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Time-Cost Optimization of a Multistory Building Project Using Primavera Software: A Case Study

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Abstract: Construction projects frequently experience schedule delays and cost overruns because of complex activity interdependencies, resource limitations, and uncertainties during execution. Effective optimization of project duration without significantly increasing project cost has therefore become a major concern in modern construction management. This study presents a comprehensive time–cost optimization framework for a multistory government building using Primavera Software Professional. The research is based on the CM Block of the VVIP Guest House Project at Ayodhya, India, comprising 422 construction activities with an estimated project cost of ₹18.86 crore.

A detailed baseline schedule was developed using the Critical Path Method (CPM) within Primavera Software. Critical activities were identified through float analysis, and schedule crashing was performed by selectively allocating additional resources to activities having the lowest cost slopes. The proposed optimization framework integrates project scheduling, critical path analysis, cost-slope evaluation, and systematic resource allocation to minimize project duration while maintaining economic feasibility. The baseline schedule required 463 days for completion. Following optimization, the project duration was reduced to 408 days, representing an 11.88% reduction while increasing the total project cost by only 0.82% (₹15.58 lakh). The findings demonstrate that targeted crashing of selected structural and finishing activities provides substantial schedule acceleration with minimal financial impact.

The proposed methodology offers a practical decision-support framework for contractors, consultants, and project managers involved in multistory building construction. Beyond demonstrating Primavera Software scheduling capabilities, the study highlights how integrated schedule optimization techniques can improve project delivery, reduce contractual risks associated with delays, and support more effective resource utilization in complex construction projects.

Keywords: Time-Cost Optimization; Critical Path Method; Construction Scheduling; Resource Optimization; Construction Project Management.

I. INTRODUCTION

The construction industry is a key driver of economic growth and infrastructure development, requiring effective planning and scheduling to manage complex projects involving numerous activities, stakeholders, and resource constraints. Project success is primarily evaluated based on time, cost, quality, and scope, with time and cost being closely interrelated. Project delays increase overhead expenses and contractual risks, while schedule acceleration often requires additional resources, resulting in higher direct costs. Therefore, achieving an optimal time–cost balance is a major objective in construction project management.

Several researchers have contributed to the development of advanced planning and scheduling techniques for improving construction project performance More recently, Zhang et al. (2024) demonstrated that genetic algorithm-based optimization can improve resource allocation and schedule efficiency by identifying near-optimal construction sequences. Similarly, Eshim (2024) demonstrated the effectiveness of the Critical Path Method (CPM) implemented through Primavera P6 for developing project schedules, identifying critical activities, and improving construction planning. Mohamed et al. (2025) further proposed an integrated decision-support framework for optimizing time–cost trade-offs, showing that advanced optimization techniques can significantly reduce project duration while minimizing overall project costs.

Traditional techniques such as the Critical Path Method (CPM) are widely used for scheduling, whereas Primavera Software Professional provides advanced capabilities for Work Breakdown Structure (WBS) development, activity sequencing, resource allocation, cost loading, and baseline scheduling. This study applies Primavera Software, CPM, and cost-slope-based schedule crashing to optimize a 422-activity VVIP Guest House project in Ayodhya, demonstrating an effective framework for reducing project duration while maintaining cost efficiency.

II. RELATED PAPERS

Time–cost optimization has been widely studied due to its significant impact on construction project performance. Early research primarily focused on deterministic scheduling techniques such as the **Critical** Path Method (CPM), while recent studies have incorporated probabilistic forecasting, optimization algorithms, and digital project management tools. Researchers have identified poor planning, inaccurate duration estimation, resource constraints, and ineffective project control as the major causes of schedule delays and cost overruns.

Among practical optimization techniques, schedule crashing remains one of the most effective methods for reducing project duration through cost-slope analysis and efficient resource allocation. Although Primavera Software provides integrated scheduling, resource management, and cost control capabilities, relatively few studies have demonstrated its application for systematic time–cost optimization of real government building projects using actual construction data.

