SIMULATION MODELLING OF COST OVERRUNS IN BUILDING PROJECTS: A PANEL DATA ANALYSIS

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Abstract: Cost overrun is often a challenge in the construction industry due to its complex nature and inefficient project management. Despite extensive research, cost overruns persist in construction. Hence, to minimise these challenges, factors attributing to the cost overrun need to be identified. A country-based assessment is needed since these factors vary from nation to nation. Research conducted almost two decades ago has identified the key cost-related factors influencing cost overrun of Sri Lankan building projects as variation, extra work, fluctuation of price and currency, day works and others. However, given the significant developments and technological advancement in the Sri Lankan construction industry since then, it is crucial to reassess the factors influencing cost overrun in the current context. Therefore, this research intends to re-evaluate the cost-related factors contributing to cost overrun in Sri Lanka. Further, a panel data analysis was conducted to analyse how the influence of the cost-related factors that cause cost overrun has changed over time. This research adopted a survey strategy and used document review on the final BOQ, tender document, and final statement as the data collection technique. Mote-Carlo simulation was adopted to analyse the data collected from twenty random building projects in the western province of Sri Lanka. The findings concluded that work sections measured as 'item' in the BOQ and variations and extra work cause overruns in Sri Lankan construction. Hence, clients, contractors, and consultants should give more priority to these factors to minimise the cost overrun by reducing the errors in BOQ, making accurate estimations, and reducing changes over time. However, as the simulation model was derived based on cost-related factors, this study recommends considering other factors influencing the cost overrun of buildings in future research.

Keywords: *Building Projects, Cost overrun, Cost-related Factors, Simulation Model, Sri Lanka*

1. Introduction

The construction sector plays a vital role in the economic development of the nation by facilitating the development of infrastructure like roads, buildings, railways, and civil structures (Olanrewaju & Anahve, 2015). However, despite its importance, the construction industry faces significant challenges, including low efficiency, time overrun, minimum quality, cost overruns and construction waste. Among these challenges, cost overruns stand out as critical due to the significant financial implications involved. Practically, the completion of construction projects within the estimated budget is very rare (Asiedu et al., 2017; Love et al., 2024). This issue of cost overrun is more delicate in the construction industry as construction projects require significant investment (Nguyen et al., 2024).

Several reasons contribute to cost overruns that vary from nation to nation. The research of Koushki et al. (2005 indicated that in Kuwait, material-related issues, contractor-related issues, and owner monetary limitations are the three primary causes of cost overruns. On the other hand, the study of Enshassi et al. (2005) revealed that project location and scope, political condition, constraint of movements between regions, and financial status of the owner are the primary factors influencing the cost overrun in Gaza. Meanwhile, the study of Kepher et al. (2024) identified a significant linear relationship between organisational capacity and cost overruns in Kenya. Wibowo and Santoso (2024) have provided evidence that contract changes significantly influence cost overruns in Indonesia. The study of Albtoush et al. (2024) revealed that critical factors contributing to cost overruns in the Malaysian construction sector include frequent design changes, increases in fuel costs, high transportation costs, additional quantities required during construction, and the financial difficulties of the owner. Therefore, country-based assessment is needed.

In the construction industry of Sri Lanka, cost overruns reflect a significant challenge in project execution and completion (Risath et al., 2016). The implementation of effective measures to mitigate the cost overrun is essential to address these challenges, especially in developing countries like Sri Lanka. Accordingly, Chamikara et al. (2024) have proposed BIM technology to mitigate the cost overrun in Sri Lankan building projects. Similarly, Sheamar et al. (2024) have evaluated new models of construction procurement to overcome cost overruns. Despite the extensive research that has been done, cost overruns still exist as a significant challenge in the construction industry (Lebunu Hewage et al., 2024; Love et al., 2024). Hence, to address this research gap, it is crucial to identify the factors contributing to cost overruns to mitigate them in future constructions (Xie et al., 2022).

