stage. This article aims to approach Monte-Carlo simulation using stochastic mathematical modelling to measure cost-risks error (i.e., adjusting cost-risks).

Methodology – The approach of this research is solely quantitative. It is using statistical modelling and simulations to ensure the accuracy and precision of the developed Monte-Carlo model. However, this study is utilizing Microsoft Office Excel Software Mersenne twister algorithm to generate random numbers to ensure most accurate Monte-Carlo approach. The mathematical equations system is built into Excel.

Findings – The research outputs are considered significant in project management body of knowledge. This is because of the resulted evidence that is proving the applicability to measure cost risks error using Monte-Carlo simulation. This study presented cost risks and differentiated between contractors' and clients' views.

Unique contribution to theory, practice and policy – The originality of this article comes from providing the first Monte-Carlo approach for measuring projects' cost-risks error from client's perspective. The theoretical-implications, practical-implications, and limitations are presented in the conclusion for future research.

Keywords: *Adjusting Cost-Risks, Monte-Carlo, Probability, Normal Distribution, Residential Buildings, Project's WLC, Mathematical Modeling, Relativity Change.*

1. INTRODUCTION

In this article, the process of computing accurate risks' errors will be detailed. This research will conduct Monte-Carlo Simulation to compute the adjusted and adjusting risks used in the cost estimation modelling. Therefore, this article Monte-Carlo simulation will be based on taking 10,000 random measures for each risk factor (i.e., 117 final validated risks) to provide accurate cost estimation results.

It is important to know about the Monte Carlo approach's history to understand its value and importance (Jackel, 2002). In the 1940s, the Monte Carlo method for mathematical computation started by three American mathematicians (i.e., Nicholas Metropolis, John von Neumann, and Stanislav Ulam) during the entrance programable computers for the first time (Jackel, 2002). The approach did not have a name until Nicholas Metropolis, and Stanislav Ulam scientists used it to conduct a multi-dimensional statistical calculation analysis in 1949 and called it the Monte Carlo method (Jackel, 2002). Monte Carlo analysis is based on a computer algorithm to generate sufficiently random numbers to support mathematical

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021 www.carijournals.org

prediction equation approaching a stochastic process (Jackel, 2002). The following parts are including (1) cost risks minimum-maximum limits, (2) Monte-Carlo simulation approach, (3) Data Mean Shifting Mathematics, and (4) cost risks Monte-Carlo modelling.

2. LITERATURE REVIEW

This part of the research will review relevant literatures to justify scientifically the reasons of approaching Monte-Carlo simulation to measure cost risks from clients' perspective. The following literatures is including: (1) Cost Risks Minimum-Maximum Limits and (2) Monte-Carlo Simulation Approach.

2.1. Cost Risks Minimum-Maximum Limits

The cost risk range identification, including minimum and maximum limits, is an essential mathematical process before moving to Monte Carlo simulation. It is done after validating all collected data (i.e., risks, impact, and probability). Each validated cost risk has a mean and standard deviation value. This research is using experts' data to simulate actual costs in the future. It will require a minimum sample size equal to 385 for unknown populations using Equation 1 (Sathian et al., 2010). Alternatively, a sample size equal to 400 from published quantitative sample-size tables (Singh & Masuku, 2014).

$$n_0 = \frac{z^2\,p\,q}{e^2} \tag{1}$$

n_0= Sample Size

Z= Standard score

p = the (estimated) proportion of the population (variability)

q = 1 – p

e = Desired precision level (i.e., 0.05 for 95% confidence level)

Therefore, the following quantitative minimum required sample calculation of unknown population, using Equation 1, is including Z= 1.96 (Sathian et al., 2010). It is assuming the population error of confidence level 95% as e (i.e., 1 - 0.95 = 0.05) and it is assuming maximum variability as justified earlier (i.e., P = 0.5).

$$Sample\ Size = \frac{1.96^2 * 0.5 * 0.5}{0.05^2} = 384.16\ \approx 385$$

Alternatively, it is possible to use the Monte Carlo simulation to cover the smaller sample size gaps. This research study is justified in how the acceptable sample size is equal to 55 face-to-face survey interviews. Therefore, this research study does not follow the published table or sample size mathematical calculations, as mentioned in Equation 1. However, it still requires to include accurate mathematical modelling to deliver an accurate final cost estimation model. Monte Carlo simulation can guaranty the high precision of each modelled variable (Heijungs, 2020). It requires upper and lower limits to ensure

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021 www.carijournals.org

precise accuracy (Heijungs, 2020). These limits need to be around the actual population's mean using standard deviation (Heijungs, 2020). Therefore, adequate sample size and data collection methods ensure accurate means and standard deviations as justified earlier. These data will successfully represent the population's mean and standard deviation, as proved earlier. Therefore, in this research study, Monte Carlo variables' modelling limits are extracted from the validated experts' face-to-face survey interviews to ensure accuracy. Figure 1 clarifies the difference between accuracy and precision (Heijungs, 2020). Valid data will ensure accuracy, and Monte Carlo simulation will ensure the precision of each variable.

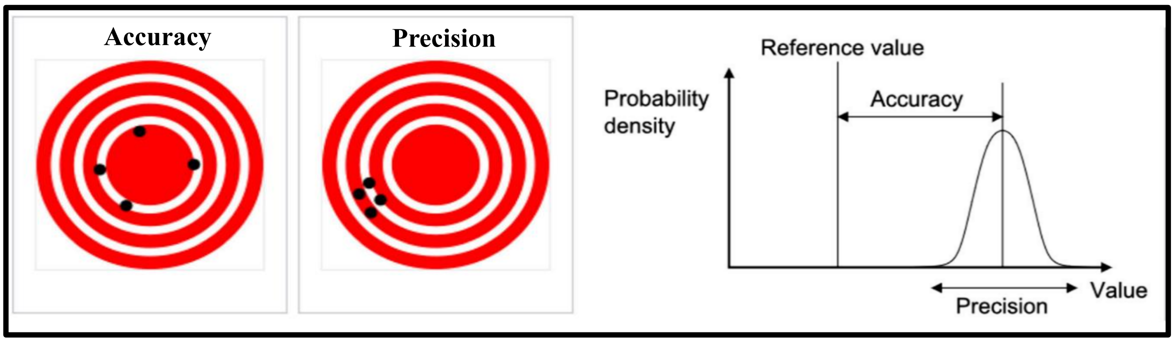

Figure 1. *The difference between accuracy and precision (Heijungs, 2020).*

Finally, Equation 2 is used to define the Monte Carlo upper and lower limits. The following part will detail how Monte Carlo simulation is accomplished in this research study.

$$\textit{Monte Carlo Upper and Lower Limits} = \textit{Cost Risk Mean} \pm \textit{Standard Deviation} \quad (2)$$