III. NOVELTY OF THE RESEARCH

The originality of this research lies in the following contributions:

1) Development of a comprehensive Primavera Software scheduling model comprising 422 construction activities for a real multistory government building project.
2) Integration of Critical Path Method analysis with systematic cost-slope evaluation for identifying economical crashing opportunities.
3) Quantitative evaluation of schedule compression using practical resource allocation rather than theoretical optimization algorithms.
4) Demonstration of an 11.88% reduction in project duration with only 0.82% increase in project cost, highlighting the economic feasibility of targeted schedule crashing.
5) Presentation of a replicable framework suitable for contractors, consultants, and government agencies involved in multistory building construction.

IV. RESEARCH OBJECTIVES

The primary objective of this research is to develop and evaluate an integrated framework for time–cost optimization of a multistory building project using Primavera Software.

The specific objectives are:

1) To develop a project Network using Software.
2) To identify the Critical Activity and Critical Path.
3) To allocate Resources for Optimization of Project Duration and Cost.
4) To evaluate the variation in Project cost associated with the normal and optimized project duration.

V. MATERIALS AND METHODS

A. *Research Methodology*

The present research adopted a quantitative case study methodology to investigate the optimization of project duration and construction cost for a multistory government building project using Primavera Software Professional. The methodology integrates conventional Critical Path Method (CPM) scheduling with schedule crashing based on cost-slope analysis to achieve an economically feasible reduction in project completion time.

Unlike optimization approaches based solely on mathematical programming or simulation techniques, the proposed framework emphasizes practical implementation under actual construction conditions. The methodology combines detailed project planning, logical activity sequencing, critical path identification, selective crashing of critical activities, and comparative evaluation of baseline and optimized schedules.

The complete research methodology consists of six sequential stages:

1) Collection of project information.
2) Development of the baseline schedule in Primavera Software.
3) Critical Path Method (CPM) analysis.
4) Schedule crashing through cost-slope evaluation.
5) Optimization of project duration.
6) Comparative assessment of time and cost performance.

B. Case Study Description

The proposed methodology was validated using the CM Block of the VVIP Guest House Project located at Ramnagari, Ayodhya, Uttar Pradesh, India. The selected project represents a large-scale government infrastructure facility designed to provide residential accommodation for the Hon'ble Chief Minister, senior government officials, and other dignitaries.

The project was selected because of its large number of interdependent construction activities, extensive structural works, finishing operations, and significant financial investment, making it highly suitable for project scheduling and optimization studies.

Project Characteristics

Table 5.1 Project Characteristics

Parameter	Description
Project Type	Government Multistory Building
Location	Ayodhya, Uttar Pradesh
Software Used	Primavera Software Professional
Total Activities	422
Total Built-up Area	6,732.92 m²
Ground Floor Area	1,500.53 m²
Estimated Cost	₹18,86,38,252.49
Baseline Duration	463 Days
Optimized Duration	408 Days

The project includes:

1) Site preparation 2) Excavation 3) Foundation construction 4) RCC structural works 5) Brick masonry 6) Internal plaster 7) Waterproofing 8) Flooring 9) Electrical services 10) Plumbing 11) HVAC 12) Interior finishing 13) External façade 14) Painting works

C. Data Collection

Project data were collected directly from the construction project records.

The collected information included:

1) Detailed Project Report (DPR) 2) Bill of Quantities (BOQ) 3) Structural Drawings 4) Architectural Drawings 5) Construction Specifications 6) Quantity Estimates 7) Resource Schedule 8) Equipment Details 9) Labour Productivity 10) Activity Durations 11) Cost Estimates

These data formed the basis for developing the Primavera Software schedule and subsequent optimization analysis.

D. Development of Project Schedule in Primavera Software

The complete project schedule was developed in Primavera Software Professional following standard project management procedures.

The resulting schedule consisted of 422 logically connected construction activities.

E. Work Breakdown Structure (WBS)

The project was divided into logical work packages to facilitate planning and monitoring.