Many studies propose models for cost overrun risk assessment; however, only a few are concerned with predicting cost overrun. Simulation modelling helps to identify the key factors contributing to cost overruns by interplaying between multiple variables and their impact on costs (Aslam & Baffoe-Twum, 2024). The development

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FARU Journal: Volume 11 Issue 01 DOI: https://doi.org/10.4038/faruj.v11i1.312

of a simulation model is imperative as it offers greater flexibility in representing complex systems that are difficult to analyse using traditional mathematical models (Ashworth & Perera, 2015). The research conducted by Rexi (2004) developed a simulation model for cost overrun in building projects in Sri Lanka, focusing on cost-related factors such as variation, extra work, fluctuation of price, day works and others. Given the substantial transformations in the sector due to the end of the civil war and the 2009 impacts of the COVID-19 pandemic and the economic crisis 2020, a static cross-sectional or time-series analysis would be insufficient. The variables influencing cost overruns might have changed over time due to changes in labour involvement, foreign investment, construction methods, materials, and techniques. Since there is a considerable deviation in the level of factors contributing to cost overruns between the current context and that of 2004, this research aims to analyse how differently the contributing factors were composed and influenced the cost overruns of current projects. Therefore, the development of an updated simulation model for cost overrun in building projects by identifying the current composition of factors influencing the cost overruns is considered essential.

Hence, the research objectives were formulated to identify the factors influencing cost overruns in building construction, to analyse the cost-related factors influencing cost overruns in building projects in Sri Lanka in the current context, and to undertake a panel data analysis to study how the influence of the factors that cause cost overrun has changed over time.

2. Literature Review on Factors Contributing Costs Overruns in Building Projects

2.1 FACTORS CONTRIBUTING COSTS OVERRUNS IN BUILDING PROJECTS

Cost overrun is defined as the difference between forecasted and actual construction costs (Shihadeh et al., 2024). It has become a global phenomenon which increases pressure on investment decisions. Cost overrun is typically calculated as a percentage that represents the difference between actual construction costs, determined upon project completion, and estimated costs, forecasted at the initial tender stage (Al-Nahhas et al., 2024).

Cost overruns in construction projects can be formed due to a number of factors. Therefore, the major factors of cost overruns in building construction identified through various recent literature are tabulated in Table 1.

Table 1: Factors influencing cost overrun in building projects

Type	Factors	Source
Cost-related factors	Errors in BOQ	[3], [8], [13]
	Discrepancies in provisional sums and prime cost sums	[5]
	Price fluctuations	[1], [3], [9]
	Inflation	[1], [9]
	Variations	[1], [2], [6]
	Extra works	[1], [4], [10]
Time-related factors	Prolonged delays	[1], [2], [7]
	Delay in payments	[3], [5]
Quality-related factors	Deficiencies in materials, workmanship	[4], [10]
	Adherence to specifications and standards	[5], [10]
	Inadequate skills and negligence among workers	[3], [12]
	Use of low-quality materials	[3], [4], [11]
Other factors	Inadequate contract management	[1], [13]
	Improper site management	[1], [6]
	Unforeseen ground conditions	[3], [4], [5]

[1] - (Abbasi et al., 2024), [2] - (Al-Btoush et al., 2024), [3] - (Alhammadi et al., 2024), [4] - (Antoniou & Tsioulpa, 2024), [5] - (Asiedu & Adaku, 2019), [6] - (Asiedu & Ameyaw, 2021), [7] - (Flyvbjerg et al., 2018), [8] - (Liu et al., 2024), [9] - (Musarat et al., 2024), [10] - (Nuako et al., 2024), [11] - (Pavate, 2024), [12] - (Raouf & Al-Ghamdi, 2019), [13] - (Sholichan & Husin, 2024)