2.2. Monte-Carlo Simulation Approach

This part will explain how Monte Carlo modelling is validated in this research study. Monte Carlo modelling is the stochastic mathematical estimation modelling of this research study (Bukaçi et al., 2016). This method is used to maximize the likelihood of functions representing actual results at absent data incidence (Caffo et al., 2005). It is also used in previous research to maximize linear equations' likelihood to represent actual data (Lai & Lin, 2011). Also, researchers proved that it is valuable for conducting unbiased simulations (Thompson & McLeod, 2009). However, it is found in previous research that Monte Carlo simulation requires a minimum number of iterations (i.e., random values) to validate functions' likelihood of actual representation (Heijungs, 2020; Bukaçi et al., 2016; Caffo et al., 2005; Nowak et al., 2016; Thompson & McLeod, 2009). It is found that previous research used a wide range of valid Monte Carlo iterations, including 100, 1,000, 10,000, 1x105, and 1x107 (Heijungs, 2020; Nowak et al., 2016; Thompson & McLeod, 2009). It is also extracted from the literature that Monte Carlo required the number of iterations based on the research type (Heijungs, 2020; Bukaçi et al., 2016; Caffo et al., 2005; Nowak et al., 2016; Thompson & McLeod, 2009). It is unnecessary to have more accurate outputs by adding more iterations; in other words, previous research proved that using 1x105 iterations is more accurate than using 1x107 iterations for the same study (Thompson & McLeod, 2009). It is essential to identify the minimum required iteration number in this research. Moreover, in literature, similar life cycle assessment studies declared that it is common to use ≥10,000 iterations for Monte Carlo modelling and recommended this minimum valid number (i.e., 10,000) for life cycle assessment studies (Heijungs, 2020). Therefore, this research study uses 10,000 iterations for each cost risk Monte Carlo simulation without increasing iterations to prove its validity.

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021 www.carijournals.org

The mathematical modelling equations of this research Monte Carlo simulation require several assumptions to validate it from a client perspective at the pre-construction stage. These assumptions are listed based on what is explained earlier as the following:

- Constructions and projects industry experts provide all survey risks.
- All weighted risks have an appropriate risk management system set by contractors with values equal to what is provided by industry experts. These risk values are identified and assessed successfully by contractors throughout the projects' whole life cycle.
- All risks identified by industry experts have been considered by contractors and included in the contract value cost. Therefore, the contract bill of quantity pricing is done by contractors and is including all identified risks by industry experts.
- The Monte-Carlo simulation will be used to calculate the error in the project's risk management system and find the adjustment value for each risk factor. It is required because the project's actual costs are not matching pre-construction estimated costs as justified earlier. Therefore, this is evidence of having errors in experts identified risk values. Moreover, it will be corrected through this research Monte Carlo method.
- The adjustment values are errors of mean risks, minimum risks, and maximum Risks. It will be used in the final system dynamics model to ensure that the estimated cost includes all its possible impacting risks. This will be including the known risks' weightage identified by experts (i.e., known-known and known-unknown risks). Moreover, it will include the unknown risk error (i.e., unknown-unknown risks) by conducting Monte-Carlo Simulation for each cost risk variable.
- Based on the justified reasons behind considering the error of experts' judgment when estimating costs at the pre-construction stage from a client perspective, the final model's minimum, mean, and maximum risks are the error of minimum, mean, and maximum risks.

The adjusted mean is the sample mean after implementing Monte Carlo outputs. This research assumes that the population mean equal to the adjusted mean after finding out each risk variable's error and embracing it in the variable's sample mean. This declaration is to recommend further research periodically to measure risks error and update it continuously. However, as of this research time, all risks are considered accurate and reflect the population's actual data.

From Figure 1, it is clear why using Monte Carlo simulation is essential. However, shifting data means should be done based on moving the full distribution to avoid discrediting experts' data. The mean only shall be moved toward the believed actual population means μ without changing each risk's standard deviation. Figure 2 clarifies how this research intends to conduct the required shift successfully.

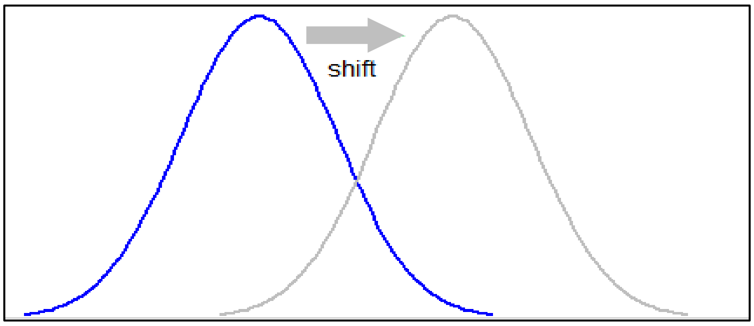

Figure 2. *Shifting data mean without discredit distribution reliability should be without changing the standard deviation.*

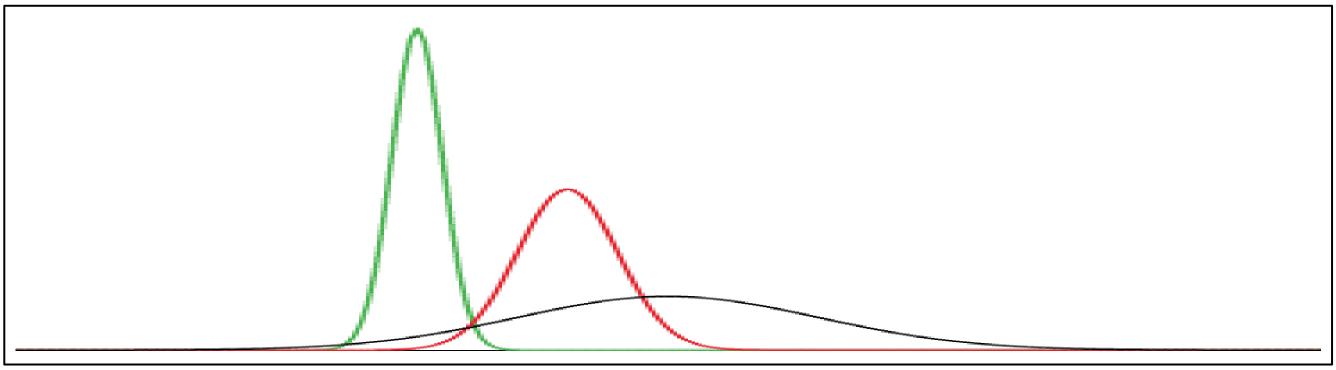

Figure 3. *Showing how shifting data mean while changing its standard deviation discredit the full data distribution and withdraw its reliability and validity.*

The reason behind fixing each variable's standard deviation is to maintain experts' data reliability and validity. Figure 3 shows how standard deviation change impacts data distribution significantly and withdraws data credibility. However, the normal back distribution has the largest standard deviation. The red-normal distribution has a smaller standard deviation than the black one, but it is larger than the normal green distribution standard deviation. Finally, the green-normal distribution has the smallest standard deviation.

3. RESEARCH METHODOLOGY

The research methodology of this article is to develop statistical and mathematical systems using Microsoft Office Excel software Mersenne twister algorithm to satisfy the requirements of the desired Monte-Carlo stochastic approach. Therefore, the research approach in this paper is pure quantitative. This paper approached 55 construction/project experts, in a face-to-face survey interview, to collect quantitively the cost risks values and validated them statistically prior utilizing it in the developed Monte-Carlo model.

4. ANALYSIS AND DISCUSSION

Monte Carlo cost risks model is developed in this part of the research and analysed using the validated data and the developed equations system. Each raw in the Excel sheet shown in the appendix is a separate Monte Carlo model for the identifies cost risk. The following parts in this section are detailing the analysis processes through a critiqued discussion; however, this is including: (1) Data Mean Shifting Mathematics and (2) Cost Risks Monte-Carlo Modelling.

