CHAPTER 20

Cost Performance Analysis in Construction Projects

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ABSTRACT

The management of construction costs is a major factor that determines the success of a project and it is normally quantified in terms of deviations to the approved budget, which include monetary and timing overruns. In India, despite highly developed estimating and monitoring procedures, the construction projects are often faced with cost over runs. The cost performance of construction projects is the focus of this research which provides a pragmatic framework towards optimization of decision making and fiscal control. The identification of critical cost drivers, i.e., rework, inefficient coordination, schedule delays, payment delays, and inaccurate estimates, was proven with the help of a controlled survey of the construction professionals. Cost Performance Index (CPI), Cost Overrun Percentage (COP), Schedule Performance Index (SPI), Rework Cost Percentage, Payment Delay Days and Estimate Accuracy Percentage were identified as the most salient indicators which were transformed to measurable Key Performance Indicators (KPIs). With the help of forecasting methods, sensitivity analysis, decision rules, an organised frame was developed on the basis of these indicators. The framework provides a statistical approach to the monitoring of project performance that enables quick corrective action in construction projects.

Keywords: Cost performance, Key performance indicators, Framework, Cost drivers.

1.0 Introduction

Cost performance is a very important element in the performance of construction projects. The appraisals usually depend on the maintenance of estimated costs and schedules. The industry is plagued by cost overruns both in the construction projects and in the infrastructural projects. Despite sophisticated estimation methods, sophisticated monitoring systems, and powerful project controls, overruns are also a thorn in the flesh. They compromise the feasibility of projects, demoralize stakeholders, and diminish profitability.

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The construction projects are dynamic and as such are associated with uncertainties that occur due to rework, lack of coordination, delay in construction schedule, delay in payment schedules and incorrect initial costs estimates. Conventional cost management practices are based on the use of static budgets and periodic reviews of the financial side. Nevertheless, such strategies tend to identify deviations when major overruns become a reality; such a reactive position does not allow time to act. In my case, the growing amount of project data opens up the prospects of increasing cost control with the help of data analysis procedures. Business analytics can help monitor the indicators of performance systematically, showing the trend and warning signs in time. However, literature on analytical and predictive models often require specialised approaches or commercial software, which makes it hard to use in practical projects where practitioners are expected to use Microsoft Excel and other simple tools.

Accordingly, an existing gap exists between the provision of cost-management models and the delivery of the same into a construction environment. The proposed work fills that gap as it examines the performance of construction projects in terms of cost, develops a cost control framework, and bases the analyses on the easily accessible project data to make rapid decisions without the use of complicated tools and in depth technical solutions. The cost drivers identified in the literature are also supported by poll results; the variables are reworked as KPI s and integrated into a monitoring system that is integrated with forecasting techniques and decision rules. The suggested framework aims at achieving cost containment and enhancement of the general performance of the project.

2.0 Literature Review

The construction projects are still encountering the cost overruns and time overrun in the new economies like India. Various literature attributes such failures to poor planning cooperation amongst the stakeholders, poor skill base of the contractors and consultants as well as poor coordination of the project. There is a longstanding lack of contact between theory and practice. Although underlying factors that cause cost overruns, delays are well understood, empirical support of suggested solutions is limited.

The use of advanced and data based analytical tools to strengthen cost performance has been the focus of recent scholarly attention. Predictive modelling, machine learning, and big data analytics demonstrate significant opportunities to improve the profitability analysis and forecast accuracy. However, the cost of implementation is high, data access is a problem, and it is of a technical nature which bars its practical adoption, particularly in small and mediumsized construction companies. The cost estimation predictive models at the early

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stages will usually require large volumes of high quality data that is challenging to acquire in varied construction settings.

