

“Optimization of Resource Allocation using Primavera”

¹Shraddha Mohan Jogdankar, ²Mithun Kumar, ³Dr. I. N. Shaikh

M.E. Civil Engineering (Construction Management)

¹M.E. Student (construction management) Department of Civil Engineering, TSSM's Bhivarabai Sawant college of Engineering and Research, Narhe, Pune, Maharashtra.

²Assistant Professor, Department of Civil Engineering, TSSM's Bhivarabai Sawant College of Engineering and Research, Narhe, Pune, Maharashtra

Abstract- Efficient resource allocation is a critical determinant of success in modern construction management, where improper distribution of labor, materials, and equipment can result in delays, cost overruns, and inefficiencies. This study explores the optimization of project resources using Primavera P6, a robust enterprise project portfolio management software, applied to the residential case study of Belmont Skyverse in Lohegaon, Pune. By integrating Work Breakdown Structure (WBS), activity sequencing, and resource levelling techniques, the research systematically assigns labor, materials, and equipment to project activities, while considering constraints of time, cost, and quality. Data were collected from both primary sources, including detailed project schedules, activity durations, and resource requirements, and secondary sources such as literature, manuals, and case studies. Comparative analysis between traditional Excel-based scheduling and Primavera-optimized planning demonstrates a reduction in total project duration from 789 to 735 days and a cost decrease of approximately 10%, reflecting significant gains in efficiency. Phase-wise evaluation shows optimized durations and costs for substructure, superstructure, finishing, and MEP works. The study also highlights the potential of scheduling optimization and real-time monitoring to enhance decision-making, improve resource utilization, and minimize idle time. Findings confirm that systematic application of Primavera P6 in construction projects can deliver improved project performance, cost-effectiveness, and workflow continuity, supporting its adoption for complex multi-activity construction environments.

Keywords: Resource Allocation, Primavera P6, Construction Management, Optimization, Scheduling, Cost Reduction, Resource Levelling, Work Breakdown Structure

INTRODUCTION

In the modern construction and project management environment, efficient utilization of resources has become a critical factor for achieving project success. Resource allocation refers to the systematic assignment of available resources such as labor, materials, equipment, and finances to various project activities in a manner that ensures optimal productivity and cost-effectiveness. In large-scale construction projects, improper allocation often leads to delays, cost overruns, idle resources, and reduced efficiency. Therefore, optimization of resource allocation is essential to balance project constraints including time, cost, and quality. With the increasing complexity of infrastructure and industrial projects, traditional planning methods are no longer sufficient to manage dynamic project requirements. This has led to the adoption of advanced project management tools such as Primavera P6, which provides comprehensive solutions for planning, scheduling, monitoring, and optimizing resources throughout the project lifecycle. Primavera P6 is a powerful enterprise project portfolio management software widely used in construction, engineering, manufacturing, and IT industries. It enables project managers to develop detailed schedules, assign resources efficiently, and track project performance in real time. One of the key features of Primavera is its ability to perform resource leveling and resource smoothing, which are essential techniques for optimizing resource allocation. Resource leveling helps in resolving resource over-allocation by adjusting activity schedules, while resource smoothing ensures that resource usage remains within predefined limits without affecting the project duration. These techniques allow project managers to minimize idle time, reduce peak demand, and maintain a balanced workload across the project timeline. Additionally, Primavera integrates cost management with scheduling, enabling better control over project budgets and ensuring that resources are utilized in the most economical manner.

The optimization process in Primavera involves several analytical and computational approaches, including critical path method (CPM), resource-constrained scheduling, and what-if scenario analysis. The Critical Path Method helps in identifying the sequence of activities that directly impact the project duration, thereby allowing managers to prioritize resource allocation for critical tasks. Resource-constrained scheduling, on the other hand, focuses on

allocating limited resources in a way that minimizes project delays while maintaining efficiency. Primavera also supports advanced features such as earned value management (EVM), which integrates scope, schedule, and cost data to evaluate project performance. Through these analytical tools, project managers can simulate different scenarios, identify potential bottlenecks, and implement corrective actions to optimize resource distribution. This systematic approach enhances decision-making and ensures that project objectives are achieved effectively. One of the major advantages of using Primavera for resource optimization is its ability to provide real-time monitoring and control. The software allows users to track resource utilization, identify underutilized or overburdened resources, and make necessary adjustments during project execution. It also facilitates collaboration among project stakeholders by providing centralized data access and detailed reporting features. In complex projects involving multiple activities and interdependencies, Primavera helps in maintaining transparency and accountability by offering visual tools such as Gantt charts, resource histograms, and network diagrams. These tools enable project managers to analyze resource distribution patterns and make data-driven decisions. Furthermore, Primavera supports integration with other tools such as BIM and ERP systems, enhancing its capability to manage large-scale projects efficiently.