4.1. Data Mean Shifting Mathematics

In this part of the paper, a detailed process of how to satisfy the previously discussed approach mathematically to achieve a successful Monte Carlo Modelling of costs risks. Therefore, the adjusted mean value can be calculated for each risk variable using Equations 3. Then, the adjustment mean value (i.e., error) can be calculated for each risk variable using Equation 4. This process is clarified in Figure 4 for better understanding.

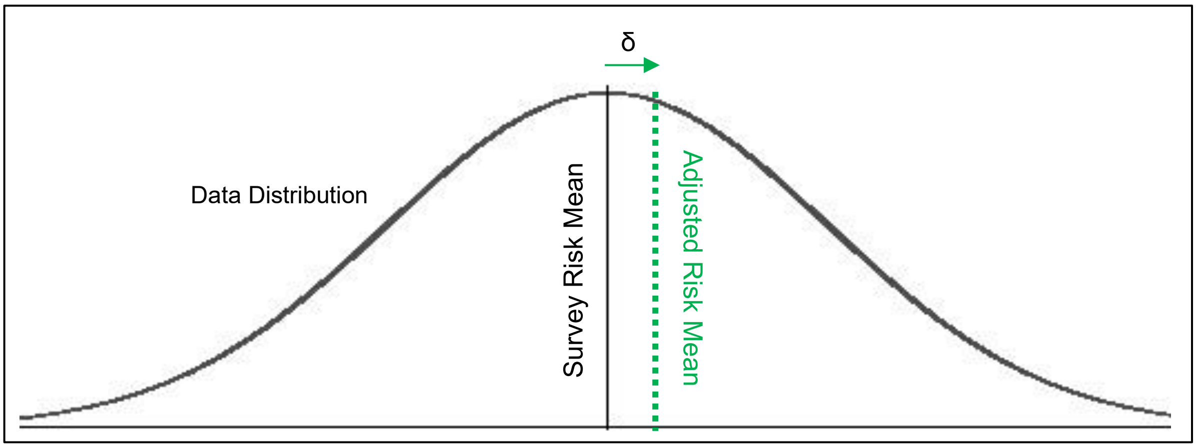

Figure 4. *clarify the difference between survey risk mean and adjusted risk mean for the same data distribution of each variable.*

Adjusted Mean Value = Min+[MC*(Max–Min)] (3)

Min is the Minimum Survey Risk Value

Max is the Maximum Survey Risk Value

MC is Monte Carlo average of 10,000 random values (between 0 to 1).

Adjusted Mean Value = $\delta = \left|\frac{\nu_A - \nu_E}{\nu_E}\right| * 100$ (4)

δ is the percent error.

ν_E is the Maximum Survey Risk Value

ν_A is the Believed actual value (i.e., adjusted value).

After implementing the Monte Carlo simulation method, final system dynamics data inputs can achieve the required accuracy and precision, as shown in Figure 5. This will improve the final cost estimation using the system dynamics approach.

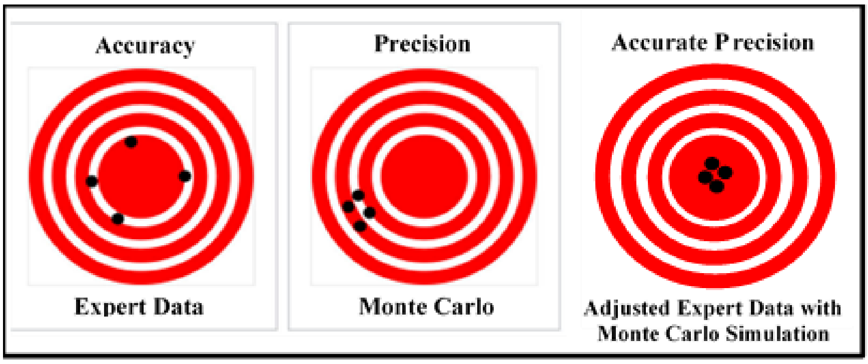

Figure 5. *Experts' data and Monte Carlo modelling impact on final outputs' accuracy and precision.*

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021

However, it is found that Adjusted Mean Risk, Adjusted Maximum Risk, and Adjusted Minimum Risk have the same mathematical relationship between Survey Mean Risk, Survey Maximum Risk, and Survey Minimum Risk. This is justified and proved in Equations 5 to 14. These equations clarify how the adjusted minimum and adjusted maximum values are mathematically calculated.

Based on 95% Confidence:

$$\textbf{Max Risk} = \bar{X} + 2\sigma \qquad (5)$$

$$\textbf{Min Risk} = \bar{X} - 2\sigma \qquad (6)$$

$\boldsymbol{\sigma}$ is the risk standard deviation

$\bar{x}$ is the survey sample mean risk

Max Risk is the Normal Distribution Upper Limit

Min Risk *is the Normal Distribution Lower Limit*

From equations 5 and 6:

$$2\boldsymbol{\sigma} = \boldsymbol{Max\ Risk} - \bar{\boldsymbol{x}} = \bar{\boldsymbol{x}} - \boldsymbol{Min\ Risk} \qquad (7)$$

$$\mathbf{2}\ \bar{\boldsymbol{x}} = \boldsymbol{Min\ Risk} + \boldsymbol{Max\ Risk} \qquad (8)$$

From equation 4:

$$\text{Adjustment Mean Value (error)} = \frac{Adjusted\ Mean - \bar{x}}{\bar{x}} \qquad (9)$$

By feeding equation 9 into equation 8 and by using mathematical multiplication and division properties:

$$2\ \bar{x} * \frac{Adjusted\ Mean - \bar{x}}{\bar{x}} = (Min\ Risk + Max\ Risk) * \frac{Adjusted\ Mean - \bar{x}}{\bar{x}} \qquad (10)$$

$$2\ \bar{x} * Adjustment\ Mean = (Min\ Risk + Max\ Risk) * Adjustment\ Mean \qquad (11)$$

$$2\ Adjustment\ Mean = \left(\frac{Min\ Risk}{\bar{x}} + \frac{Max\ Risk}{\bar{x}}\right) * Adjustment\ Mean \qquad (12)$$

$$\text{Adjustment minimum risk value} = \frac{Min\ Risk}{\bar{x}} * Adjustment\ Mean \qquad (13)$$

$$\text{Adjustment maximum risk value} = \frac{Max\ Risk}{\bar{x}} * Adjustment\ Mean \qquad (14)$$

Therefore, it is mandatory to approach the Monte Carlo method in this research to obtain the minimum, mean, and maximum risks error. This process will have the required 10,000 random iterations generated using the Microsoft Office Excel software program. Then, start computing using equations 5 to 14.

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021
www.carijournals.org

In order to ensure the implementation of accurate and successful Monte Carlo simulation for the verified data, it is mandatory to understand the basic software mathematics used to generate random numbers. Furthermore, to confirm that chapter 4 developed mathematical modelling equations that can be computed utilizing Excel software. Therefore, by reviewing the Microsoft Office Excel official manual, it has been found that Excel RAND() function is the approach to generate random numbers between 0 and 1 (RAND function, 2020). It is also stated clearly that RAND() function uses the Mersenne twister algorithm to generate random numbers (RAND function 2020). According to the literature, the Mersenne twister algorithm is one of many computer algorithms to generate pseudorandom outputs (Self & Mackey, 2016; Graham & Talay, 2013). According to the linear feedback shift register, the Mersenne twister is one of the most important random number generating algorithm based on its historical strength (Self & Mackey, 2016). It has been proved accurate for linear congruential generation and linear functions (Self & Mackey, 2016). Therefore, this research will use the Microsoft Office Excel software program to approach Monte Carlo stochastic mathematical modelling to compute risks error using Figure 6 algorithm and equations 15 and 16.