As tabulated in Table 1, extensive research studies have categorised these factors into four main groups: cost-related factors, time-related factors, quality-related factors, and other factors. Cost-related factors are pivotal contributors to cost overruns in construction projects. These factors encompass various aspects of construction projects, including work sections measured in the Bill of Quantities (BOQ), price fluctuations, provisional sums, variations, and extra work. The inaccurate estimations of the cost of construction often lead to cost overruns (Liu et al., 2024; Sholichan & Husin, 2024). Deliberate underestimations can be the most common practice among contractors when procuring projects as the lowest tenderer. However, those underestimations have a higher possibility of causing cost overruns (Liu et al., 2024). Even the strategic misrepresentation of project data from the employer to reduce the offers or the strategic misrepresentation from the contractor when pricing the works may directly lead towards a cost overrun (Asiedu & Adaku, 2019). The inaccuracy of costs, the quantity of Work, material requirement or even the labour requirement can be a major cause of cost overrun (Alhammadi et al., 2024). Price fluctuations in construction projects are often influenced by broader economic factors, including the instability and inflationary rates within a country (Musarat et al., 2024). These fluctuations occur when demand surpasses supply or when artificial shortages are created, leading to increases in the costs of raw materials, machinery, labour, and other essential materials and services. Variations and extra works are common in all types of construction projects and often result in significant adjustments to both the contract period and construction costs (Abbasi et al., 2024).

Delays in construction projects lead to significant financial consequences, particularly through the accrual of interest expenses. Prolonged delays may result in projects becoming trapped in interest, where income is deferred while interest continues to accumulate (Flyvbjerg et al., 2018). Quality-related factors significantly impact cost overruns in construction projects. These factors often arise from deficiencies in materials, workmanship, or adherence to specifications and standards. Addressing quality-related issues is crucial because they directly influence the durability, safety, and performance of the constructed facilities (Hussain et al., 2018). Additionally, the quality of materials used in construction plays a crucial role in determining the longevity and performance of the finished structure (McKerahan, 2023). The use of low-quality materials results in early deterioration, necessitating repairs or replacements, which can increase project costs (Pavate, 2024).

Ineffective project management can lead to severe cost overruns (Abbasi et al., 2024). The resource allocation without having a logical base may incur higher wastage, idling and negative cost implications on the project. The lack of coordination among those stakeholders may be an underlying cause for cost overruns as well (Asiedu & Ameyaw, 2021).

Addressing each factor is necessary to mitigate the cost overrun. However, this study has considered the current and most significant cost-related factors to develop the simulation model to enable the comparison with the previous panel, as it also focused on cost-related factors.

2.2 SIMULATION MODELLING

Simulation modelling is a quantitative research analysis method used to create a mathematical or logical representation of a system and conduct experiments to study its behaviour (López-Pintado et al., 2024). Simulation modelling is performed based on the following key principles: Creating a simplified model of a real-world system that captures essential characteristics and behaviours, conducting virtual experiments on the model to study its performance under different conditions and analysing simulation results to gain insights into the behaviour and make informed decisions (Zeigler et al., 2000). There are four main methodologies for simulation modelling: Discrete Event Simulation (DES), Continuous Simulation, Monte Carlo Simulation and Agent-Based Modelling (ABM) (Collins et al., 2024; Zeigler et al., 2000).

Monte Carlo simulation is a computational technique used to model the probability distribution of potential outcomes within complex systems (Shonkwiler & Mendivil, 2024). It allows for the analysis of uncertainty and risk by introducing random samples into the simulation process (Maia et al., 2024). This method involves defining probability distributions for input variables, generating random samples from these distributions, and repetitively running simulations to assess the impact of different input combinations on output parameters (Shonkwiler & Mendivil, 2024).

Simulation modelling, particularly Monte Carlo simulation, is well-suited for analysing cost overruns due to its ability to handle uncertainty in various project parameters (Choudhry et al., 2014). By generating random values from these parameters, it estimates the likelihood of cost overruns and their potential impacts (Afzal et al., 2020; Bhargava et al., 2017).