Problem Statement

“Construction management projects frequently face challenges related to inefficient resource allocation, rising material costs, and strict project deadlines. Traditional planning methods often rely on experience-based decisions, which may not effectively handle multiple constraints such as budget limitations, material availability, and demand requirements simultaneously. This frequently results in cost overruns, material wastage, and suboptimal utilization of critical resources such as steel, bricks, concrete blocks, and cement. Additionally, the increasing scale and complexity of modern construction projects demand analytical tools capable of evaluating multiple alternatives and providing optimal solutions. Although Linear Programming offers a structured optimization approach, its practical application in construction planning remains limited due to computational complexity and lack of systematic.”

Aim

“To develop and apply a MATLAB – based LP model integrated with ANN to optimise construction resource allocation.”

Objective

- To analyze the existing resource allocation practices in construction projects and identify inefficiencies such as over-allocation, underutilization, and scheduling conflicts.
- To develop an optimized project schedule using Primavera (P6) by integrating activities, resources (labour, materials, equipment), and time constraints.
- To evaluate the effectiveness of resource leveling and smoothing techniques in Primavera for minimizing resource fluctuations and improving utilization.
- To reduce project duration and cost overruns by applying optimized resource allocation strategies within Primavera.
- To compare planned vs. optimized resource allocation scenarios using Primavera outputs such as resource histograms, S-curves, and tracking reports.

RELATED WORK

The related work on construction optimization and project management reflects a gradual shift from conventional scheduling practices toward data-driven, intelligent, and software-supported decision-making models. Xu et al. (2022) conducted a scientometric review of 112 articles published between 2000 and 2020 and showed that Artificial Neural Networks (ANN) have gained substantial importance in construction management for solving complex and nonlinear problems. Their review revealed growing scholarly interest in ANN-based applications, but it also pointed out several persistent limitations such as poor data quality, difficulties in data collection, weak collaboration among stakeholders,

and the absence of standardized implementation platforms. Extending the role of intelligent systems, Zhang and Mo (2024) proposed an integrated Building Information Modeling and Elman Neural Network (BIM–ENN) model for construction cost prediction and optimization. Their model used BIM-generated digital data related to structure, pipelines, and electromechanical systems as inputs for ENN, enabling accurate forecasting of cost variations caused by design changes, labor fluctuations, and supply chain instability. The model achieved a prediction accuracy of 95.83%, with a coefficient of determination above 0.95, demonstrating strong predictive reliability. Bahuguna (2019) also emphasized the value of artificial intelligence and simulation in improving construction planning and scheduling. By combining machine learning algorithms with simulation techniques, the study showed that project managers can better forecast delays, identify bottlenecks, reduce cost, and optimize resource utilization under uncertain project conditions.

Several studies have additionally focused on mathematical optimization and project management software as practical tools for resource allocation and scheduling efficiency. Sujithra and Gopan (2022) applied Linear Programming (LP) to optimize resource utilization in building construction projects, aiming to maximize profit and minimize cost. Using real project data from the Public Works Department, they formulated LP models and validated the results through PRIMAVERA P6, concluding that LP serves as an effective managerial tool for identifying feasible and optimal resource combinations. Narlawar et al. (2019) examined Primavera in construction project management and found that it plays a critical role in planning, monitoring, scheduling, and controlling project activities. The study highlighted Primavera’s capability to detect resource over-allocation through histograms and profiles, thereby supporting resource leveling and smoothing. Likewise, Elbeltagi (2014) discussed resource-constrained project scheduling and stressed the significance of heuristic methods, simulation models, and mathematical programming in achieving efficient project outcomes. Hegazy (2002) earlier demonstrated that advanced optimization techniques can outperform traditional scheduling approaches when projects involve multiple constraints, resulting in improved timelines and better resource distribution. More recently, Saboor Ahmed et al. (2023) analyzed Primavera P6 and confirmed that software-assisted planning improves time management, critical path tracking, and cost control, with labor cost reductions of nearly 5%–8% and shorter project durations. Together, these studies establish that optimization models and intelligent scheduling tools are essential for enhancing efficiency, reliability, and performance in modern construction management.

RESEARCH METHOD

The main objective of this study is to quantify resource allocation in construction projects so that a more objective comparison can be made between economic implications and scheduling performance. The construction industry is one of the most dynamic, complex, and uncertain industrial sectors, where successful project execution depends heavily on the proper coordination of time, cost, labour, materials, and equipment. Because of increasing project complexity and rising construction costs, it has become essential for firms to manage their budgets and schedules efficiently. In many cases, poor planning and ineffective resource allocation lead to delays, cost overruns, and project failure. This makes resource optimization a critical concern in modern construction management.