Adjusted Mean Using Excel = RAND()*(b-a)+a (15)

$$= \frac{\sum_{1}^{10,000} RAND()}{10,000} * (b - a) + a \quad (16)$$

a = the Minimum Survey Risk Value

b = the Maximum Survey Risk Value

RAND() = Monte Carlo pseudo-random values (between 0 to 1).

Formula	Description	Result
=RAND()	A random number greater than or equal to 0 and less than 1	varies
=RAND()*100	A random number greater than or equal to 0 and less than 100	varies
=INT(RAND()*100)	A random whole number greater than or equal to 0 and less than 100	varies
	Note: When a worksheet is recalculated by entering a formula or data in a different cell, or by manually recalculating (press **F9**), a new random number is generated for any formula that uses the RAND function.	

Figure 6. *Microsoft office official random equation used in excel (RAND function. 2020).*

This research data's calculated error is based on normally distributed data as explained and justified earlier. It will be taken based on using distribution properties (i.e., Mean and Standard Deviation) to apply risks' error impact on the contract value at the design stage to estimate final costs and cashflows. Therefore, each error set related to a variable requires to have the same behavior of its data (i.e., normal distribution

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021 www.carijournals.org

mean, standard deviation, upper limit, and lower limit). The detailed process shown in Figure 7 must be followed and reflected in the analysis to satisfy this requirement. Otherwise, the mean risk might be lower than the upper limit or more than the upper limit. The procedure shown in Figure 7 ensures that mathematical statistics theory applies on a higher generalization level. Similar research about buildings' operations and management used this approach to check if a theory's relevance can be extended (Meredith, 1998). Researchers' evidence, for approaching testing theories' relevance extension, is based on replacing Newton's gravity theory with Einstein's relativity theory due to generalization (Meredith 1998). Previous literature declared that weighted cost-risks measurement in a project's delivery is achieved by conducting a sensitivity analysis to measure its relativity using a risk assessment probabilistic approach (Akinyemi et al., 2009). It is essential to understand the driving risk force to assign it as the relativity gravity center of each problem (Flores-Colen et al., 2010). Gravity term is used because objects' behavior relatively changes toward each other concerning their response to gravity force. Relativity change in this research can be defined as the change of data errors (i.e., ΔMinimum and ΔMaximum) using ΔMean as the main driving force connecting all data distribution changes relative to its change.

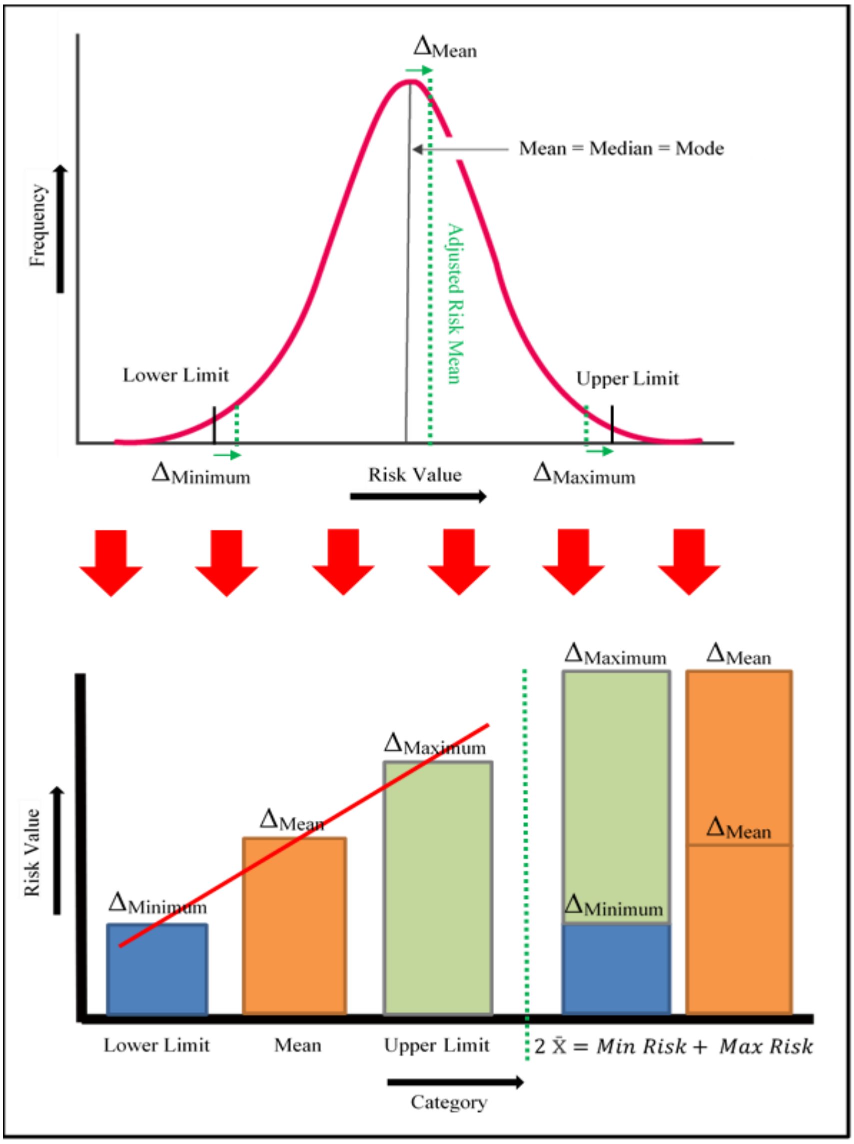

Figure 7. Computing ΔMinimum and ΔMaximum using ΔMean and equations 9 to14.

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021
www.carijournals.org

4.2. Cost Risks Monte-Carlo Modelling

According to researchers, to identify the accuracy of parameters and attributes measurements, it is most recommended to have a stepwise regression followed by a Monte Carlo simulation (Yang et al., 2019). Built environment projects have cost estimation issues due to client requirements (Ahiaga-Dagbui & Juffermans, 2019; Oswald et al., 2020). This requires having an estimation model from client perspectives. Monte-Carlo calculation of adjusted and adjusting risks is based on the final SPSS validated data outputs.

In the appendix table, Monte Carlo modelling is fully detailed to obtain the final desired outputs (i.e., risks errors). The first column from the left side is including the serial numbers of each cost risk and the alphabet letter of each variables' group, as shown in Figure 8. However, in Figure 8, the risk description is represented in the second column of the appendix table, and its reference is CA1 (i.e., C = CAPEX, A = Group Symbol, and 1 = the activity number under the group).

SN	Cost Variable Description
A	Construction Activities' Risks
1	Selection Method

Figure 8. *Cost risks description and reference code (i.e., CA1) from the appendix table.*

Survey Risk Mean % X1	Risk Standard Deviation %
31.930	22.386

Figure 9. *CA1 Cost risks SPSS Mean and Standard Deviation from the appendix table.*

The third and fourth columns are the survey risk mean and standard deviation after validating data using SPSS software, as shown in Figure 9. However, to facilitate clarifying further coming calculations in the appendix Table, the survey risk mean column is given a symbol X1 as shown in Figure 9. After that, the lower and upper limits are calculated, as shown in Figure 10, using equations 5 and 6 fifth and sixth column of the appendix table. However, they are given symbols Xmin and Xmax, respectively, to facilitate further calculations understanding of Monte Carlo simulation. In Figure 11, the seventh and eighth columns present the average percentage of 10,000 random values used in Monte Carlo simulation and the adjusted Mean value (i.e., X2 in the appendix table) using equation 9.

