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New cost control techniques in mega construction projects

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ABSTRACT

The construction industry in the U.K. is a vital sector of the country's economy. However, this industry is faced by various types of uncertainties and risks due to their dynamic environment, particularly for megaprojects. The study aimed to determine the modern and effective cost control techniques that are utilized in for mega construction projects in the U.K. A mixed-method approach that involves both qualitative and quantitative approaches were adopted in this research for data collection and analysis. Five semi-structured interviews with construction professionals were conducted first to find out modern and effective techniques used for projects cost control. This is followed by carrying out Delphi survey twice with 42 and 39 construction professionals. Results revealed that the top five techniques that can be utilized for controlling megaproject costs were: Activity-based costing method, Contract Variance – Unit Costing, To-Complete Performance Index (TCPI), Cost-Value Reconciliation and BIM.

Keywords: Cost control techniques, Mega construction projects, Construction industry, Project management

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1. Introduction

Mega construction projects are highly interdepending, and the work implementation is fragmented among various technical specialties, which makes it subjected to different types of risks that can be developed progressively through the project lifecycle. These projects are characterized by interdependence and unpredictability and tend to suffer from unsatisfactory functionality and with overruns in schedule and cost. Examples of megaprojects mainly include airports, bridges, tunnels, high-speed rail lines, oil and gas projects, expressways and dams along with the complex logistics systems which are used for running giant companies such as Amazon and Walmart.

The shortage of megaprojects is an important obstacle to meeting populations' demands, enterprise development and in achieving governmental goals of progress [1]. According to the study of Aziz, et al. [2], the megaprojects play a significant role in addressing the needs of the people such as transportation, food, clothing, education, healthcare and entertainment. Most importantly, these projects can stimulate the economy of the country. For example, the investment in the megaprojects has been frequently utilized by the authorities as to the renowned policy for stimulating the economic condition in the mid of 1930s. In light of the study conducted by Ji et al. [2], it has been assessed that it is a significant way for growing and maintaining profitability from the construction projects. Although cost regulation and controlling have been applied internationally in managing large construction projects in the last 20 years, the existing literature lacks an investigation and analysis on the application status of cost control and regulation in big construction projects. The issue of cost overrun in the construction of megaprojects is ensured to be primary complexity and challenges specifically for organizations which are solely project-based, and their profitability is based on reduced cost of the project and higher returns.

In addition to the above statement, there are certain problems associated with the cost overruns which are focused on the unexpected cost that is incurred for excessing of budgeted amounts because of underestimation of the actual cost within the context of budgeting [3]. Such practices are common in the megaprojects. For this

purpose, the organizations which are governing the cost of the projects try to control the project cost under their planned budget. Despite several techniques and methods established for the purpose of cost control and utilization of sophisticated tools such as PRISM, PRIMAVERA, P6, and SAP there are still control problems faced by the mega construction project managers. This problem is also a major concern for all other stakeholders of the projects, for example, investors, and shareholders whose returns are based on cost control cost reduction and profitability [4]. An illustration of the above cost problem can be given as an example of recent construction projects in Singapore that also faced severe problems of cost overrun. The statistics presented in Fig.1 reflects the cost overrun of mega construction projects which have exceeded the original budgets [5].