The major WBS elements included:

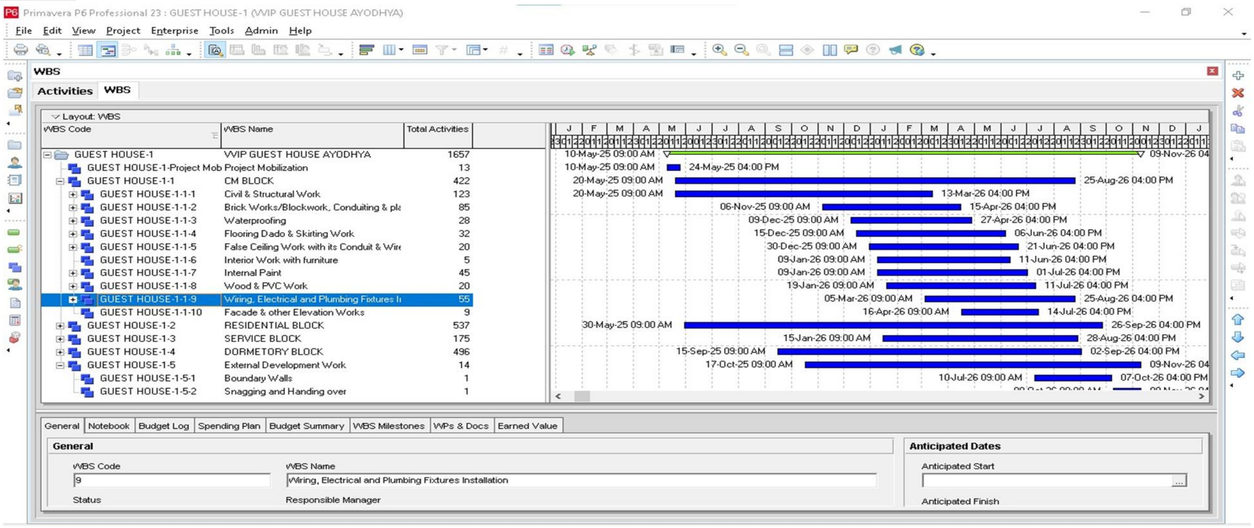

Figure 5.1 WBS

F. Activity Relationship Development

Project activities were linked using the Precedence Diagramming Method (PDM).

Four logical relationships available in Primavera Software include:

1) Finish-to-Start (FS)
2) Start-to-Start (SS)
3) Finish-to-Finish (FF)
4) Start-to-Finish (SF)

Approximately 92% of project activities followed Finish-to-Start relationships, reflecting the actual sequence of multistory building construction.

G. Resource Assignment

Three categories of resources were assigned:

Labour

1) Skilled workers 2) Semi-skilled workers 3) Helpers

Equipment

1) Tower crane 2) Concrete mixer 3) Vibrators 4) Excavators 5) Transit mixers

Materials

1) Cement 2) Reinforcement steel 3) Aggregates 4) Bricks 5) Sand 6) Paint 7) Plumbing

Resource allocation enabled accurate cost loading and optimization.

H. Critical Path Method (CPM)

The project schedule was analysed using the Critical Path Method.

For every activity, Primavera Software computed:

1) Early Start (ES)
2) Early Finish (EF)
3) Late Start (LS)
4) Late Finish (LF)
5) Total Float (TF)
6) Free Float (FF)

Activities with $TF = 0$ were identified as **critical activities**.

I. Schedule Crashing

Schedule crashing was performed only for critical activities.

Each activity was evaluated using:

1) Technical feasibility
2) Resource availability
3) Cost implication
4) Construction sequence
5) Safety considerations

Activities with the lowest crash cost were selected first.

J. Optimization Algorithm

The optimization followed the sequence below.