The research strategy adopted in this study is mixed in nature, although it leans more toward qualitative analysis. This is because the study does not only focus on software-generated outputs, but also on understanding how managers interpret project constraints, scheduling logic, and practical decision-making during planning and execution. Methods commonly associated with qualitative research, such as data analysis, activity observation, and expert-based understanding, support the investigation. At the same time, quantitative scheduling outputs generated through Primavera P6 provide measurable evidence for evaluating optimization performance. The increasing dependence on digital project management systems is justified by industry concerns, especially as many projects exceed their assigned budgets and fail to meet expected delivery timelines. In this context, Primavera P6 and Primavera Contract Management are examined as effective tools for preparing resource allocation schedules in less time and with less effort while also improving documentation, tracking, and claim preparation.

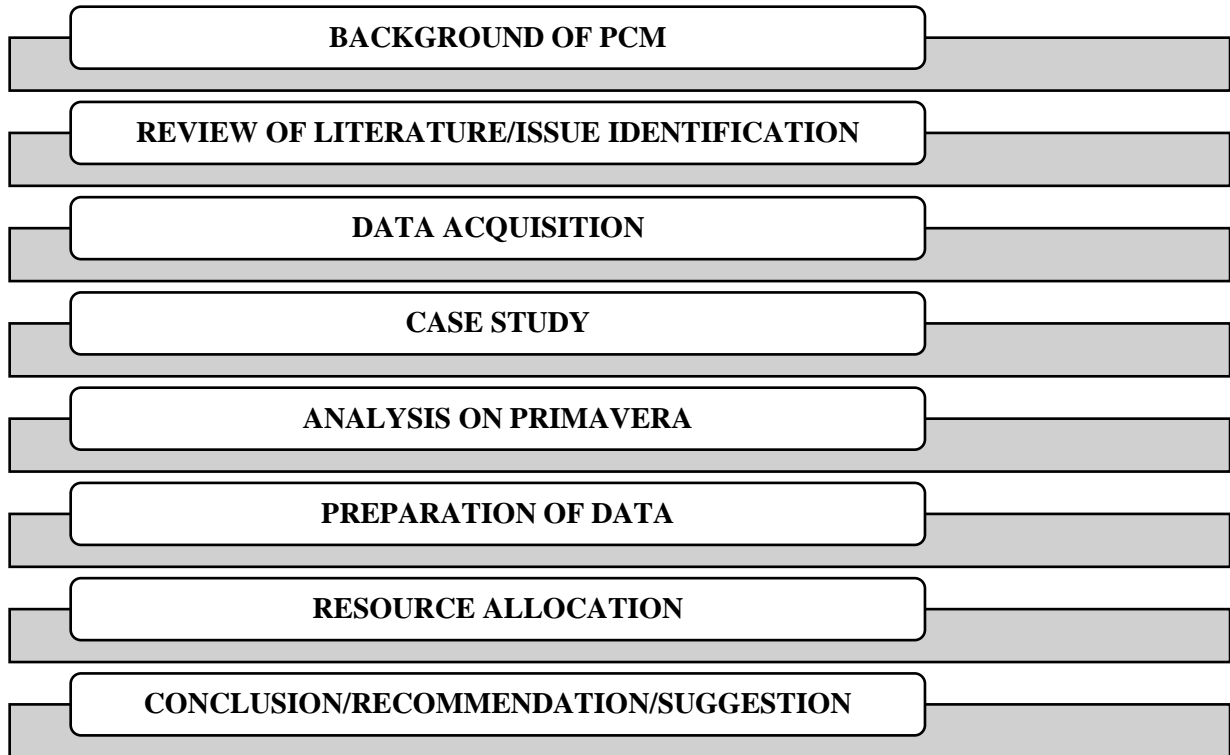


Fig 1. Flow Chart Showing Research Structure

3.1 Development of Work Breakdown Structure (WBS)

The Work Breakdown Structure is a fundamental element in this study because it provides the structural basis for project planning and resource allocation. In construction project management, the WBS is used to divide the entire project into manageable and logically organized components. This structured decomposition enables project managers to identify major work packages and break them down further into smaller activities that can be scheduled, monitored, and assigned resources effectively. In Primavera P6, the WBS acts as the foundation for linking project scope with execution planning. It helps classify work under major heads such as substructure, superstructure, finishing works, and MEP services, ensuring that each segment of work is clearly defined and controlled.

The importance of WBS in this study goes beyond project organization. It directly supports resource optimization by allowing labour, material, and equipment resources to be assigned systematically at each activity level. Primavera P6 uses tools such as resource usage profiles and red-capped histograms to help managers detect overutilization, resource imbalance, and inefficient distribution across WBS elements. This makes it easier to understand whether specific work packages are overloaded or under-supported. The WBS also enables impact analysis, because changes in one section of the project can be traced more accurately through connected activities and their associated resources. Thus, the development of a clear and logical WBS strengthens scheduling accuracy, improves managerial control, and enhances the overall effectiveness of project resource planning.