3. Research Methodology

This research adopted a quantitative approach to assess the cost-related factors influencing cost overrun and to develop a simulation model for cost overruns in building projects in Sri Lanka. In addition, panel data analysis was conducted to study how the influence of the factors that cause cost overrun has changed over time. Panel data or longitudinal data typically refer to data containing time series observations of several individuals (Hsiao, 2007). The panel data was used to compare the extent of the factors influencing cost overruns within the Sri Lankan construction industry. Panel data provide a more comprehensive understanding of how these changes have affected cost overrun patterns over time, facilitating a comparative analysis with the previous findings of Rexi (2004). This research has adopted the survey strategy and document review to collect the data. Accordingly, twenty random building projects in the Western province of Sri Lanka were selected, consisting of 07 commercial buildings, 07 residential buildings, and 06 other types. In order to collect the information relevant to the additional cost of selected buildings, the final BOQ, tender document and final statement were reviewed. Project details were collected from contractors, consultants and client organisations involved in building projects, which were affected by cost deviations at the final stage of completion. Project details were collected based on variables such as estimated contract Sum, final accounted figure, amount of work sections measured as 'item' in the BOQ, amount of Price fluctuation, amount of Variations and Extra work, amount of Provisional Sum, amount of Day works, amount of miscellaneous, form of contract (ICTAD grade), type of contract, type of building. Collected data was analysed using MS Excel to develop the simulation model.

Subsequently, simulation analysis was carried out to analyse the collected data. Simulation analysis is a quantitative research analysis method that is used to understand the impact of risk and uncertainty on prediction and forecasting models (Ferry & Brandon, 2000). Monte Carlo simulation is one type of simulation based on repeated random sampling techniques and statistical analysis to obtain the outcomes (Bairami Habashi et al., 2021). Accordingly, Monte Carlo Simulations were used to model the probability of different outcomes in a process that cannot easily be predicted due to the intervention of random variables from data of selected 20 projects.

4. Findings and Analysis

4.1. MONTE CARLO ANALYSIS

Monte Carlo analysis proceeds by producing a series of simulations of proposed projects, and price predictions are brought out in each simulation for the project (Afzal et al., 2020). The predictions are represented as a cumulative frequency curve and then represented as a histogram (Bhargava et al., 2017). Steps followed in the development of simulation models, along with the analysis, are discussed below.

Step 01: Recognition of cost overruns

Initiated the recognition of specific cost overrun classes and their probability distributions, which represent variations and fluctuations in prices. Data collected from the twenty projects revealed six factors of cost overruns: work section measured as 'item' in BOQ, price fluctuation, variation and extra work, provisional sum, day works and miscellaneous. 'Miscellaneous' refers to items or costs that are not categorised under specific work sections but are necessary expenses that arise during a construction project. In addition, as a suitable distribution is essential for accurate analysis, mean and variation were obtained from sample data to reflect measures of centrality and dispersion. Accordingly, beta distribution was preferred due to its ability to represent mean, variance, and other desired attributes. Unlike other distributions, it does not have limitations such as an infinite range or a bell shape.

The equation for the beta distribution is given below.

$$\boldsymbol{p(x) = \frac{1}{B_{(p,q)}} \cdot \frac{(x-a)^{p-1}.(b-x)^{q-1}}{(b-a)^{p+q-1}}} \tag{1}$$

Here $\boldsymbol{B_{(p,q)} = \int_0^1 x^{p-1}.(1-x)^{q-1}.dx}$, $0 \le x \le 1, (\boldsymbol{a \le x \le b})\ (\boldsymbol{p, q > 0})$

Where $p(x) = Frequency\ density\ function$

$a = Minimum\ cost\ overrun$

$b = Maximum\ cost\ overrun$

$p, q = Parameters\ of\ the\ distribution; p, q > 0$

$B_{(p,q)} = Beta\ function$

The equation for the parameter calculation is given below.

$$p = \frac{\left\{\frac{(\mu_1-a)^2}{(b-a)}\right\}\left\{1-\frac{\mu_1-a}{b-a}\right\}}{\frac{\mu_2}{(b-a)^2}} - \frac{(\mu_1-a)}{(b-a)} \tag{2}$$

$$q = \frac{\left\{\frac{\mu_1-a}{b-a}\right\}\left\{1-\frac{\mu_1-a}{b-a}\right\}^2}{\frac{\mu_2}{(b-a)^2}} - \left\{1 - \frac{\mu_1-a}{b-a}\right\} \tag{3}$$

Where $\mu_1 = Mean$

$\mu_2 = Variance$

Table 2 illustrates the mean, variance a, b, p and q values of each cost-related factor of cost overruns.