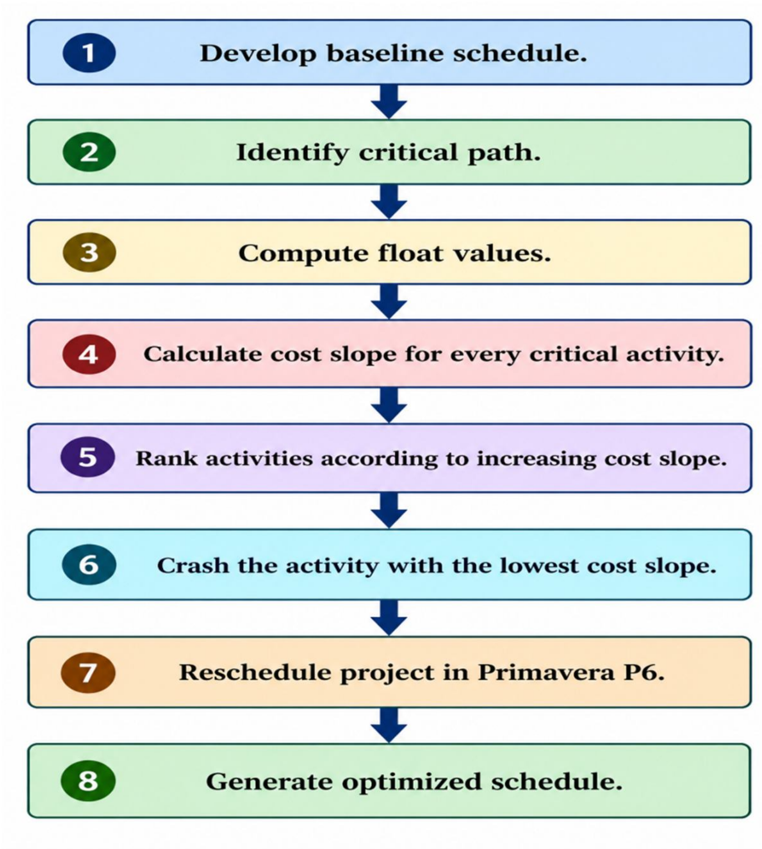

Figure 5.2 Optimization Algorithm

VI. ANALYSIS

A. Baseline Schedule Analysis

After developing the Work Breakdown Structure (WBS), defining activities, assigning logical relationships, allocating resources, and loading costs, the project schedule was generated using Primavera Software Professional. The Software automatically calculated the planned start and finish dates, identified the critical path, and established the baseline schedule for subsequent optimization.

The baseline schedule consisted of **422 construction activities** organized into major work packages, including foundation works, reinforced cement concrete (RCC), masonry, waterproofing, flooring, electrical installations, plumbing, interior finishing, façade works, and external development. The total estimated project cost was **₹18.86 crore**, and the planned project duration was **463 calendar days**. These values formed the benchmark for evaluating the effectiveness of schedule crashing and time–cost optimization.

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Table 6.1 Baseline Project Summary

Parameter	Value
Total Activities	422
Baseline Duration	463 Days
Estimated Cost	₹18,86,38,252.49
Critical Activities	31
Project Calendar	7-Day Working
Software	Primavera Software Professional

*Number of critical activities to be verified from the final Primavera output before journal submission.

B. *Work Breakdown Structure Analysis*

The Work Breakdown Structure (WBS) organized the project into manageable work packages that facilitated planning, scheduling, cost allocation, and progress monitoring. Each WBS element represented a major phase of construction and was further decomposed into detailed construction activities.

The distribution of project cost among different WBS elements indicated that **Civil and Structural Works** accounted for the largest proportion of the project budget (approximately 47.16%), followed by Facade and Elevation Works (16.44%), Flooring (11.30%), and Internal Painting (8.08%). This distribution demonstrates that optimization of structural activities has the greatest potential to influence overall project duration.