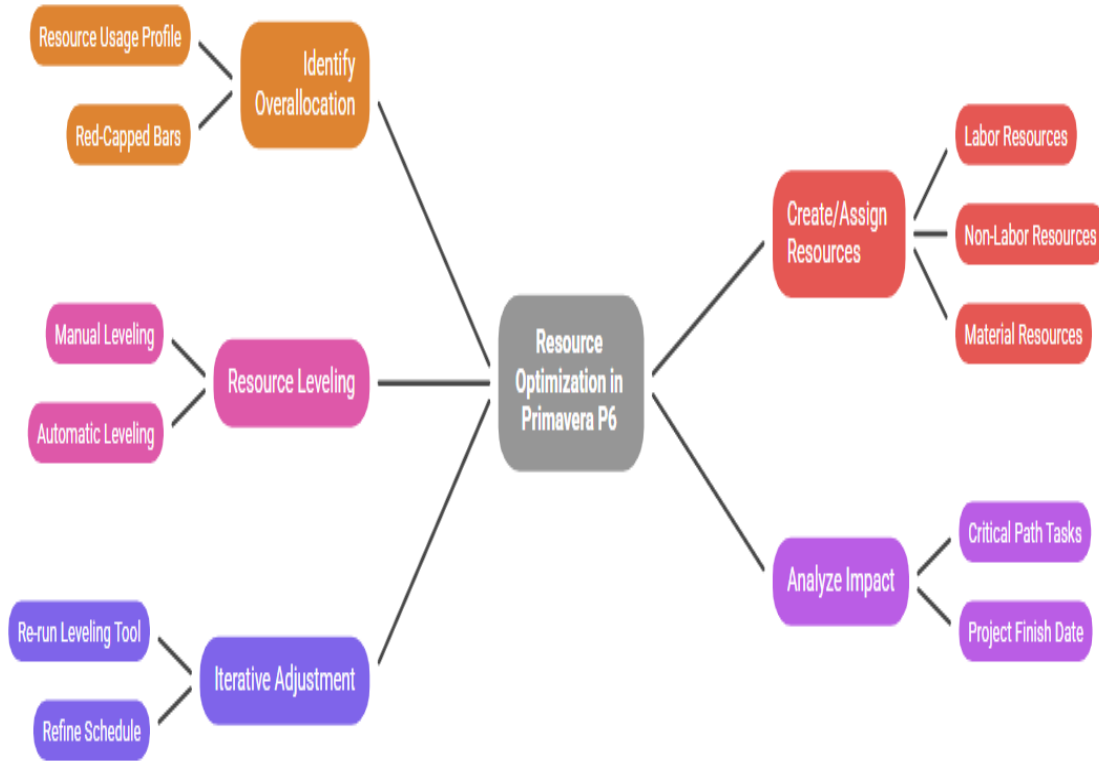


Fig 2. Resource Optimization in Primavera P6

3.2 Process of Resource Levelling

Resource levelling is one of the most important processes in this research because it ensures that project activities are scheduled in such a way that available resources are used efficiently without exceeding practical limits. The process begins by allocating resources serially over time according to the planned schedule. At this stage, resources are assigned to activities based on project needs and task durations. Once this initial allocation is completed, all activities are scheduled while considering resource constraints. This step helps identify whether the original schedule is realistic in terms of labour, equipment, and material availability.

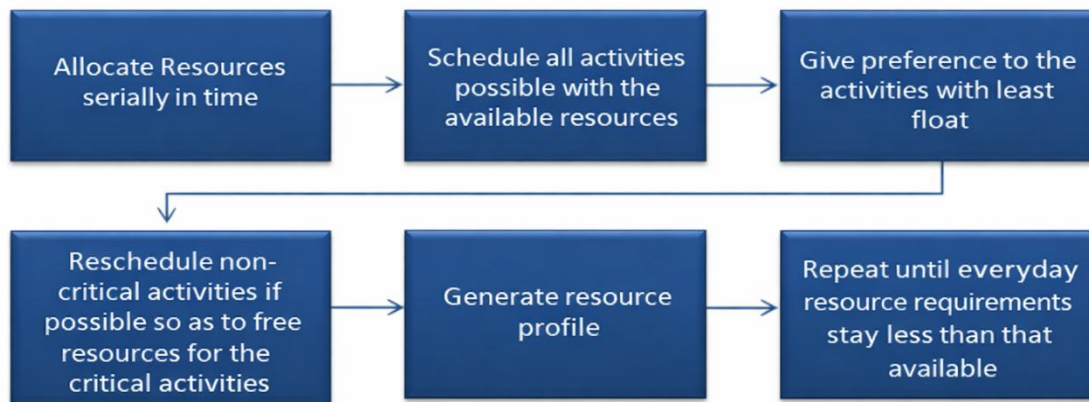


Fig 3. Process of Resource Levelling

The next stage of the levelling process is prioritization. Activities with the least float are given more importance because delays in these tasks are more likely to affect the project completion date. Non-critical activities are then