The role of procurement procedures, governance arrangements and organisational regulation on the cost performance is indisputable. Cost overruns, through efficient managerial control, open procurement procedures and systematic contractor selection are reduced. Several studies though provide theoretical understanding or data reviews without providing practical instruments to the project teams. Another issue highlighted in the literature is the increased significance of business process management and business intelligence in cost control. Organisations that incorporate performance indicators in decision making processes significantly enhance monitoring as well as accountability. However, formal measures of performance and decision making are not used widely because of lack of direct connection between cost management models and low cost analysis tools.

The evaluated literature shows the evident research gap: whereas the factors of cost-overruns and sophisticated analytical methods are considered in the existing literature, the lack of simple, quantifiable data based frameworks that could help to convert key cost drivers into the quantifiable performance indicators is evident. This research paper bridges that gap by developing a framework that builds on the basis of business analytics that combines forecasting and decision rules with costperformance performance metrics to provide a practical answer to the cost management in construction projects.

3.0 Research Methodology

The main purpose of this research is to calculate the construction cost performance, and to come up with a complete KPI monitoring model, this study uses an organized analytical methodology that combines primary survey data with secondary project data.

Step 1: Cost Performance Parameters (Primary Data) Identification

Detailed questionnaire survey at the first phase was conducted to a purposive sample of experts of the construction sector comprising of site engineers, estimators, and project managers. The tool used five point Likert scale to extract professional opinions regarding the variables that are relevant to the cost performance of the construction projects. The responses obtained were analyzed using both frequency analysis and percentage analysis to identify consensual trends as well as how to draw line on the cost performance measures that are most salient. Such criteria were therefore identified as being pivot issues of scheduling delays, re work, payment delays, inefficiencies in coordination and errors in estimation. These criteria were later put in the form of measurable Key Performance Indicators (KPIs) as the analytical foundation of the proposed framework.

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Step 2: Using Secondary Project Data to implement KPIs

The second phase involved operationalisation of the framework by secondary data based on an accomplished infrastructure project. The data used was audit documentation which included approved project costs, final cost project escalation, expected compared to actual project timeframes and recorded factors which have caused costs to escalate such as scope change, design change, project delay, and procurement inefficiencies. The percentages of time and cost overruns are the core cost performance indicators that were computed. Cost Performance Index (CPI) which was a proxy computed derived metrics like Cost Variance, Cost Overrun Index and Cost Variance to determine cost effectiveness and performance variation against projections.

Stage 3: Sensitivity and Scenario Analysis for Predictive Analysis

The study has used scenario analysis to enhance the analytical rigour of the study. This included analyzing the impact of change in major variables of the project like completion on time and smaller rework use on cost outcome in the end. Significant elements by cost were repurposed with established assumptions to come up with projections of scenarios. This was followed by sensitivity analysis, which involved manipulated changes that were used to determine the relative effect they had on the KPIs. This demonstrated what the framework did predict, which enabled priorities of the cost risks to be set and the disclosure of threshold based decision rules.

Step 4: Modelling of the Framework

The monitoring structure, in the form of spreadsheets, was compiled by applying the information of the scenario and sensitivity analysis to the KPI calculations. The methodology highlights the fact that timely identification of the risk of costs and active managerial measures in the process of project implementation could be made through the systematic use of KPIs, the predictive analysis, and the strict adherence to decision rules.

4.0 Data Findings

The results of structured questionnaire surveys given to experts in the construction business are shown in this section. Finding the most important factors affecting cost performance and deriving quantifiable Key Performance Indicators (KPIs) for framework development were the goals of the investigation. To identify prevailing patterns in professional perceptions, frequency and percentage analysis were used to examine the survey data. According to the study results, the biggest internal causes of cost overruns are inefficiencies in coordination and rework. Many respondents concurred that design modifications, inconsistent drawings, and inadequate stakeholder cooperation lead to more work, wasted materials, and higher expenses.