Table 6.2 Distribution of Project Cost Among Major WBS Elements

Work Package	Cost (₹)	Budget (%)
Civil & Structural Work	8,89,58,734	47.16
Brickwork & Plastering	1,51,21,392	8.02
Waterproofing	21,15,082	1.12
Flooring	2,13,18,671	11.30
False Ceiling	55,54,387	2.94
Interior Work	13,16,985	0.70
Internal Painting	1,52,51,765	8.08
Wood & PVC Work	73,79,445	3.91
Electrical & Plumbing Fixtures	6,31,256	0.33
Façade & Elevation	3,10,09,134	16.44

The predominance of structural activities in the project cost confirms their strategic importance during schedule optimization.

C. *Critical Path Analysis*

The Critical Path Method (CPM) was applied to determine the sequence of activities governing project completion. Primavera Software automatically performed forward and backward pass calculations and identified activities with **zero total float** as critical.

The critical path primarily consisted of the following construction stages:

1) Site preparation 2) Excavation 3) Foundation 4) RCC columns 5) RCC beams 6) RCC slabs 7) Staircase construction 8) Brick masonry 9) Internal plaster 10) Flooring 11) Electrical rough-ins 12) Plumbing installation 13) Painting 14) Façade work 15) Final finishing 16) Project handover

These activities formed a continuous chain with no scheduling flexibility. Any delay in one of these activities would directly increase the overall project duration.

The CPM analysis also enabled project managers to prioritize supervision, optimize resource allocation, and evaluate the impact of schedule acceleration strategies.

D. Schedule Crashing Analysis

Schedule crashing was performed only on critical activities after evaluating their technical feasibility and economic viability.
The selection criteria included:

1) Low cost slope
2) Availability of additional labour
3) Availability of equipment
4) Availability of construction materials
5) Safety requirements
6) Construction quality
7) Sequential dependency

Activities having the lowest cost slope were crashed first to achieve maximum schedule reduction at minimum additional cost.

Table 6.3 Crashing Analysis

Activity	Normal Duration (Days)	Crashed Duration (Days)	Time Saved	Cost Slope (₹/Day)
Column Reinforcement	2	1	1 Day X 5 floors =5 Days	3,600
RCC Beam	7	5	2 Days X 5 floors =10 Days	35,000
RCC Slab	7	5	2 Days X 5 floors =10 Days	36,600
Brick Masonry	5	4	1 Day X 5 floors =5 Days	32,000
Internal Plaster	10	7	3 Days X 5 floors =15 Days	26,600
Flooring	5	4	1 Days X 5 floors =5 Days	36,000
Painting	20	15	5 Days	19,000

E. Optimized Schedule

Following the crashing process, Primavera Software generated an optimized schedule.
The project duration was reduced from: 463 Days to 408 Days. Representing a total reduction of: 55 Days. This corresponds to a percentage reduction of: $\frac{55}{463} \times 100 = 11.88\%$
The optimization was achieved without compromising construction quality or violating resource constraints.

F. Cost Analysis

Schedule acceleration increased the direct construction cost because additional labour, equipment, overtime, and resources were required during crashing.
However, the increase in project cost remained relatively small compared with the achieved reduction in project duration.

Table 6.4 Comparison Between Baseline and Optimized Schedule

Parameter	Baseline	Optimized
Project Duration	463 Days	408 Days
Time Saved	-	55 Days
Project Cost	₹18.86 Crore	₹19.02 Crore
Additional Cost	-	₹15.58 Lakh
Cost Increase	-	0.82%

The relatively small increase in direct cost demonstrates that systematic schedule crashing can significantly improve project performance while maintaining economic feasibility.

G. Time–Cost Relationship

The relationship between project duration and project cost follows the classical time–cost trade-off.

1) Increasing project duration generally reduces direct costs but increases indirect costs.
2) Decreasing project duration increases direct costs due to additional resources.
3) An optimum project duration exists where the total project cost is minimized.

The present study indicates that reducing project duration by approximately **12%** required only a **0.82%** increase in direct project cost, representing a favorable trade-off.