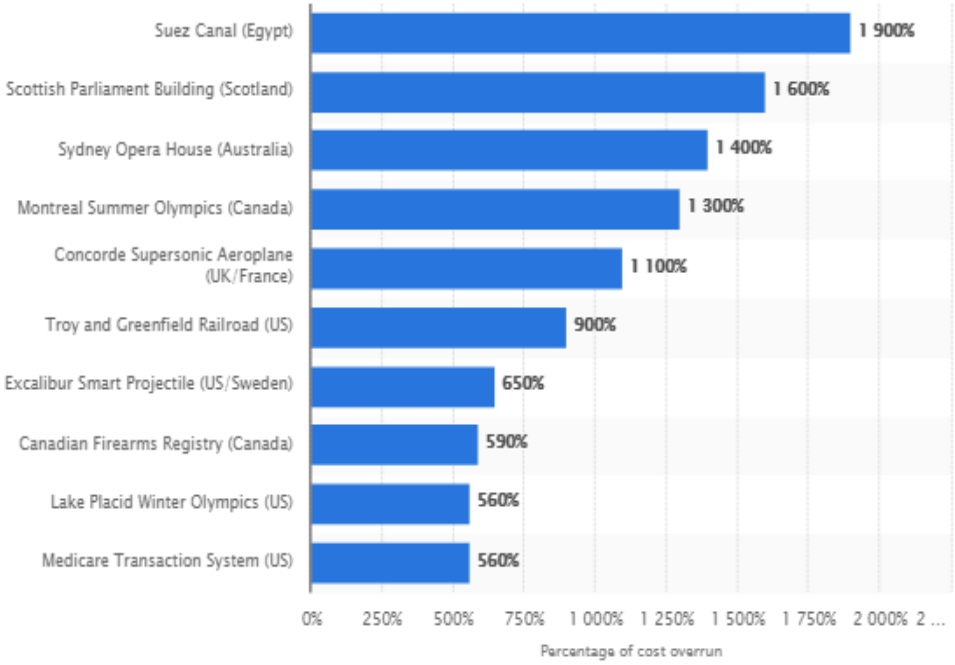

Figure 1. Cost overruns in mega projects

Ref. [6]. Stated that cost overrun, combined with time overrun and under advantages were the topmost complexities and challenges faced by mega construction projects. Thus, to counter and address the issue of cost control and cost overrun in the construction projects, the utilization cost controls techniques were suggested by Gharaibeh [7]. Referring to Project Management Institute [8], the control of cost is the procedure of checking and tracking the project status by developing and updating the budget of the project and addressing changes to the cost baselines. In consideration of the discussion carried out above, the following research has been developed, which is intended towards providing effective strategies for managing the costs of megaprojects in the U.K.

In the U.K., a survey has been carried out by the Chartered Institute of Building (CIOB) which has revealed that mega projects in the U.K. can be finished within the agreed time if the costs are planned appropriately [9]. The need for cost controlling technique is increasing as the mega construction projects tend to utilize high resources which commonly lead to cost overrun. Hence, it is vital for the construction industry to implement effective cost control technique that can support the organization in reducing the cost while utilizing the cost-effectively. The study of Hwang et al. [9], has highlighted the most common cost control techniques, namely, maintaining the approved project budget, achieve a balanced distribution of project funds and forecasting techniques. In addition, Vasista [10], has demonstrated several new techniques that are used in the strategic cost management, which consist of expert judgment, analogous estimating, parametric estimating, bottom-up estimating and three-point estimates. Furthermore, Tahir et al. [11], has highlighted Building Information Modelling (BIM) as an effective tool for improving and controlling the costs of such projects.

New techniques for cost control in the mega construction project has been suggested by Ahmed et al. [12], where the research studied to anticipate and estimate the future cost of project completion phases with the help of fundamental metrics and factors by utilizing the technique of modified earned value. They first divided the entire project into five phases with enhanced cost decisions. According to Amanda and Kule [4], budget

checking and control is a common technique that is used for monitoring the cash flow for planning the construction projects while not taking into the account the uncertainty and risks.

Accordantly, the objective of this research is to investigate the modern and effective cost control techniques for mega construction projects.

The scope of this research focuses on mega construction projects in the U.K. The research is limited to construction professionals represented by consultants, contractors, owners, project managers, and academics.

2. Method

This research adopts a mixed-methods approach to data collection and analysis. The use of both qualitative and quantitative data can enrich the study with more insightful information and explore newer techniques used to control the costs associated with mega construction projects. Thus, the limitations associated with both methods separately have been delimited with the use of both approaches to data collection. In this research, we carried out online semi-structured interviews and Delphi surveys. The recruited participants were experts belonging to the construction industry of the U.K. The decision of the selected research methods depends on the study nature, the purpose of the research, research objectives, the availability of the resources and previous literature [13].

Semi-structured Interviews. To accumulate qualitative data, we first conducted semi-structured interviews via Skype with five construction experts to explore the modern and effective techniques used for controlling the megaproject costs. The details of the respondents have been provided as follows in Table 1.