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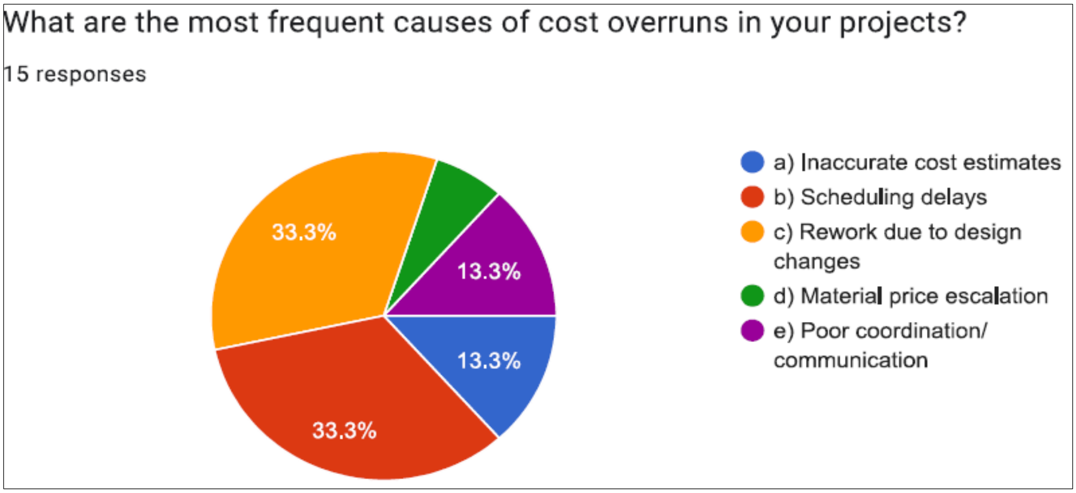
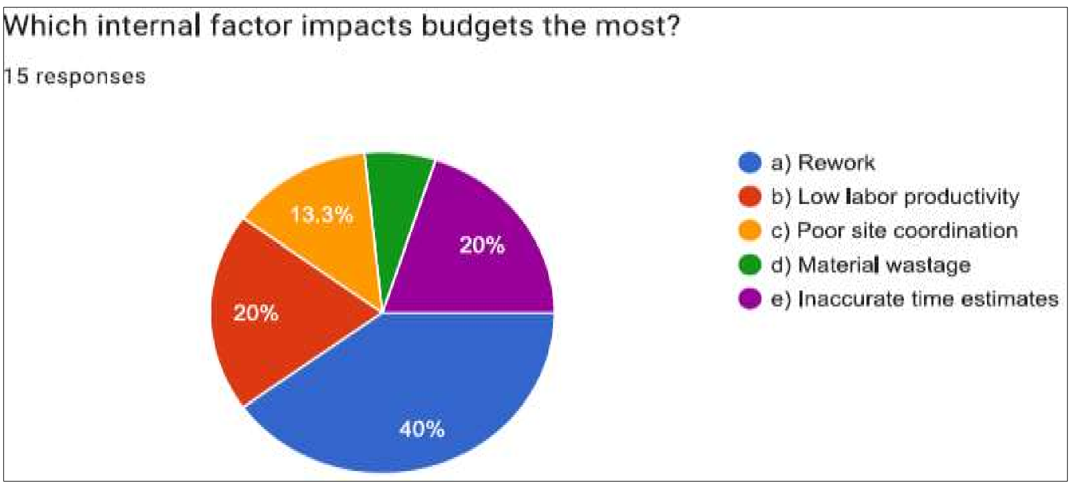
Figure 1: Pie Chart of the Causes of Cost overuns



Source: Created by authors

Figure 2: Pie Chart of the Impact of Rework on Cost Performance



Source: Created by authors

It was also found out during the survey that the external factors, namely scope changes and schedule slips were the primary sources of cost increase. Changes in scope when requested by the clients were reported to increase budgets whereas the postponement of the key tasks increases indirect costs. This brings into the fore the close association between the performance in terms of cost and the time.