Min. Survey Risk Value % Xmin	Max Survey Risk Value % Xmax
9.544	54.316

Figure 10. *CA1 Cost risks Lower and Upper Limits from the appendix table.*

10,000 Random Values Avg.	Monti-Carlo Modelling adjusted Mean Risk value % X2
0.503	32.082

Figure 11. *CA1 10,000 iterations average & cost risks adjusted Mean from the appendix table.*

Relativity Change Between Survey Minimum Risk Value % and Survey Mean Risk value % Rmin= (Xmax/X1)*Rmean	Relativity Change Between Survey Maximum Risk Value % and Survey Mean Risk value % Rmax= (Xmax/X1)*Rmean	Relativity Change Between Monti-Carlo Modelling adjusted Risk Mean Value % and Survey Mean Risk value % Rmean=ABS(X2-X1)/X1
0.001422906	0.008097921	0.004760413

Figure 12. *CA1 ΔMinimum , ΔMean, and ΔMaximum from the appendix table. Calculations are using equations 9 to 14 and figure 7.*

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021 www.carijournals.org

Then, the calculations of mean error and the relativity change of data upper and lower limits, as explained earlier, is done using equations 9 to 12, as shown in Figure 12. However, these calculations occur in each cell of the ninth, tenth, and eleventh columns of the appendix table, respectively. However, the equations used in each of these columns use introduced symbols mentioned previously in the appendix table column for better understanding, as shown in Figure 12.

Finally, in Figure 13, the difference between validated data survey means and adjusted Monte Carlo simulation means is presented graphically and numerically, respectively, in the twelfth column. It is used to have a balanced random value's average by ensuring almost 50% of the differences under positive and negative changes. This will avoid any bias with or against experts provided data, as shown in Figure 14.

Deference between Survey Risk Mean and Adjusted Mean %		
		0.152
		-0.008

Figure 13. *CA1 and CA2 Cost risks deference between the survey and the adjusted Means from the appendix table.*

Deference between Survey Risk Mean and Adjusted Mean %	
Positive	Negative
58	**59**
117	

Figure 14. *Balancing the appendix table Cost risks deference between the survey and the adjusted Means.*

The model is finalized after simulating several random iterations and fixed the values that caused 58 positives and 59 negatives (i.e., almost 50% in positive and 50% in negative) as counted in the last column of the appendix table and as shown in Figure 14. After that, from Figures 8 to 13, the appendix table is explained using the same cost risk (i.e., under CAPEX, construction activities group, selection method risk = CA1=first raw). Thus, the Monte Carlo simulation of this risk will be detailed as an example of what the appendix table data reflects. The most important part is how columns nine to eleven calculate relativity change using Figure 7 approach. From using equation 8 (i.e., $2\,\bar{x} = Min\ Risk + \ Max\ Risk$) Figure 12 shows that R_{min} (i.e., risk lower limit relativity change) is equal to 0.001422906. Furthermore, R_{max} (i.e., risk upper limit relativity change) is equal to 0.008097921. Moreover, R_{mean} (i.e., risk's adjustment Mean) is equal to 0.004760413. Therefore, equation 8 can be satisfied through the following substitution.

$$2 * \ 0.004760413 = 0.001422906 + \ 0.008097921$$

$$✓\ 0.00952083 = 0.00952083$$

Each row in the appendix table is a Monte Carlo Simulation for each risk, as explained in this article.

4. CONCLUSION

In summary, this article introduced the history of Monte Carlo modelling and its importance in estimating unknown numerical values using a probabilistic stochastic approach. Also, it is clarified how the Monte Carlo simulation relates to cost-risks outputs. Therefore, this article is presenting 117 Monte Carlo simulations to end with the 117 values of Rmin, Rmean, and Rmax to be used in system dynamics cost modelling.

4.1. Originality

According to the best knowledge of the author, there is no previous research approached identifying residential projects whole life cycle cost-risks, from client perspective at the preconstruction stage, using Monte-Carlo simulation approach.

4.2. Theoretical Implications

This article output is considering the cost-risks from client perspective after obtaining the tender contract value from contractors. The project's contract value is including identified cost risks and its assessment costs by contractor's experts. Further research is recommended to investigate the reason of project cost estimation error compared with the actual completion costs.

4.3. Practical Implications

This article provides Monte-Carlo approach to measure the error to adjust estimated contractual costs and predict the actual cost at the end of the project. Project management professional.

4.4. Limitations and Future Research

The limitations of this research have been collected and summarized as the following:

1- The collected data was based on experts' face-to-face survey interviews and Monte Carlo stochastic modelling. It is recommended to investigate the model response after using published tables sample size for data collection. Experts identified risk values against previous historical completed projects (i.e., at least 30 projects) to calculate each risk error and adjust risk value feed into the system dynamics cost model.

2- Finally, this research included, in Monte Carlo simulation, 10,000 iterations as the minimum required iterations. However, according to the researcher's best knowledge, no one used system dynamics for cost modelling in previous research. It is recommended to investigate the impact of changing the Monte Carlo iterations number on the developed system dynamics cost modelling accuracy.

REFERENCES

[1] Ahiaga-Dagbui, D. and Juffermans, T. (2019). DEVELOPING COLLABORATIVE AND LESS ADVERSARIAL PROJECT TEAMS, THE BUILDING ECONOMIST, vol. 3(March), pp. 43–47.

[2] Akinyemi, B., Ojiako, U., Maguire, S., Steel, G. and Anyaegbunam, A. (2009). Nigerian Banks and the Perception of Risk in PPP Project Delivery, Journal of Finance and Management, vol. 8(2), pp. 1–20.

[3] Bukaçi, E., Korini, T., Periku, E., Allkja, S. and Sheperi, P. (2016). Number of iterations needed in Monte Carlo Simulation using reliability analysis for tunnel supports, Int. Journal of Engineering Research and Applications, vol. 6(6), pp. 60–64.

[4] Caffo, B. S., Jank, W. and Jones, G. L. (2005). Ascent-based Monte Carlo expectation – maximization, Royal Statistical Society, vol. 67(2), pp. 235–251.

[5] Flores-Colen, I., de Brito, J. and Freitas, V. (2010). Discussion of Criteria for Prioritization of Predictive Maintenance of Building Façades: Survey of 30 Experts, Journal of Performance of Constructed Facilities, vol. 24(4), pp. 337–344.

[6] Graham, C. and Talay, D. (2013). Stochastic Simulation and Monte Carlo Method, Springer Heidelberg.

[7] Heijungs, R. (2020). On the number of Monte Carlo runs in comparative probabilistic LCA, The International Journal of Life Cycle

Assessment, vol. 25(1), pp. 394–402.

[8] Jackel, P. (2002) Monte-Carlo methods in finance, Interscience.wiley.com. [online]. [Accessed 10 October 2020]. Available at: http://www3.interscience.wiley.com/journal/114179393/abstract.

[9] Lai, G. and Lin, X. (2011). Condition for relaxed Monte Carlo method of solving systems of linear equations, Supercomput, vol. 57(1), pp. 256–264.