Table 1. Details of interviewees

Interviewee	Role	Educational qualifications	Years of Experience	Sector of work
1	Consultant	BSc	15	Private
2	Professor of Construction Management	PhD	24	Public
3	Contractor A	BSc	17	Private
4	Contractor B	MSc	20	Private
5	Contractor C	BSc	15	Private

Delphi Survey. In accordance with the techniques identified using expert interviews, the next step was to rank these techniques through experts associated with the U.K.'s construction industry. Experienced professionals were considered for Delphi survey. Those experts are consultants, contractors, clients and academics, and they have more than ten years of experience in mega construction projects.
The survey was conducted in two rounds in order to examine the Inter-Rater Agreement (I.R.A.). A total of 42 respondents ranked the identified cost control techniques in the first round; however, in the second round, 39 professionals were recruited. The rating scale comprised of ordinal5-points scale, where one indicated 'least important' and five indicated 'most important'. The questionnaire was disseminated online using Google Forms.

Data Process and Analysis. For the purpose of assessment of the data accumulated using the mentioned process, various techniques were utilized. The data was pre-processed using reliability testing and normality testing. Cronbach Alpha, Shapiro-Wilk, and Kolmogorov-Smirnov tests have been utilized respectively. First, the data was tested using Kendall's Coefficient of Concordance to assess the agreement within each round, and the results were obtained by employing each cost-control technique. Second, the validation of the concordance is done using Friedman's Chi-square analysis to compare the two rounds results. Later, the confirmation of the results was done using Inter-rater Agreement (I.R.A.) analysis where average deviation was computed and, in this regard, the data accumulated in the second round of Delphi survey helped. The process used in this research can be seen in Figure 1 as well.

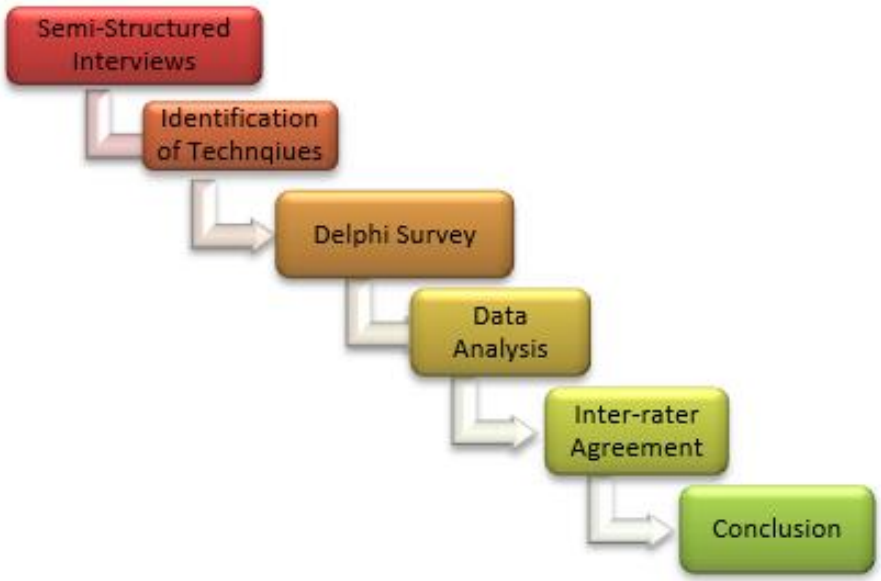

Figure 1. Research plan and structure

3. Results

Expert interviews. Based on the interviews, twelve cost control techniques for megaprojects were identified as presented in Table .

Table 2. The identified cost control techniques based on expert interviews

No.	Identified Technique
1	Cost-Value Reconciliation
2	Contract Variance – Unit Costing
3	Earned Value Analysis
4	Program Evaluation and Review Technique (PERT/COST)
5	Performance Recording
6	Status Reporting and site meetings
7	Just in time method
8	Activity-based costing method
9	BIM
10	Forecasting methods
11	To-Complete Performance Index (TCPI)
12	Reserve analysis

Delphi Survey. The reliability of the data is tested using Cronbach Alpha. According to Hinton et al. [14], Cronbach Alpha's threshold is said to be 0.6. Considering this, the results presented in Table 3 depict that the data in both rounds have internal consistency since Cronbach Alpha is computed to be higher than 0.6 in both rounds. Therefore, this dataset can be used for further analysis. The outputs of this phase were tested for normality, and it was found that the data follows the non-normal distribution. The results have been presented in Table 3. The inference has been drawn based on the p-values of Shapiro-Wilk and Kolmogorov-Smirnov tests. The null hypothesis of both the tests assume normality; however, the p-values are lower than 5% or 0.05; therefore, the data is declared to be non-normal.