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Figure 3: Responses on Scheduling Delays and Scope Changes

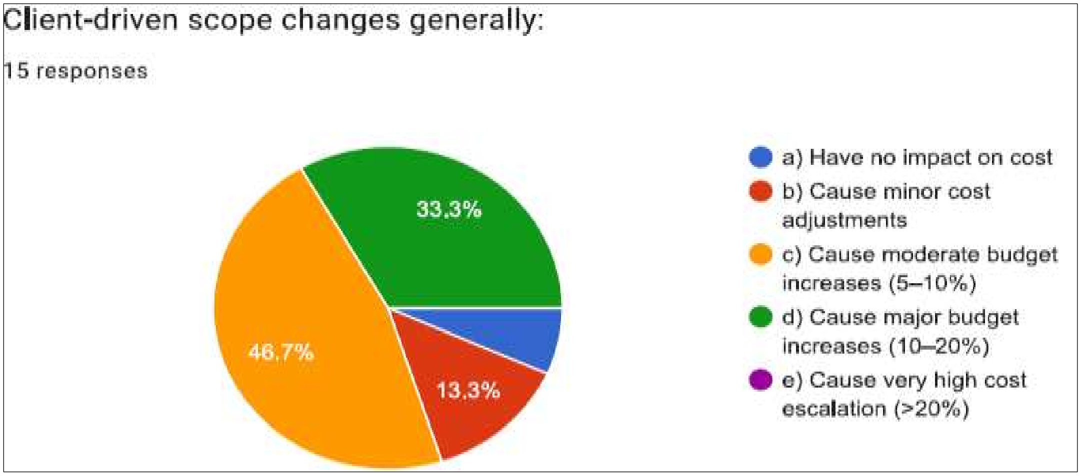

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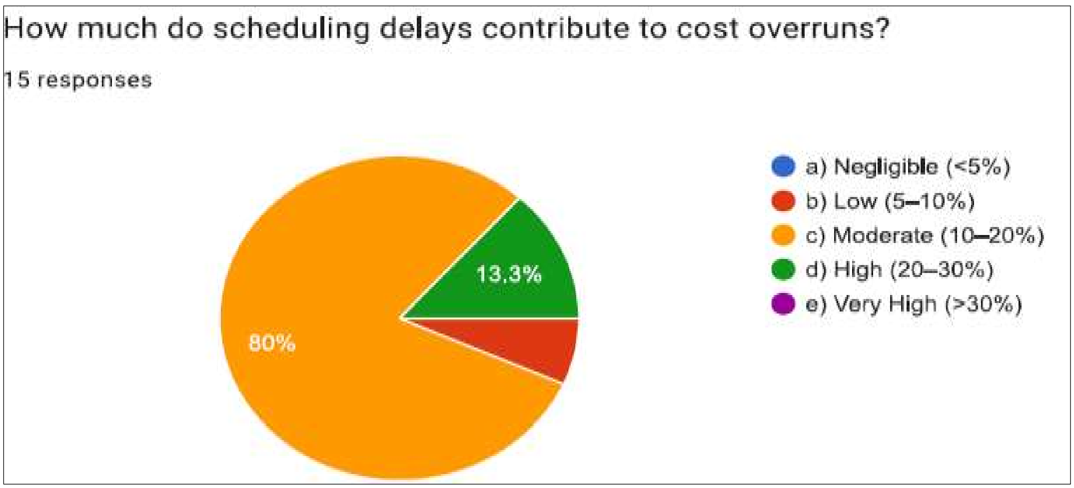
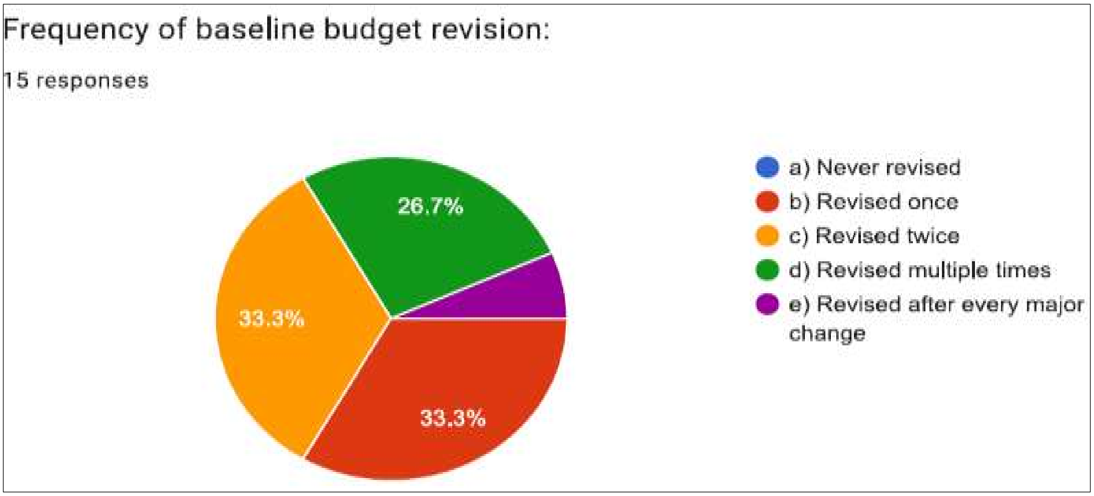
Figure 4: Pie Chart Showing Severity of Scheduling Delay Impact