Table 2: Development process of beta distribution

Cost-related factors of Cost Overruns	(Mean) μ_1	(Variance) μ_2	a	b	p	q	Beta	step
Work sections measured as 'item' in the BOQ	5.995	20.200	0.876	15.646	0.501	0.944	1.440	0.738
Price fluctuation	0.695	2.651	0.000	4.968	0.017	0.103	39.541	0.248
Variations and Extra work	3.795	18.543	0.493	13.369	0.181	0.524	1.623	0.644
Provisional Sum	1.995	16.750	0.080	11.970	0.023	0.118	3.260	0.595

Day works	0.145	0.172	0.000	0.902	-0.058	-0.303	64.780	0.045
Miscellaneous	1.970	9.499	0.127	8.162	0.046	0.155	2.870	0.402

In accordance with Table 2, six variables have been identified as influential factors contributing to cost overruns in building projects. The parameters 'a', 'b', 'p', and 'q' associated with each variable were utilised in the beta distribution formula. Consequently, beta distributions were formulated for all six variables employing Equation (1), where x ranges as follows.

1. Work sections measured as 'item' in the BOQ, $0.88 \le x \le 15.65$
2. Price fluctuation, $0.00 \le x \le 4.97$
3. Variations and Extra work, $0.49 \le x \le 13.37$
4. Provisional Sum, $0.08 \le x \le 11.97$
5. Day works, $0.00 \le x \le 0.90$
6. Miscellaneous, $0.13 \le x \le 8.16$

Step 02: Generation of random numbers for each beta distribution

Once the beta distribution has been established for each relevant elemental category, random numbers are generated for each distribution. This is typically done using a computer with a pseudo-random number generator. Each of those random numbers is an estimated value of Cost overruns for the relevant elemental category (Rexi, 2004).

Step 03: Simulation-Based Forecasting of Project Contract Sums Using Random Number Generation

In order to provide a forecast of the contract sum of the project, outcomes of Step 02 for relevant elemental categories are summed. This estimate is stored, and the process returns to the 2nd step, repeating it a set number of times, denoted as n where n= 50, 100, 200 and so forth. This generates n simulations of projects. After underlying distributions of input parameters were identified for a simulation model, random numbers were generated for relevant distributions. These random numbers showed distinct values of the variable. For instance, if the normal distribution was determined as the best fit for the cost of relevant categories, random numbers were generated from this distribution and used as representative costs in the model.

Step 04: Computation of Cumulative Frequency Graphs and Histograms

A cumulative frequency graph and a histogram should be prepared by plotting n estimates. The selection of n is a subsequent problem. Since this would provide a smooth cumulative frequency diagram and histogram, n should be large. Conversely, additional simulations are not without cost, either in computer time or manual processing (Rexi, 2004).

4.2. CONSTRUCTION OF SIMULATION MODEL

The Simulation Model was developed through the computer-based programme using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. The number of samples from each Beta Distribution graph was selected automatically by the computer. Here, iteration is equal to five hundred (500), having inserted Beta Distribution parameters of each cause of the cost overruns were inserted.

The number of outputs was equal to the interaction; the calculation adhered to the mathematical formula.

$$Total\ Cost\ Overruns\ in\ \% = W\% + F\% + V\% + P\% + D\% + M\% \quad (4)$$

Here,

$W\% = Percentage\ of\ Work\ sections\ measured\ as\ `item'\ in\ the\ BOQ$

$F\% = Percentage\ of\ Price\ fluctuation$

$V\% = Percentage\ of\ Variations\ and\ Extra\ work$

$P\% = Percentage\ of\ Provisional\ Sum$

$D\% = Percentage\ of\ Dayworks$

$M\% = Percentage\ of\ Miscellaneous$

The following Table 3 illustrates the total cost overruns percentage of the total contract sum of each project.