Table 3. Normality and reliability testing

Cost Control Techniques	Round 1		Round 2	
	Kolmogorov-Smirnov	Shapiro-Wilk	Kolmogorov-Smirnov	Shapiro-Wilk
	Statistic	Statistic	Statistic	Statistic
Program Evaluation and Review Technique (PERT/COST)	0.338***	0.637***	0.328***	0.728***
BIM	0.363***	0.634***	0.35***	0.704***
Earned Value Analysis	0.305***	0.677***	0.279***	0.749***
Status Reporting and site meetings	0.325***	0.748***	0.304***	0.765***
Performance Recording Contract	0.341***	0.728***	0.324***	0.732***
Variance – Unit Costing	0.409***	0.674***	0.46***	0.577***
Cost-Value Reconciliation	0.351***	0.746***	0.286***	0.794***
To-Complete Performance Index (TCPI)	0.302***	0.795***	0.335***	0.76***
Reserve analysis	0.258***	0.818***	0.254***	0.824***
Just in time method	0.337***	0.753***	0.298***	0.791***
Activity based costing method	0.375***	0.693***	0.358***	0.739***
Forecasting methods	0.214***	0.836***	0.234***	0.793***
Cronbach Alpha	0.606		0.619	
***: significant at 1%				

Kendall's Coefficient of Concordance (W) and Freidman's Test. In order to determine the agreement between the experts within each group, here we used Kendall's Coefficient of Concordance (W) which ranges from 0 to 1. According to Sprent and Smeeton [15], the closer the coefficient is to 0, the weaker the agreement will be whereas, values closer to 1 indicate agreement. Moreover, the researcher also used Freidman's Chi-square, and in accordance with Schultz (2010), the distribution of the population is said to be unequal against the considered sample if the p-value is below 0.05. Therefore, based on the results presented in 5 concerning round 1, it can be inferred that with respect to all experts, the agreement is weak (W= 0.162); however, it is statistically significant based on Chi-square (p-value< 0.05). In addition, concerning consultant, the agreement level is moderate (W= 0.502) which is also statistically significant (p-value< 0.05). In the context of clients, W is 0.579 showing a moderate level of the agreement while the significance is also obtained (p-value< 0.05). Moreover, concerning the agreement level between contractors, the W is computed to be 0.211, which is showing weak agreement while the results are statistically significant (p-value< 0.05). Lastly, the concordance between the academicians is computed to be 0.628 while the significance is also found (p-value< 0.05); therefore, the concordance is moderately high. The results of this test are presented in Table 4.

Table 4. Kendall's W and Chi-square testing for Round 1

Cost Control Techniques	All Experts Ranking	Consultants' Ranking	Clients' Ranking	Contractors' Ranking	Academicians' Ranking
Program Evaluation and Review Technique (PERT/COST)	1	1	9	1	6
BIM	2	7	1	2	6
Earned Value Analysis	3	3	1	9	1
Status Reporting and site meetings	4	7	5	5	1

Cost Control Techniques	All Experts Ranking	Consultants ' Ranking	Clients' Ranking	Contractors ' Ranking	Academician s' Ranking
Performance Recording Contract	5	3	1	12	1
Variance – Unit Costing	7	7	6	5	8
Cost-Value Reconciliation	8	2	12	9	4
To-Complete Performance Index (TCPI)	10	6	8	7	11
Reserve analysis	9	5	6	11	4
Just in time method	6	11	1	3	12
Activity based costing method	11	7	11	8	9
Forecasting methods	11	12	9	3	9
Number of Respondents	42	11	12	15	4
Kendall's Coefficient of Concordance (W)	0.162	0.502	0.579	0.211	0.628
Friedman's Chi-Square	81.67	66.264	83.38	38.041	30.168
Significance Level	0.000	0.000	0.000	0.000	0.003

Concerning the results obtained in the 2nd round, the statistical significance is found in each group (p-value< 0.05) except for all experts, however, if the significance level is considered to be 0.1 or 10% then the results can be deemed significance even in the case of all experts. Concerning the level of agreement, the results indicate that weak agreement is found in the case of all experts (W= 0.041) and contractors (W= 0.288). In the case of consultants (W= 0.305) and clients (W= 0.350, the agreement is weakly moderate. Lastly, the level of agreement in the case of academicians is moderately high with W= 0.686. All the results have been depicted in Table 5.