Source: Created by authors

In addition, poor estimation and failure to make payments on time were revealed to be serious hindrances to cost performance of the project. Early budget estimates were usually considered as moderately precise, and repeated budgetary revisions were required during implementation; delay in payment stalled the cash flow as well as project continuity.

Figure 5: Responses on Payment Delays and Estimate Accuracy



Source: Created by authors

The survey data gave rise to five important features including inaccurate estimations, schedule delays, payment delays, inefficiencies in the coordination, and rework. Those factors were translated into measurable KPIs, which served as the analytical basis of the proposed framework of cost performance monitoring, which was repeatedly known to have a strong impact on respondent groups.

Table 1: Key Paramters Affecting Cost Performance

Sr. No.	Parameter	Description / Rationale
1	Rework	Rework is an increment of work caused by mistakes in design, or bad supervision, or other quality related failures, which lead to a direct increase in cost.
2	Coordination Inefficiencies	Refers to the miscommunication (or absence of synchronisation) between the stakeholders (designers, estimators, and site teams), and causes wastage of resources and wastage of time.
3	Scheduling Delays	Are delays in execution of a piece of work, delays in procurement or dependency bottlenecks that negatively impact a time and cost.
4	Payment Delays	Slow money flow in the company due to tardy payments by customers or contractors which frustrate the flow of progress and lead to extra financing expenses.
5	Estimation Inaccuracy	Occurs when the initial estimates deviate significantly from actual costs due to data insufficiency or changes during execution This happens when the original estimates are significantly different at the actual costs because of lack of adequate information or fluctuation in the course of execution. .

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Table 2: Key Performance Indicators For Analysis

Key Performance Indicator (KPI)	**Formula / Method of Calculation**	**Purpose**
Cost Performance Index (CPI)	Budgeted Cost / Actual Cost	Measures the cost as a whole, index below 1 represents cost overrun.
Cost Overrun Percentage (COP)	(Actual Cost − Budgeted Cost) / Budgeted Cost × 100	defines the level of difference between the agreed budget and actual expenditures.
Schedule Performance Index (SPI)	Planned Progress (%) / Actual Progress (%)	Standards of schedule compliance; SPI of less than one means a project lag.
Rework Cost Percentage	Rework Cost / Total Project Cost × 100	Measures the impact of cost on the project caused by design change, rework and error.
Average Payment Delay (Days)	Actual Payment Date − Planned Payment Date	Evaluates cashflow efficiency and financial discipline.
Estimate Accuracy Percentage		Final Actual Cost − Initial Estimate

Source: Created by authors

The chosen KPIs give a holistic understanding of the performance in the schedule and costs, thus, facilitating successful monitoring and making wise decisions.