VII. RESULTS AND DISCUSSIONS

The present study demonstrates the practical applicability of **P**rimavera Software integrated with the Critical Path Method (CPM) and schedule crashing for optimizing the execution of a multistory government building project. Unlike many theoretical optimization studies, this research was conducted using actual project data from the CM Block of the VVIP Guest House Project, Ayodhya, thereby providing realistic insights into construction planning and project control.

The baseline schedule generated in Primavera Software established a project duration of 463 days, with the critical path consisting of major structural, architectural, and finishing activities. Subsequent application of schedule crashing reduced the project duration to 408 days, achieving a reduction of 55 days (11.88%) while increasing the project cost by only 0.82%. This demonstrates that selective crashing of carefully identified critical activities can significantly improve schedule performance without imposing excessive financial burden.

One of the most important findings of this study is that optimization should focus exclusively on activities located on the critical path. Crashing non-critical activities does not contribute to project acceleration because these activities possess positive float. Consequently, the combination of float analysis and cost-slope evaluation enables project managers to allocate additional resources only where they generate measurable schedule benefits.

The study also confirms that resource allocation is a decisive factor in schedule optimization. Additional manpower, equipment, and construction resources must be deployed strategically rather than uniformly across all activities. Activities with lower cost slopes provide the greatest opportunity for economical schedule compression and therefore should receive priority during optimization.

The use of Primavera Software significantly simplified project planning by automatically generating the project network, identifying critical activities, recalculating schedules after each crashing iteration, and providing real-time updates of project duration and cost. Compared with manual scheduling methods, Primavera Software reduces computational effort, improves scheduling accuracy, and enables rapid evaluation of alternative construction scenarios.

The findings also support the growing adoption of digital project management tools in large infrastructure projects. Modern scheduling Software not only improves planning efficiency but also enhances transparency, facilitates communication among stakeholders, and supports data-driven decision-making throughout the project lifecycle.

VIII. COMPARISON WITH PREVIOUS STUDIES

The findings of the present research align with previous studies emphasizing the importance of project scheduling and optimization in improving construction performance. However, the proposed framework extends earlier work in several important aspects.

Earlier studies primarily focused on deterministic scheduling techniques such as CPM and PERT, while later research introduced Earned Value Management (EVM), Earned Schedule (ES), probabilistic forecasting, Bayesian networks, artificial intelligence, and machine learning approaches for project duration prediction. Although these methods improve forecasting accuracy, their implementation often requires sophisticated computational models and specialized expertise.

In contrast, the present study demonstrates that significant improvements in project performance can be achieved using commercially available Software through systematic application of CPM, Primavera Software scheduling, and cost-slope-based schedule crashing. This approach is easier to implement in practice and is readily applicable to construction projects executed by government agencies and private contractors. Furthermore, unlike many published optimization studies based on hypothetical examples or simulated data, the present investigation employs actual construction data from a government infrastructure project comprising 422 activities. The practical nature of the study increases its relevance for construction professionals and project managers responsible for real-world project execution.

IX. CONCLUSIONS

This research presented a comprehensive framework for time–cost optimization of a multistory government building project using Primavera Software Professional, Critical Path Method (CPM), and schedule crashing techniques.

A detailed baseline schedule consisting of 422 construction activities was developed using Primavera Software. Critical Path Method analysis identified the sequence of activities governing project completion, enabling systematic selection of crash activities based on cost-slope evaluation.

The optimization process reduced the overall project duration from 463 days to 408 days, resulting in a schedule reduction of 55 days (11.88%). This improvement was achieved with only a 0.82% increase in total project cost, demonstrating that significant schedule acceleration can be accomplished without substantial financial impact.

The study confirms that effective schedule optimization depends on three major factors:

1) Accurate project scheduling,
2) Proper identification of critical activities,
3) Economical allocation of additional construction resources.

The findings demonstrate that Primavera Software is an effective decision-support tool for planning, monitoring, and optimizing complex construction projects. The proposed methodology is practical, replicable, and suitable for application in government as well as private sector construction projects.

Overall, the research contributes to the field of construction project management by providing a practical and industry-oriented framework for achieving an optimal balance between project duration and project cost.

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