adjusted or rescheduled wherever possible in order to release resources for critical or near-critical tasks. This helps reduce bottlenecks and ensures smoother project execution. After these changes, a resource profile is generated to assess resource demand over the project timeline and identify periods of over-allocation or underutilization. The process is iterative, meaning that scheduling and adjustments continue until resource demand falls within available limits. In this way, resource levelling becomes a continuous optimization cycle that improves efficiency, stabilizes workflow, and supports balanced utilization of available project resources.

3.3 Data Collection

Data collection is a critical part of the study because the reliability and usefulness of the optimization process depend strongly on the accuracy of input data. The study uses both primary and secondary data sources to create a realistic and academically supported model of resource allocation in Primavera P6. By combining direct project-related data with reference-based knowledge from published sources and software manuals, the research ensures both practical relevance and theoretical grounding. This combination is particularly valuable in construction studies, where real project conditions must be understood alongside accepted planning principles. The collection approach is designed to support not only scheduling and resource assignment, but also the later comparison between pre-optimization and post-optimization project conditions. The use of multiple data sources improves the completeness of the analysis and reduces the possibility of relying on assumptions alone. Realistic construction activity sequences, resource requirements, and managerial judgments are combined with secondary references to build a reliable framework for project planning and evaluation. Overall, data collection in this study is not treated as a routine step but as a strategic foundation for meaningful optimization outcomes.

3.3.1 Primary Data

Primary data refers to the original information collected specifically for the purpose of this study. It plays a central role in constructing the Primavera P6 model and ensuring that the scheduling and optimization outputs reflect practical construction conditions. One major component of primary data is project planning input, which includes activity lists, estimated durations, and logical dependencies. Activities are identified by dividing the project according to construction stages such as substructure, superstructure, finishing, and MEP works. Each activity is assigned a realistic duration based on industry practices and expected site conditions. Logical relationships such as Finish-to-Start, Start-to-Start, and Finish-to-Finish are then defined to reflect the actual sequence of construction operations. Another important component of primary data is resource detail. This includes labour, equipment, and materials required for the execution of each activity. Labour resources may consist of skilled workers, supervisors, engineers, and unskilled workers. Equipment resources may include cranes, excavators, and concrete mixers, while material resources include steel, cement, bricks, and other essential construction items. These resources are assigned characteristics such as availability, productivity, working hours, and cost rates. In addition, expert inputs from project managers, site engineers, and other construction professionals are incorporated to validate activity sequencing, durations, and resource requirements. These expert opinions improve the realism of the model and ensure that the resource optimization process aligns with practical site-level decision-making.

3.3.2 Secondary Data

Secondary data is used in this study to complement the primary information and to provide conceptual, technical, and benchmark support for the research. It is obtained from existing sources such as research articles, journal papers, technical manuals, software documentation, and case studies related to construction project management and resource optimization. These sources help the researcher understand established approaches, common challenges, and best practices in the use of Primavera P6 and other optimization techniques within construction environments. Research papers and journals provide insights into scheduling methodologies, resource allocation strategies, and performance evaluation frameworks. Primavera manuals and official documentation are particularly important because they explain how the software should be used for activity linking, resource loading, leveling, and performance tracking. Case studies of construction projects offer real-world illustrations of how resource conflicts, delays, and cost overruns can be addressed through systematic planning. In situations where complete live project data is not available, standard planning assumptions based on industry norms are used for durations, cost parameters, and resource requirements. This ensures continuity in the study while maintaining reasonable practical relevance. Thus, secondary data strengthens the analytical foundation of the research and supports the interpretation of optimization results.

3.4 Tools and Software Used

The effectiveness of this study depends greatly on the appropriate selection of software tools for planning, organizing, analyzing, and interpreting data. The primary software used is Primavera P6, which serves as the core platform for project scheduling, resource allocation, resource leveling, and critical path analysis. Primavera P6 allows the user to create a detailed schedule by entering activities, durations, relationships, calendars, and constraints. It also offers resource histograms, usage profiles, leveling tools, and tracking options, which make it highly suitable for research on resource optimization in construction projects. Microsoft Excel is used as a supporting tool to prepare and organize data before it is entered into Primavera and to analyze outputs after optimization. Excel assists in arranging activity lists, resource details, and comparative calculations in a structured form. It also supports the preparation of summary tables and performance indicators. In addition, graphical tools such as histograms, S-curves, and comparison charts are used to present results visually. These visuals help identify trends, resource peaks, improvements after leveling, and changes in schedule performance. The combination of Primavera P6, Excel, and graphical analysis tools creates an integrated research environment that supports both technical evaluation and effective interpretation of results.