Table 5. Kendall's W and Chi-square testing for Round 2

Cost Control Techniques	All Experts Ranking	Consultants' Ranking	Clients' Ranking	Contractors' Ranking	Academicians' Ranking
Program Evaluation and Review Technique (PERT/COST)	1	1	9	1	4
BIM	2	9	2	3	7
Earned Value Analysis	3	3	3	8	1
Status Reporting and site meetings	4	8	1	8	1
Performance Recording Contract	5	3	3	12	1
Variance – Unit Costing	7	9	8	5	8
Cost-Value Reconciliation	7	2	11	8	4
To-Complete Performance Index (TCPI)	6	7	6	7	10
Reserve analysis	10	5	7	11	4
Just in time method	7	11	3	3	12
Activity-based costing method	10	6	9	6	8
Forecasting methods	12	12	12	2	10
Number of Respondents	39	9	12	15	3
Kendall's Coefficient of Concordance (W)	0.041	0.305	0.35	0.288	0.686
Friedman's Chi-Square	17.772	30.209	46.222	47.459	22.636
Significance Level	0.087	0.000	0.000	0.000	0.020

Inter-rater Agreement Analysis (I.R.A.). In order to verify the results, the researcher utilized I.R.A. technique where the average deviation (A.D.) has been computed. The consistency is found in the first five ranked cost-

control techniques. Those specifically include maintaining an approved budget for the project, achieving a balanced distribution of the project funds, using project management software, monitoring project status and maintaining contractor's profit margin. The results having a high deviation lead to low concordance, whereas, the low deviation has resulted in high concordance. In the case of the top three techniques, the concordance is ranging from moderate to high. The discussed results can be seen in Table 6.

Table 6. Inter-rater agreement analysis (I.R.A.) using average deviation (A.D.)

No	Category of Respondent	A.D. Computation (Round 1)	Rank (R1)	A.D. Computation (Round 2)	Rank (R2)	A.D. (R1 & R2)	Deviation	Concordance
1	Program Evaluation and Review Technique (PERT/COST)	0.500	7	0.552	7	0.526	Moderate	Moderate
2	BIM	0.495	8	0.505	9	0.5	Weak	High
3	Earned Value Analysis	0.599	5	0.592	5	0.595	Moderate	Moderate
4	Status Reporting and site meetings	0.649	4	0.650	4	0.649	Strong	Low
5	Performance Recording	0.730	2	0.789	2	0.759	Strong	Low
6	Contract Variance – Unit Costing	0.385	11	0.304	12	0.344	Weak	Extremely High
7	Cost-Value Reconciliation	0.437	10	0.521	8	0.479	Weak	High
8	To-Complete Performance Index (TCPI)	0.474	9	0.463	10	0.468	Weak	Extremely High
9	Reserve analysis	0.571	6	0.581	6	0.576	Moderate	Moderate
10	Just in time method	0.861	1	0.824	1	0.842	Extremely Strong	Extremely Low
11	Activity-based costing method	0.279	12	0.402	11	0.340	Weak	Extremely High
12	Forecasting methods	0.698	3	0.681	3	0.689	Strong	Low

4. Conclusions

The study aimed to determine the modern and effective techniques utilized in controlling the cost of mega construction projects, and the case of the U.K. was specifically considered. A combination of semi-structured interviews and Delphi survey has been used in this research twice, with 42 and 39 construction professionals to identify these techniques. Following a thorough analysis using Kendall's W, Friedman and I.R.A., it has been inferred that the top five cost control techniques for mega construction projects were:

1. Activity-based costing method,
2. Contract Variance – Unit Costing,
3. To-Complete Performance Index (TCPI),
4. Cost-Value Reconciliation, and
5. Building Information Modelling (BIM)

Moreover, the interviews also helped identify the most effective techniques that can be deemed the future of cost controlling, for instance, forecasting methods, such as the implementation of Artificial intelligence **(**A.I.), big data analytics and Monte Carlo Simulation.
Clearly, further research is needed to cover more techniques beyond the top five. Also, the effectiveness of these techniques needs to be investigated in future research.

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