Table 3: Total cost overruns of each selected project

Projects	Total cost overruns (%)	Projects	Total cost overruns (%)
P1	38.54	P11	17.46

P2	16.73	P12	3.41
P3	20.21	P13	19.78
P4	18.88	P14	7.06
P5	6.40	P15	1.83
P6	14.37	P16	19.28
P7	28.88	P17	19.72
P8	17.90	P18	21.01
P9	2.22	P19	5.92
P10	5.87	P20	5.57

As shown in Table 3, All 20 projects in the table exhibit cost overruns, ranging from a minimum of 1.83% (Project P15) to a maximum of 38.54% (Project P1). The presence of cost overruns in every project highlights the prevalence of this issue within the Sri Lankan construction industry.

4.2.1 The composition of factors influencing cost overruns in building construction in Sri Lanka.

According to the data collected from the document reviews, mean, variance and standard deviation were calculated to find out the composition of each cost overrun factor. The findings are tabulated in Table 3.

Table 4: Total cost overruns mean, variance and standard deviation

Cost-related cost overrun factors	Mean	Variance	Standard deviation	%
Work sections measured as 'item' in the BOQ	6.024	16.671	4.083	30%
Price fluctuation	0.568	1.909	1.382	10%
Variations and Extra work	3.906	10.396	3.224	24%
Provisional Sum	1.941	7.044	2.654	20%
Day works	0.141	0.053	0.230	2%
Miscellaneous	1.971	3.634	1.906	14%

As indicated in Table 4, work sections measured as 'item' in the BOQ carry the highest impact, constituting 30% of the total cost overrun. Provisional sum and variations and extra work contribute significantly with a comparable impact of 24% and 20%, respectively. Although miscellaneous expenses have a low proportion in BOQ amount, they notably contribute 14% to the overall cost overrun. Day work has the lowest impact on the overall cost overrun, 2%.

4.2.2 Bootstrapping of simulated samples

Bootstrapping is a statistical process that resamples a single dataset to generate many simulated samples. This process helps to compute standard errors, construct confidence intervals, and accomplish hypothesis testing for numerous types of sample statistics (Ferry, Brandon, & S, 2000). In this study, 500 simulated samples of total cost were created from single using SPSS programme.

4.3 PANEL DATA ANALYSIS COMPARING PANEL 01 AND PANEL 02

4.3.1 Panel data analysis for compositions of identified cost overrun factors

In order to carry out panel data analysis, the study conducted by Rexi in 2004 was considered panel 01, and the current study was considered panel 02. The comparison of factors influencing cost overrun in building projects are tabulated in Table 5.

Table 5: Comparison between Panel 01 and Panel 02

Cost-related cost overrun factors	Panel 01 (Study in 2004)	Panel 02 (Study in 2022)
Work sections measured as 'item' in the BOQ	-	30%
Price fluctuation	7%	10%
Variations	33%	24%
Provisional Sum	-	20%
Day works	7%	2%
Extra Works	31%	-
BOQ item increase or decrease	12%	-
Miscellaneous	7%	14%

As shown in Table 5, Variations, Extra Works, BOQ item increase or decrease, Day works, Price fluctuation and other factors were identified in Panel 01 to develop the Simulation. According to the Panel 01 analysis, variations and extra work were found to be the most significant factors, with the average cost overruns amount of 33% and 31% of the total cost overruns, respectively. Further, BOQ item increase or decrease was 12% of the total cost overruns, and others were below 10% of the total contract sum. According to the Panel 02 (current) analysis, work sections measured as 'item' in the BOQ and variation and extra work are the most significant factors, with the contribution of 30% and 24% of the total cost overruns respectively. Provisional sum, miscellaneous and price fluctuation contributed significantly, ranging between 10% and 20%. Conversely, the contribution of the day work stands at 2%.