3.5 Methodology Procedure

The methodology adopted in this study follows a systematic step-by-step process to ensure that resource optimization is carried out in a structured and transparent manner. The first step is project definition, where the selected construction project is identified in terms of its scope, objectives, and major deliverables. This helps establish the boundaries of analysis and clarifies the purpose of optimization. The second step involves preparing the Work Breakdown Structure, which divides the project into hierarchical components such as substructure, superstructure, finishing, and MEP works. This simplifies planning and facilitates better control of activities and resources. The third step is activity definition and sequencing. All activities under the WBS are listed and assigned durations and logical relationships using Critical Path Method principles. The fourth step is resource identification and assignment, where labour, equipment, and materials are allocated to each activity along with their availability, calendars, and productivity values. The fifth step is initial scheduling, in which a baseline schedule is generated without optimization. This schedule helps identify the original project duration and detect initial resource over-allocation. The sixth step is resource loading analysis, carried out through histograms and related tools to observe peaks, shortages, and imbalances. The seventh step is resource leveling, where activity timings are adjusted, critical tasks are prioritized, and non-critical tasks are delayed where permissible. Finally, the eighth step is comparison and evaluation, in which the project is assessed before and after optimization based on resource utilization, cost efficiency, and project duration. This methodology ensures a logical progression from project setup to performance assessment.

3.6 Performance Evaluation Metrics

The study evaluates the effectiveness of resource optimization through several performance metrics that reflect both project efficiency and scheduling quality. One major metric is resource utilization rate, which measures how effectively labour, equipment, and materials are deployed across project activities. A high utilization rate indicates that resources are being used productively with minimal idle time. Another important metric is the reduction in resource over-allocation, which shows the extent to which resource conflicts have been minimized after optimization. This is particularly important in construction projects, where overlapping activities often compete for the same limited resources. Project duration variation is another key metric used in the study. It helps determine whether resource leveling has caused the project duration to increase, decrease, or remain stable. Cost variation is also considered wherever applicable in order to assess the financial effects of improved resource distribution and reduced wastage. In addition, schedule efficiency is analyzed to understand whether workflow continuity and sequencing have improved after optimization. Together, these indicators provide a comprehensive basis for assessing the success of the resource optimization process and for determining whether Primavera P6 has contributed meaningfully to project performance improvement.

3.7 Data Analysis Techniques

To interpret the results meaningfully, the study uses multiple data analysis techniques that combine numerical comparison with visual interpretation. Comparative analysis is used to examine the differences between the project condition before optimization and after optimization. This helps identify improvements in resource utilization, project duration, and cost-related outcomes. The comparison forms a direct basis for evaluating the practical value of

Primavera-based resource balancing. Graphical analysis is also used through resource histograms, S-curves, and other visual charts. These tools make it easier to identify over-allocation, uneven demand patterns, and post-leveling improvements across the project timeline. In addition, percentage improvement calculations are applied to quantify the extent of change in measurable terms. This allows the findings to be expressed not only descriptively but also numerically. The use of these techniques ensures that the results are interpreted from both qualitative and quantitative perspectives, thereby strengthening the analytical depth of the study and improving the clarity of conclusions drawn from the resource optimization process.

CASE STUDY AND DATA COLLECTION

This chapter presents the data collection process and detailed case study analysis undertaken for the research on optimization of resource allocation using Primavera P6. The study is based on the residential project Belmont Skyverse located in Lohegaon, Pune, developed by Mahadik and Shirsagar Developers. Both primary and secondary data sources are utilized to ensure accuracy and practical relevance. Primary data includes project planning inputs such as activity lists, durations, sequencing, and resource details including labour, equipment, and materials, which are structured using Excel and later integrated into Primavera P6. Secondary data is obtained from research papers, Primavera manuals, and standard construction planning references to support methodological consistency. The collected data is systematically organized into a Work Breakdown Structure (WBS) and converted into a scheduling framework for further analysis. This chapter focuses on transforming raw project data into a structured format suitable for resource allocation, scheduling, and optimization. It provides a comprehensive foundation for evaluating project performance, identifying resource constraints, and applying optimization techniques to improve efficiency, reduce overallocation, and enhance project execution outcomes.

4.1 Case Study Description: Belmont Sky verse, Lohegaon, Pune

4.1.1 Project Description

The selected case study for this research is *Belmont Skyverse*, a residential construction project located in Lohegaon, Pune, Maharashtra. The project has been chosen as a representative model to analyze the effectiveness of resource allocation optimization using Primavera P6. Belmont Skyverse reflects a typical mid-rise residential development, incorporating modern construction practices, structured planning, and a multi-phase execution strategy. The project is being developed by Mahadik and Shirsagar Developers, a recognized local builder known for delivering affordable and mid-range residential housing projects within the Pune region. The significance of selecting Belmont Skyverse lies in its alignment with real-world construction challenges, particularly in terms of activity sequencing, resource allocation, and scheduling constraints. The project includes multiple floors and a variety of construction activities, ranging from foundation work to finishing and service installations.