5.0 Data Analysis

This section presents the analysis of project cost performance which is based on the methodological framework outlined in the previous chapters. To examine the cost and schedule performances and isolate the antecedent cause of cost overrun, the analysis is based on the application of the fully realised Key Performance Indicators (KPIs) to the second dataset of the project under analysis. All arithmetic tasks were calculated by the Microsoft Excel using approved project cost, actual cost incurred, projected and realised project duration, rework cost, payment schedules and estimation data.

5.1 Application of KPIs on metro project data

In order to test cost and schedule performance, the completed KPIs were initially implemented on the metro project dataset. The three basic performance indices included Cost Performance Index (CPI), Cost Overrun Percentage (COP), and Schedule Performance Index (SPI) which were computed using approved cost, actual cost, and planned versus realised progress measures. These results indicated that there was a slippage of the schedule and inefficiency in costs in the project as the values of CPI and SPI were not within the optimal values. The COP measure was used to measure the level of increase in the budget, thus validating the existence of cost overruns during the project implementation.

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5.2 Core cost and schedule performance analysis

The combined study of CPI, COP, and SPI was used to evaluate the performance of the undertaking as a whole. Although the SPI luminous delay was certain in realizing planned milestones of progress, the CPI reflected that real spending was more than expected costs. The simultaneous presence of cost increases and schedule overruns highlights a strong interdependence of both the time and financial performance in the metro project.

Table 3: Project Details – Nagpur Metro Stations

Cost Figure	Value (₹ Cr)	Meaning
Approved Project Cost (DPR)	6,862	Baseline estimate at planning stage
Actual Expenditure till Mar 2021	7,878	Cumulative spending (intermediate)
Final Project Cost	8,680	Projected total cost at completion

Source: CAG audit

Table 4: Project Details – Nagpur Metro Stations Timeline

Corridor / Component	Planned Completion	Actual Completion & Operation	Delay
North–South Corridor	Apr-18	Mar-19	~11 months
East–West Corridor	Apr-18	Jan-20	~21 months
Full Phase-I operationalization	Apr-18	Jan-20	~22 months

Source: CAG audit

Table 5: Core KPI Calculations

Core KPIs				
Estimated Cost (₹ Cr)	**Actual Cost till date (₹ Cr)**	**Cost Variance**	**Cost Overrun %**	**CPI**
6,862	8,680	-1,818	26.49	0.79
Project Start Year	**Estimated Completion Year**	**Actual Completion Year**	**Time Overrun (Years)**	**Delay Risk Level**
2013	2018	2020	1.4	High

Source: Created by authors

5.3 Diagnostic KPI analysis based on finalized parameters

The KPIs used in the diagnostics in line with the finalised specifications of the survey were analysed in order to determine the root cause of the variance in costs. The Rework Cost Percentage revealed that a large percentage of the overall spending on the project could be

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explained by the rework, which highlighted the consequences of the design changes and mistakes in the implementation process. Payment Delay (days) Analysis revealed financial disbursement delays which undermined procurement and execution cycles. The reliability of baseline estimation was challenged through the Estimate Accuracy Percentage that revealed differences in initial predictions and the actual costs. The low CPI and SPI results of the project are explained by the combination of the diagnostic KPIs.

Table 6: Cost Variations with Respect to Execution

Sr. No.	Cost Component / Driver	Amount (₹ Cr)	% of Final Project Cost (₹8,680 Cr)	Remarks
1	Baseline Approved Project Cost	6,862	79.05%	Original sanctioned cost for Phase-I
2	Cost Escalation due to Schedule Delays	~620	7.14%	Prolongation costs, idle resources, extended overheads
3	Rework due to Design Changes & Re-awarding	~480	5.53%	Alignment changes, station modifications, contract termination & re-award
4	Price Escalation & Inflation Impact	~380	4.38%	Extended execution period increased material & labour costs
5	Pending Government / ULB Contributions (Payment Delay Impact)	793.89	9.14%	Delayed fund release affecting cash flow
6	Delayed Recovery of Mobilisation Advances	130.86	1.51%	Cash flow blockage from contractors
7	Estimation Inaccuracy (Cost Deviation)	1,818	26.50%	Difference between approved and final cost
8	Final Escalated Project Cost (Actual Cost – AC)	8,680	100%	Expected total cost at full financial closure