The comparison revealed that there is no massive difference in price fluctuations, variations, day works and miscellaneous. Further Work section measured as 'item' in the BOQ and Provisional sum were rather identified in Panel 02 with the 30% and 20% of total cost overruns, respectively. The above two factors were identified in Panel 02 instead of the factor, BOQ item increase or decrease, which contributed to the total cost overruns, which was 12% in Panel 01.

The comparison between the current study (Panel 02) and the existing study in 2004 (Panel 01) on factors influencing cost overruns in building projects reveals notable consistencies over time. Both studies identify common factors such as price fluctuations, variations, day works, and miscellaneous factors as significant contributors to cost overrun. Moreover, the current study combines variations and extra work, which were separately addressed in the earlier study. Additionally, the current study introduces "Provisional Sum" as a factor influencing cost overruns, which was not included in the study conducted in 2004. The identification of "Work sections measured as 'item' in the BOQ" in the current study corresponds to the category labelled "BOQ item increase or decrease" in the earlier study.

Furthermore, findings from recent studies by Abbasi et al. (2024), Alhammadi et al. (2024), Liu et al. (2024), and Musarat et al. (2024) validate the factors influencing cost overrun, such as work sections measured in the BOQ, price fluctuations, variations, day works, and miscellaneous. Notably, the inclusion of "Provisional Sum" as a significant factor contributing to cost overruns is further supported by global research findings (Asiedu & Adaku, 2019; Haslinda et al., 2018), underscoring its increased recognition over nearly two decades. This emphasises that factors contributing to cost overruns in construction projects are evolving over time, hence it need for updated management strategies to mitigate these risks effectively.

4.3.2 Panel data analysis for Simulation model for building projects in Sri Lanka

The process of Simulation model developing of Panel 01 was undertaken for thirty building projects. The cumulative frequency curve of five hundred simulations is visualised in Figure 1.

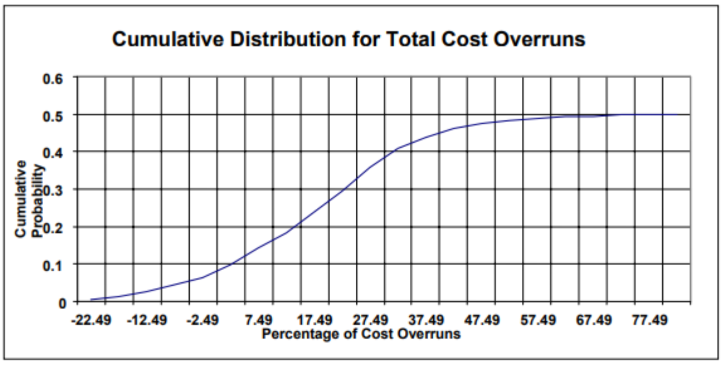

Figure 1: Simulation model for building projects in Sri Lanka of Panel 01

As shown in Figure 1, the cost overruns range between -22.49% and 77.49%. The graph starts with a negative value, indicating that there were some projects without any cost overruns. Further, there is a 50% probability that cost overruns are less than approximately in between 20% and 24.99% of the total contract sum. Additionally, there is a 90% probability that cost overruns are less than approximately 40% and 44.99% of the total contract sum.

In panel 02 analysis, the simulation model was carried out for twenty building projects, and the results were converted through the bootstrapping method. The cumulative frequency curve of five hundred simulations is visualised in Figure 2.

As shown in Figure 2, there is a 50% probability of cost overruns, which is less than approximately between 12% and 13% of the contract sum. Additionally, there is a 90% probability that the cost overruns are less than in between

22% and 23% of the contract sum. Further, the graph starts with a positive value, indicating that projects in Panel 02 (100%) were affected by cost overruns in building projects in Sri Lanka.