The construction of Belmont Skyverse follows the Reinforced Cement Concrete (RCC) framed structure system, which is widely used in residential construction due to its strength, durability, and flexibility in design. The RCC structure involves the integration of concrete and steel reinforcement to create load-bearing elements such as columns, beams, and slabs. This structural system requires careful coordination of materials, labour, and equipment, making resource planning a critical aspect of project execution. The project is divided into several key construction stages, including substructure development, superstructure erection, finishing works, and MEP (Mechanical, Electrical, and Plumbing) services. Each stage consists of multiple interdependent activities that must be executed in a specific sequence to ensure structural stability and project continuity. For instance, substructure activities such as excavation and foundation work must be completed before initiating superstructure tasks like column and slab construction. Similarly, finishing works and MEP installations are carried out after the structural framework is completed.

RESULTS AND DISCUSSION

This section presents the results and discussion based on the detailed activity scheduling and resource allocation data derived from the Belmont Skyverse project. The analysis is carried out using structured Excel datasets covering all major construction phases, including substructure, superstructure, finishing works, and MEP services. Each activity is defined with parameters such as activity ID, duration, start and end dates, predecessor relationships, assigned resources, and budgeted costs. The data is systematically integrated into Primavera P6 to generate the baseline schedule and identify initial issues related to resource over-allocation, scheduling inefficiencies, and uneven workload distribution. The results obtained from the initial schedule serve as a reference point for further optimization and comparative analysis. The discussion further evaluates the impact of resource leveling and optimization techniques applied through Primavera P6. By analyzing activity sequencing, resource histograms, and dependency networks, improvements in resource utilization, reduction in peak demand, and better workflow continuity are observed. The comparison between pre-optimization and post-optimization scenarios highlights changes in project duration, cost distribution, and scheduling efficiency. Special attention is given to critical path activities and their influence on overall project performance. The findings demonstrate that proper resource planning and leveling significantly enhance project execution by minimizing delays, reducing idle time, and ensuring balanced utilization of labour and equipment. This section provides a comprehensive interpretation of results, linking data-driven insights with practical construction management strategies.