Source: Created by authors

Table 7: Diagonostic KPI Calculation

Diagnostic KPI	Value
Rework Cost %	5.53%
Payment Delay Impact	₹924.75 Cr
Estimate Accuracy (Deviation)	26.50%

Source: Created by authors

5.4 Predictive forecasting and scenario analysis

The forecasting methods in Excel introduced the monitoring framework to predictive analytics. Projected final project cost in the current situation was estimated based on past trend of cost escalation of projects and delay information.

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This was later followed by scenario analysis to determine several alternatives. The simulated scenarios included the completed timely, less rework, improved coordination, and less delay in payments. Findings showed that even small changes in these parameters would have generated measurable decreases in the end project cost, thus highlighting the ability to make decisions by using the framework.

Table 8: Scenario Analysis with respect to Cost Variations

Scenario ID	Scenario Description	Delay Cost (₹ Cr)	Rework Cost (₹ Cr)	Inflation Cost (₹ Cr)	Revised Total Cost (₹ Cr)	Reduction (%)
S0	Baseline (Audit)	620	480	380	8,680	–
S1	Timely Completion (No Delay)	0	480	380	8,060	7.14%
S2	Improved Design Coordination (50% Rework Reduction)	620	240	380	8,440	2.76%
S3	Inflation Control (25% Reduction)	620	480	285	8,585	1.09%
S4	Delay + Rework Control	0	240	380	7,480	13.82%
S5	Integrated Control (Delay + Rework + Inflation)	0	240	285	7,387	14.89%

Source: Created by authors

5.5 Sensitivity analysis and decision rules

Sensitivity analysis was used to evaluate the behaviour of key cost performance measures to controlled changes in major cost drivers which were identified using diagnostic analysis. The study was conducted to establish the comparative effects of schedule contravention, rework, and price increase on total cost performance and not to restore cost performance in a project that had been completed. The use of predefined rules of decision making makes it possible to identify the high priority risk variables that will be actively monitored and managed in future projects.

Table 9: Decision Rules for KPIs

Indicator	Decision Rule
CPI ≥ 1.00	Cost efficient
0.95 ≤ CPI < 1.00	Warning zone
CPI < 0.95	Critical
COP ≤ 10%	Acceptable deviation
10% < COP ≤ 20%	High risk
COP > 20%	Critical overrun
SPI ≥ 1.00	On schedule
SPI < 0.95	Schedule risk
Rework > 5%	Process failure
Payment delay > 30 days	Cash-flow risk

Source: Created by authors

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The decision criteria used in this investigation are based on the widely recognised standards of Earned Value Management and infrastructure audit procedures. Cost overrun limits were based on PMI recommendations that provide the basis of the CPI and SPI levels, whereas government audit standards and construction management literature (which describe cost increases in excess of 20 per cent as critical) provided recommendations on cost overrun levels. Instead of being hard performance targets, these thresholds are used to give early warning to enable predictive decision making.

Sensitivity analysis came in handy to indicate the magnitude and direction of all cost drivers impact although the base case CPI was 0.79 and COP 26.5 per cent, which shows a high cost overrun situation. The schedule control became the most important factor of cost performance because the analysis depicted that even the minor variations in schedule delay costs would have generated the strongest impact of CPI and COP. Sensitivity results, whereby the change in key drivers is converted into the change in performance indicators, are the basis of a predictive cost performance model. Project managers can predict possible cost results before the significant escalation by tracking early indicators like schedule slippage and frequent rework. The framework is also helpful when combined with thresholds based decision rules, as it helps to intervene in time and promote proactive cost management.