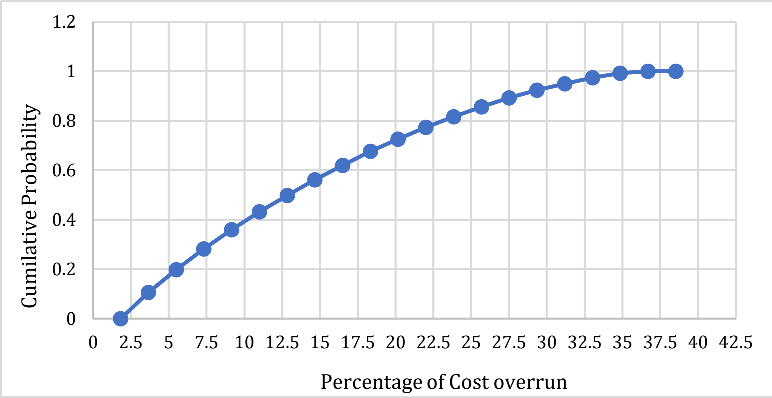

Figure 2: Simulation model for building projects in Sri Lanka of Panel 02

The main difference between the two figures is the distribution and range of cost overruns. As shown in Figure 1, cost overrun was low initially, then it rose shapely and flattened off at the probability of 0.5. However, Figure 2 is a concave downward curve, where the cost overrun increases with the frequency until it reaches the probability of 1. Figure 1 includes projects with cost savings, whereas Figure 2 indicates that all projects had cost overruns. The cumulative frequency distribution in Figure 2 suggests lower cost overruns at comparable probability levels than in Figure 1. This implies that the projects analysed in Panel 02 generally experienced lower cost overruns compared to the broader set of projects in Figure 1.

5. Conclusions

The background study emphasises that clients, contractors and consultants should prioritise the significant factors affecting the cost overruns in building projects in Sri Lanka. In comparison, numerous studies propose models for assessing the risk of cost overruns, but relatively few focus on predicting their occurrence. Simulation modelling offers a valuable approach to both identifying key factors contributing to cost overruns and forecasting their potential impact. Hence, this research aimed to minimise the cost overruns in building projects in Sri Lanka and develop a simulation model based on the probability distribution of the cost overrun factors in building projects in Sri Lanka. Accordingly, this research has been carried out by a literature review followed by a survey of 20 building projects. Document review was selected as the main data collection technique. Collected data was analysed through simulation analysis and panel data analysis.

Work sections were measured as 'item' in the BOQ, and variation and extra work were identified as the most significant factors in the current Sri Lankan construction field, accounting for 30% and 24% of the total cost overruns, respectively. Provisional sum contributed 20% of the total cost overruns, and Miscellaneous and Day works contributed 14% and 2% of the total cost overruns, respectively. Using SPSS software and MS Excel, the simulation model was developed based on data from twenty projects, updating previous research by Rexi in 2004. This model indicates a 50% probability of projects experiencing cost overruns between approximately 12% and 13% of the contract sum and a 90% probability of cost overruns falling between 22% and 23% of the contract sum. Panel data analysis revealed that there is no massive difference in compositions of cost overrun factors in building projects in Sri Lanka between the previous study and the current study. The simulation model of Rexi (2004) illustrated that there were some building projects which were not affected by any cost overruns in building projects in Sri Lanka. However, the Simulation model of the current study illustrates that 100% of projects are affected by building construction cost overruns in the current Sri Lankan construction field.

The analysis emphasises the importance of accurate cost throughout the project to control cost overruns. According to the findings Work sections measured as 'item' in the BOQ and variation and extra work are the most significant factors influencing cost overrun in Sri Lankan construction. Hence, the client, contractor, and consultant should give more priority to these items to minimise the cost overrun by reducing the errors in BOQ, making accurate estimations, and reducing the changes over time.

Although this research developed a simulation model for cost overruns in building projects in Sri Lanka, this research was limited to the twenty building projects within the western province and considered cost-related factors only in the simulation model. Hence, it is recommended that the scope be broadened to encompass a larger sample size and diverse geographical regions for more comprehensive insights into cost overrun factors in Sri Lankan building projects.

6. References

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