[10] Meredith, J. (1998). Building operations management theory through case and field research, Journal of Operations Management, vol. 16(4), pp. 441–454.

[11] Nowak, M., Miao, J., Dumonteil, E., Forget, B., Onillon, A., Smith, K. S. and Zoia, A. (2016). Annals of Nuclear Energy Monte Carlo power iteration: Entropy and spatial correlations, Annals of Nuclear Energy, vol. 94(1), pp. 856–868.

[12] Östlund, U., Kidd, L., Wengström, Y. and Rowa-Dewar, N. (2011). Combining qualitative and quantitative research within mixed method research designs: A methodological review, International Journal of Nursing Studies, vol. 48(3), pp. 369–383. doi

[13] Sathian, B., Sreedharan, J., Baboo, N. S., Sharan, K., Abhilash, E. S. and Rajesh, E. (2010). Relevance of Sample Size Determination in Medical Research, Nepal Journal of Epidemiology, vol. 1(June), pp. 4–10.

[14] Self, J. and Mackey, M. C. (2016). Random Numbers from a Delay Equation, Journal of Nonlinear Science, vol. 26(5), pp. 1311–1327.

[15] Singh, A. and Masuku, M. (2014). SAMPLING TECHNIQUES & DETERMINATION OF SAMPLE SIZE IN APPLIED STATISTICS RESEARCH : AN OVERVIEW, International Journal of Economics, Commerce and Management, vol. 2(11), pp. 1–22.

[16] Support.microsoft.com. (2020). RAND Function. [online]. [Accessed 19 January 2020]. Available at: <https://support.microsoft.com/en-us/office/rand-function-4cbfa695-8869-4788-8d90-021ea9f5be73?ui=en-us&rs=en-us&ad=us>

[17] Thompson, K. and Mcleod, A. (2009). Accelerated ensemble Monte Carlo simulation, CUTTING EDGE CREDIT RISK, vol. 4(April), pp. 86–92.

[18] Yang, P. Y., Hui, C. J., Tien, D. J., Snowden, A. W., Derfus, G. E. and Opel, C. F. (2019). Accurate definition of control strategies using cross validated stepwise regression and Monte Carlo simulation, Journal of Biotechnology, vol. 2(November), pp. 1–10.

Journal of Entrepreneurship and Project Management
ISSN 2520-9116 (Online)
Vol. 6, Issue No.1, pp 72 -89, 2021
www.carijournals.org

APPENDIX

SN	Cost Variable Description	Survey Risk Mean % X1	Risk Standard Deviation %	Min. Survey Risk Value % Xmin	Max Survey Risk Value % Xmax	10,000 Random Values Avg.	Monti-Carlo Modelling adjusted Mean Risk value % X2	Relativity Change Between Survey Minimum Risk Value % and Survey Mean Risk value % Rmin= (Xmax/X1)*Rmean	Relativity Change Between Survey Maximum Risk Value % and Survey Mean Risk value % Rmax= (Xmax/X1)*Rmean	Relativity Change Between Monti-Carlo Modelling adjusted Risk Mean Value % and Survey Mean Risk value % Rmean=ABS(X2-X1)/X1	Deference between Survey Risk Mean and Adjusted Mean %
A	Construction Activities' Risks										
1	Selection Method	31.930	22.386	9.544	54.316	0.503	32.082	0.001422906	0.008097921	0.004760413	0.152
2	Type of Client: Solo Individual	24.550	23.277	1.273	47.827	0.500	24.542	1.68972E-05	0.000634834	0.000325866	-0.008
3	Type of Client: Bank- Individual Partnership	22.580	17.649	4.931	40.229	0.495	22.411	0.001634458	0.013334541	0.0074845	-0.169
4	Type of Client: Developer	21.220	15.645	5.575	36.865	0.501	21.254	0.000420952	0.002783572	0.001602262	0.034
5	Type of Client: Group of People	26.080	15.807	10.273	41.887	0.498	26.014	0.000996841	0.004064508	0.002530675	-0.066
6	Location: City Area	22.670	19.730	2.940	42.400	0.500	22.684	8.00889E-05	0.001155024	0.000617556	0.014
7	Location: Regional Area	22.840	18.129	4.711	40.969	0.502	22.919	0.000713424	0.006204264	0.003458844	0.079
8	Location: Beach Area	23.550	16.722	6.828	40.272	0.501	23.571	0.000258542	0.001524898	0.00089172	0.021
9	Location: Desert Area	31.650	23.420	8.230	55.070	0.506	31.934	0.002333301	0.015612987	0.008973144	0.284
10	Building Services Complexity: Operational Services	26.820	17.132	9.688	43.952	0.505	26.987	0.002249226	0.010204167	0.006226696	0.167
11	Building Services Complexity: Fitness Services	24.150	15.401	8.749	39.551	0.495	23.983	0.00250519	0.011325038	0.006915114	-0.167
12	Number of Basement Levels	22.560	18.953	3.607	41.513	0.498	22.493	0.000474835	0.005464881	0.002969858	-0.067
13	Procurement Method	29.200	17.190	12.010	46.390	0.499	29.149	0.000718369	0.002774782	0.001746575	-0.051
14	Site Topography	26.930	17.920	9.010	44.850	0.499	26.903	0.000335441	0.001669758	0.001002599	-0.027
15	Site Conditions	29.330	20.110	9.220	49.440	0.490	28.934	0.00424426	0.022758809	0.013501534	-0.396
16	Working Space	19.130	16.546	2.584	35.676	0.497	19.045	0.00060018	0.008286386	0.004443283	-0.085
17	Site Access	19.910	18.686	1.224	38.596	0.498	19.823	0.000268632	0.008470695	0.004369663	-0.087
18	Frame Structure	18.450	13.281	5.169	31.731	0.499	18.416	0.000516289	0.003169348	0.001842818	-0.034
19	Foundation Type	18.870	13.951	4.919	32.821	0.500	18.881	0.000151959	0.001013913	0.000582936	0.011
20	Ground Conditions	30.310	17.055	13.255	47.365	0.501	30.338	0.000403986	0.001443589	0.000923788	0.028
21	Type of Soil	28.270	18.006	10.264	46.276	0.503	28.393	0.001579684	0.00712212	0.004350902	0.123
22	Mark-up Size	17.850	16.672	1.178	34.522	0.501	17.890	0.000147887	0.004333906	0.002240896	0.040
23	Need for Work	17.670	14.934	2.736	32.604	0.504	17.800	0.001139164	0.013575041	0.007357102	0.130
24	Deadline Requirements	36.710	20.623	16.087	57.333	0.502	36.782	0.000859486	0.003063151	0.001961318	0.072
25	Number of Stories	22.020	15.841	6.179	37.861	0.502	22.088	0.000866548	0.005309656	0.003088102	0.068
26	Project Duration	33.350	21.961	11.389	55.311	0.496	33.189	0.001648617	0.008006555	0.004827586	-0.161
27	Gross Floor Area	21.450	16.726	4.724	38.176	0.497	21.362	0.00090352	0.007301608	0.004102564	-0.088
28	Equipment Required	25.800	18.664	7.136	44.464	0.503	25.894	0.001007728	0.006279094	0.003643411	0.094
29	Construction Technology Availability	30.670	21.461	9.209	52.131	0.503	30.804	0.001311867	0.007426314	0.00436909	0.134
B	Political Risks										
1	Change in Law	27.440	23.599	3.841	51.039	0.492	27.056	0.001958878	0.026029461	0.013994169	-0.384
2	Delay in Project Approvals and Permits	41.410	20.110	21.300	61.520	0.498	41.327	0.001030973	0.002977721	0.002004347	-0.083
3	Poor Public Decision Making Process	31.540	17.959	13.581	49.499	0.499	31.502	0.00051879	0.001890848	0.001204819	-0.038
4	Government Intervention	30.570	19.296	11.274	49.866	0.500	30.559	0.000132703	0.000586957	0.00035983	-0.011
5	Unstable Government	36.650	25.307	11.343	61.957	0.501	36.693	0.000363119	0.001983403	0.001173261	0.043
6	Government Reliability	38.260	23.664	14.596	61.924	0.497	38.108	0.00151561	0.006430025	0.003972818	-0.152
7	Inconsistencies in Government Policies	29.350	22.868	6.482	52.218	0.502	29.421	0.000534258	0.004303902	0.00241908	0.071
8	Strong Political Opposition / Hostility	27.070	23.768	3.302	50.838	0.501	27.107	0.000166726	0.002566928	0.001366827	0.037
9	Expropriation/ Nationalization of Assets	26.440	22.576	3.864	49.016	0.502	26.539	0.000547204	0.006941449	0.003744327	0.099
10	Inability of Concessionaire	22.560	19.908	2.652	42.468	0.498	22.475	0.000442909	0.007092552	0.00376773	-0.085
C	Legal Risks										
1	Change in Tax Regulation	30.470	22.963	7.507	53.433	0.501	30.530	0.000485146	0.003453154	0.00196915	0.060
2	Corruption and Lack of Respect for Law	30.960	22.622	8.338	53.582	0.496	30.770	0.001652774	0.010621127	0.006136951	-0.190
3	Legislation Change	25.560	19.411	6.149	44.971	0.498	25.477	0.000781198	0.005713325	0.003247261	-0.083
4	Import / Export Restrictions	22.830	19.872	2.958	42.702	0.495	22.644	0.0010556	0.01523875	0.008147175	-0.186