Table 10: Sensitivity Analysis for Predicting Forecasting

Risk Factor (Cost Driver)	**Sensitivity Change Applied**	**Impact on Project Cost (₹ Cr)**	**Resulting CPI**	**Resulting COP (%)**	**Risk Severity**	**Management Priority**
Schedule Delay	±10%	±62	0.78 – 0.80	25.6 – 27.4	Very High	Immediate
Rework (Design / Scope)	±10%	±48	0.79 – 0.79	25.8 – 27.2	High	High
Inflation / Price Escalation	±10%	±38	0.79 – 0.79	26.0 – 26.9	Moderate	Medium
Payment Delay (Cash Flow)	Qualitative	Indirect	CPI deterioration	COP ↑	High (Indirect)	High

Source: Created by authors

The sensitivity analysis also creates a clear hierarchy of managerial priorities, with schedule delay first in the list of the most critical risk factors, as it had the largest impact on CPI and COP, then there is rework and inflation.

The sensitivity analysis illustrates that the risks associated with schedule are the major cause of cost overruns in massive infrastructure development. The suggested approach will enhance the early identification of critical risks and predictive and cost control based on data through the incorporation of sensitivity informed decision rules into an Excel based monitoring framework.

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6.0 Conclusion

This study shows that overruns on construction costs are a combination of related issues, and that their effect could be forecasted through systematic research instead of the individual occurrence. The paper demonstrates how a cost performance is possible since it can be evaluated prior to the fact and after the fact using a KPI based approach that is complemented by the scenario and sensitivity analysis.

When the Nagpur Metro Rail Project was put into practice, the framework was significantly exceeded in terms of its Cost Performance Index (CPI) of 0.79 and cost overruns of 26.5% percentage. The problem was enhanced by inflation, payment delays and schedule delays proved to be the largest source of cost increase, and rework as a result of design and coordination problems was the second largest source of cost increase. Sensitivity analysis indicated that any minor alterations in timeline related costs disproportionately impacted the cost outcomes of the project.

The scenario analysis established how various conditions of project would have changed the end cost. Remediation efforts in the later stages of the project would be of little help in terms of recovery and preventive measures as early as delays and rework would yield as much cost savings as possible. This serves the central conclusion of the study that proactive intervention is required when overruns have reached important levels and reactive intervention is no longer effective.

In practice, the research demonstrates that, the predictive cost performance management does not need advanced technology. Combining a clear spreadsheet structure with clear and specific decision rules and accessing to readily available project data will give early indicators and make well informed decisions. The project managers will have an opportunity to spend resources more efficiently, pay more attention to essential problems, and intervene in cases when the measures implemented will produce the highest effect.

The findings enhance the construction management practice by focusing the attention not on the evaluation of costs after a project, but on the risk detection during the execution stage. Despite the fact that the example focuses on one large scale infrastructure project, the general methodology can be used in the context of other projects, including residential and commercial constructions. Future studies can extend this study and include development of dashboard visualization to promote monitoring efficiency among different stakeholders.

7.0 Implications

The conclusions made by the study provide straightforward recommendations on how to ensure that control of cost is tightened when constrcucting the projects. The data show

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that the major source of overruns is the delay at timetables and in the close follow the rework because of design and coordination problems. Rather than letting the increased costs to be eminent, managers ought to consider schedule performance as the leading indicator of cost health and take action as soon as the slippage is first noticed.

The analysis also validates the fact that predictive costs can be effectively tracked using simple spreadsheet based methods. With a combination of several clearly defined KPIs and a scenario and sensitivity analysis, teams can predict overruns and focus on mitigation measures without the use of complex programs. This method increases accountability, accelerates the decision making, and also enables the managers to direct resources to the most important risk areas. Overall, the framework transforms the reactive cost reporting into pro-active risk management which allows construction companies to identify the high risk scenarios at an early stage and focus on them prior to the overruns being irreversible.

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