SN	Cost Variable Description	Survey Risk Mean % X1	Risk Standard Deviation %	Min. Survey Risk Value % Xmin	Max Survey Risk Value % Xmax	10,000 Random Values Avg.	Monti-Carlo Modelling adjusted Mean Risk value % X2	Relativity Change Between Survey Minimum Risk Value % and Survey Mean Risk value % Rmin= (Xmax/X1)*Rmean	Relativity Change Between Survey Maximum Risk Value % and Survey Mean Risk value % Rmax= (Xmax/X1)*Rmean	Relativity Change Between Monti-Carlo Modelling adjusted Risk Mean Value % and Survey Mean Risk value % Rmean=ABS(X2-X1)/X1	Deference between Survey Risk Mean and Adjusted Mean %
5	Rate of Return Restrictions	18.610	19.755	-1.145	38.365	0.496	18.470	-0.000462851	0.015508525	0.007522837	-0.140
6	Industrial Regulatory Change	24.980	20.551	4.429	45.531	0.504	25.157	0.001256302	0.012915035	0.007085669	0.177
D	Economic Change Risks										
1	Interest Rate Volatility	22.670	20.536	2.134	43.206	0.497	22.554	0.00048167	0.009752119	0.005116895	-0.116
2	Inflation Rate Volatility	26.220	21.914	4.306	48.134	0.500	26.236	0.000100214	0.001120228	0.000610221	0.016
3	Foreign Exchange and Convert	20.630	17.709	2.921	38.339	0.499	20.604	0.000178446	0.002342155	0.001260301	-0.026
4	Poor Financial Market	30.450	19.669	10.781	50.119	0.501	30.472	0.000255804	0.001189188	0.000722496	0.022
E	Natural Risks										
1	Force Majeure	18.350	18.789	-0.439	37.139	0.498	18.265	-0.000110818	0.009375123	0.004632153	-0.085
2	Environment	18.070	17.122	0.948	35.192	0.500	18.082	3.48396E-05	0.001293329	0.000664084	0.012
3	Weather	17.440	16.317	1.123	33.757	0.506	17.649	0.000771673	0.023196217	0.011983945	0.209
4	Geotechnical Condition	23.690	18.247	5.443	41.937	0.498	23.627	0.000611011	0.004707689	0.00265935	-0.063
F	Market Risks										
1	Market Supply	25.110	20.860	4.250	45.970	0.503	25.232	0.000822347	0.008894897	0.004858622	0.122
2	Market Demand	27.070	23.514	3.556	50.584	0.505	27.328	0.001252002	0.01780969	0.009530846	0.258
3	Fluctuation of Material Cost by Public/Private	24.810	20.746	4.064	45.556	0.504	24.997	0.001234644	0.013839923	0.007537283	0.187
4	Value of Production Effort	22.300	20.355	1.945	42.655	0.499	22.245	0.000215116	0.004717619	0.002466368	-0.055
G	Project Selection Risks										
1	Public Opposition to Projects	18.540	20.705	-2.165	39.245	0.498	18.443	-0.000610956	0.011074818	0.005231931	-0.097
2	Uncompetitive Tender	25.500	20.831	4.669	46.331	0.493	25.210	0.002082291	0.020662807	0.011372549	-0.290
3	Level of Demand for the Project	24.190	19.179	5.011	43.369	0.504	24.338	0.001267402	0.010969059	0.006118231	0.148
4	Land Acquisition	25.000	18.473	6.527	43.473	0.504	25.156	0.001629139	0.010850861	0.00624	0.156
5	Competition Risk	19.610	18.296	1.314	37.906	0.502	19.699	0.00030411	0.008772892	0.004538501	0.089
H	Project Finance Risks										
1	Inaccurate Estimates	31.410	22.055	9.355	53.465	0.494	31.143	0.00253174	0.014469215	0.008500478	-0.267
2	High Finance Cost	26.260	21.016	5.244	47.276	0.499	26.197	0.000479086	0.004319086	0.002399086	-0.063
3	High Bidding Costs	26.850	20.754	6.096	47.604	0.496	26.673	0.001496682	0.011687675	0.006592179	-0.177
4	Delay in Payment of Annuity	27.980	20.087	7.893	48.067	0.497	27.879	0.001018282	0.00620116	0.003609721	-0.101
5	Financial Attraction of Project to Investors	23.890	17.372	6.518	41.262	0.501	23.917	0.000308351	0.001952009	0.00113018	0.027
6	Lack of Creditworthiness	22.870	17.394	5.476	40.264	0.500	22.879	9.42266E-05	0.000692831	0.000393529	0.009
7	Delay in Financial Closure	27.850	19.082	8.768	46.932	0.504	28.002	0.001718279	0.00919734	0.00545781	0.152
8	Inability to Service Debt	26.410	17.615	8.795	44.025	0.503	26.509	0.001248344	0.006248816	0.00374858	0.099
9	Lack of Government Guarantees	23.470	20.526	2.944	43.996	0.500	23.462	4.27564E-05	0.000638965	0.000340861	-0.008
10	Financer Unwilling to Take High Risk	28.090	20.574	7.516	48.664	0.505	28.276	0.001771725	0.011471422	0.006621574	0.186
I	Building Functionality and Serviceability Risks										
1	Construction Time Delay	33.240	23.063	10.177	56.303	0.499	33.211	0.000267113	0.001477772	0.000872443	-0.029
2	Material Availability	21.720	19.022	2.698	40.742	0.501	21.760	0.000228761	0.00345448	0.001841621	0.040
3	Labor Availability	24.480	21.043	3.437	45.523	0.500	24.476	2.29412E-05	0.000303856	0.000163399	-0.004
4	Poor Quality of Workmanship	27.720	22.443	5.277	50.163	0.495	27.477	0.00166881	0.015863657	0.008766234	-0.243
5	Default of Sub-Contractors or Suppliers	27.260	22.192	5.068	49.452	0.501	27.307	0.00032054	0.003127735	0.001724138	0.047
6	Design & Construction Complexity	28.860	20.276	8.584	49.136	0.500	28.860	0	0	0	0.000
7	Design Deficiency	34.370	21.935	12.435	56.305	0.498	34.266	0.001094763	0.004957026	0.003025895	-0.104
8	Late Design Change	33.240	20.054	13.186	53.294	0.501	33.286	0.00054897	0.002218779	0.001383875	0.046
9	Construction Technology Complexity	24.090	17.485	6.605	41.575	0.502	24.170	0.000910519	0.005731241	0.00332088	0.080
10	Contractual Risk	24.610	16.973	7.637	41.583	0.501	24.641	0.000390896	0.002128405	0.001259651	0.031
11	Contractor Failure	36.290	20.888	15.402	57.178	0.500	36.279	0.000128646	0.000477582	0.000303114	-0.011

SN	Cost Variable Description	Survey Risk Mean % X1	Risk Standard Deviation %	Min. Survey Risk Value % Xmin	Max Survey Risk Value % Xmax	10,000 Random Values Avg.	Monti-Carlo Modelling adjusted Mean Risk value % X2	Relativity Change Between Survey Minimum Risk Value % and Survey Mean Risk value % Rmin= (Xmax/X1)*Rmean	Relativity Change Between Survey Maximum Risk Value % and Survey Mean Risk value % Rmax= (Xmax/X1)*Rmean	Relativity Change Between Monti-Carlo Modelling adjusted Risk Mean Value % and Survey Mean Risk value % Rmean=ABS(X2-X1)/X1	Deference between Survey Risk Mean and Adjusted Mean %
12	Quality and Reliability	25.170	18.248	6.922	43.418	0.496	25.019	0.001649841	0.01034857	0.005999205	-0.151
J	Stakeholders Relationship Risks										
1	Different Working Method Between Partners	22.670	16.968	5.702	39.638	0.499	22.629	0.000454892	0.003162223	0.001808558	-0.041
2	Inadequate Experience in Residential Projects	25.850	18.700	7.150	44.550	0.497	25.720	0.001391004	0.008667023	0.005029014	-0.130
3	Lack of Commitment From Public/Private Sector	24.800	16.725	8.075	41.525	0.500	24.806	7.87754E-05	0.000405096	0.000241935	0.006
4	Organization and Coordination Risk	17.830	15.720	2.110	33.550	0.498	17.767	0.000418139	0.006648603	0.003533371	-0.063
5	Inadequate Distribution of Responsibility & Risk	20.610	17.066	3.544	37.676	0.500	20.610	0	0	0	-0.063
6	Inadequate Negotiation Period Prior to Initiation	20.260	13.902	6.358	34.162	0.495	20.118	0.00219953	0.011818239	0.007008885	-0.142
7	Conflict Between Project's Participants	23.190	17.059	6.131	40.249	0.500	23.186	4.56026E-05	0.000299374	0.000172488	-0.004
8	Workers Strike	19.200	18.867	0.333	38.067	0.501	19.230	2.70996E-05	0.0030979	0.0015625	0.030
9	Cultural Differences Between Main Stakeholders	15.060	14.330	0.730	29.390	0.501	15.083	7.40288E-05	0.00298042	0.001527224	0.023
K	Knowledge Risks										
1	Expertise	26.260	18.559	7.701	44.819	0.504	26.427	0.00186498	0.010853984	0.006359482	0.167
2	Familiarities	21.170	15.358	5.812	36.528	0.503	21.264	0.001219023	0.007661469	0.004440246	0.094
3	Number of Bidders	20.020	15.540	4.480	35.560	0.498	19.969	0.000570059	0.004524846	0.002547453	-0.051
4	Market Conditions	25.700	20.870	4.830	46.570	0.495	25.472	0.001667308	0.016075883	0.008871595	-0.228
5	Size of the Project	25.690	21.231	4.459	46.921	0.502	25.788	0.000662118	0.00696731	0.003814714	0.098
6	Type of Building	23.190	19.125	4.065	42.315	0.502	23.254	0.00048377	0.00503585	0.00275981	0.064
7	Extent of Database	17.110	15.633	1.477	32.743	0.502	17.184	0.000373347	0.008276566	0.004324956	0.074
8	Homogeneity of Samples	14.890	15.298	-0.408	30.188	0.499	14.866	-4.41654E-05	0.003267805	0.00161182	-0.024
9	Details of Information	21.740	19.511	2.229	41.251	0.500	21.721	8.96075E-05	0.001658323	0.000873965	-0.019
O	OPEX Activities' Risks										
1	Energy Costs	27.190	21.098	6.092	48.288	0.497	27.078	0.00092291	0.007315413	0.004119161	-0.112
2	Service Life of Building Components	23.000	18.703	4.297	41.703	0.501	23.028	0.00022744	0.002207342	0.001217391	0.028
3	Building Components' Eco-Costs	17.310	15.076	2.234	32.386	0.499	17.284	0.000193848	0.002810195	0.001502022	-0.026
4	Asset Operation Eco-Costs	18.350	14.947	3.403	33.297	0.499	18.313	0.000373931	0.003658766	0.002016349	-0.037
5	Disposal Eco-Costs	16.090	15.966	0.124	32.056	0.501	16.129	1.86799E-05	0.004829052	0.002423866	0.039
6	Components' Deterioration Rate	17.540	17.103	0.437	34.643	0.501	17.570	4.26131E-05	0.003378139	0.001710376	0.030
7	Fabric Maintenance	16.020	13.216	2.804	29.236	0.502	16.068	0.000524438	0.005468071	0.002996255	0.048
8	Services	21.930	15.286	6.644	37.216	0.502	21.983	0.000732197	0.004101364	0.002416781	0.053
9	Equipment's Maintenance	21.880	13.414	8.466	35.294	0.504	21.976	0.001697676	0.007077461	0.004387569	0.096
10	Overheads	20.560	17.649	2.911	38.209	0.498	20.502	0.000399415	0.005242609	0.002821012	-0.058
11	Utilities	22.810	14.523	8.287	37.333	0.505	22.957	0.002341338	0.010547746	0.006444542	0.147
12	Cleaning	15.090	12.363	2.727	27.453	0.500	15.088	2.39517E-05	0.000241124	0.000132538	-0.002
13	Percentage of Current Replacement Value	17.760	14.762	2.998	32.522	0.496	17.644	0.001102564	0.011960499	0.006531532	-0.116
14	Ratio of Maintenance to Capital Cost	19.190	15.857	3.333	35.047	0.501	19.209	0.000171965	0.001808233	0.000990099	0.019
15	Ratio of Operation to Capital Cost	22.220	16.769	5.451	38.989	0.497	22.106	0.001263945	0.009040534	0.005152239	-0.114