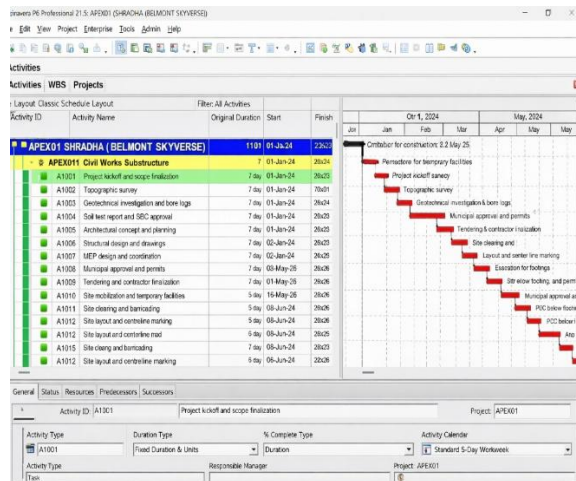


Fig 4. Primavera P6 Project Scheduling Interface

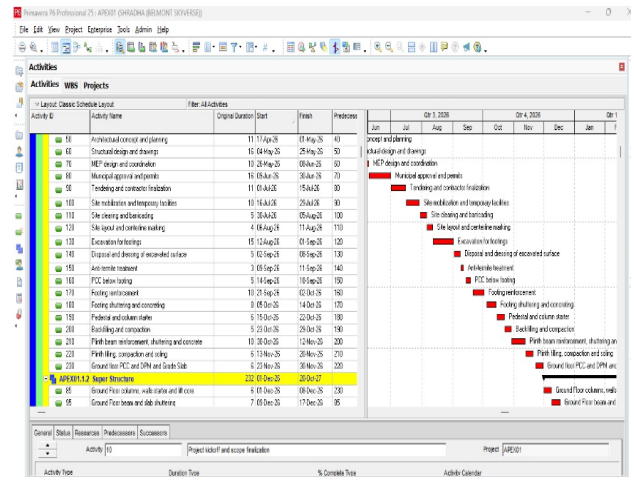


Fig 5. Primavera P6 Activity Sequencing and Timeline

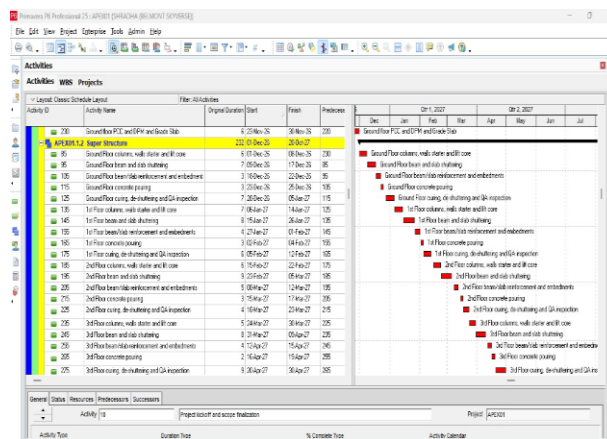


Fig 6. Superstructure Scheduling and Floor-wise Progress

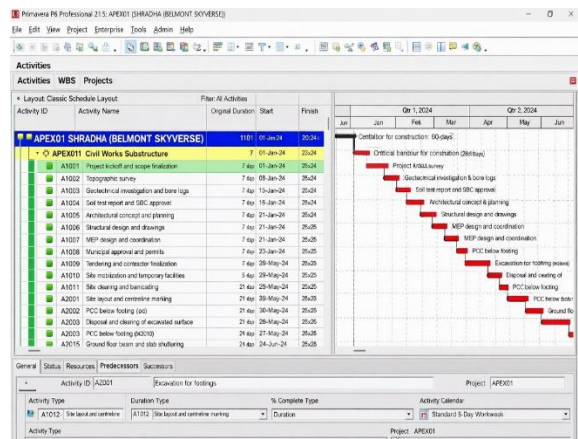


Fig 7. Primavera P6 Substructure Schedule View

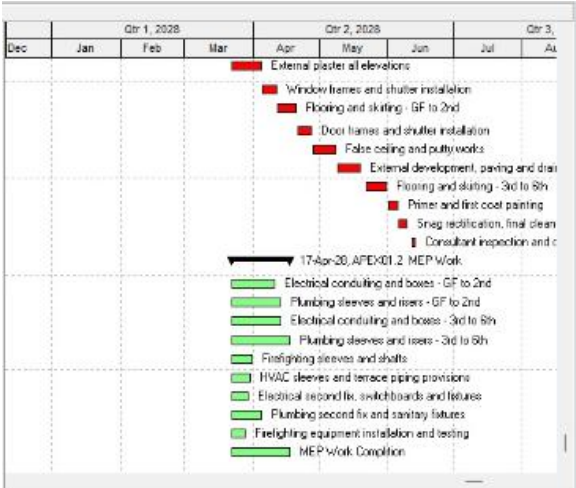


Fig 8. Finishing and MEP Scheduling Overview

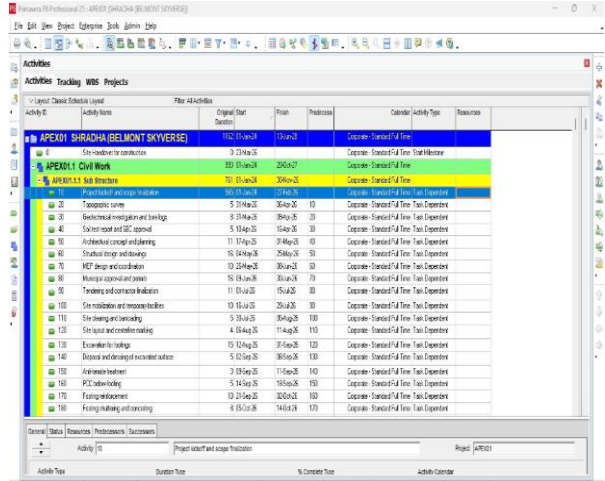


Fig 9. Primavera P6 Resource and Activity Table

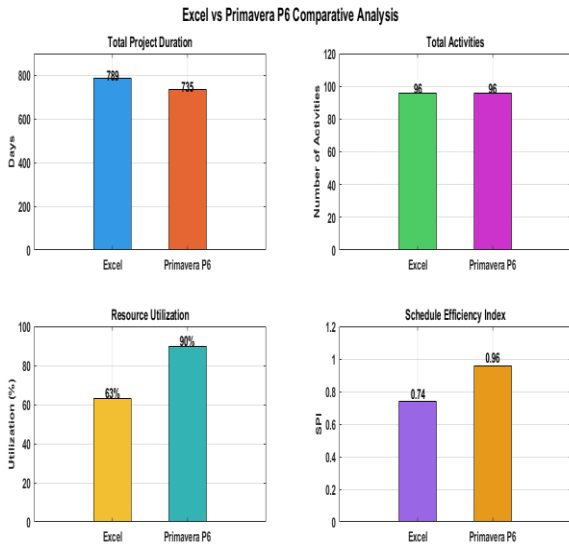


Fig 10. Optimized Project Results (Excel vs Primavera P6)

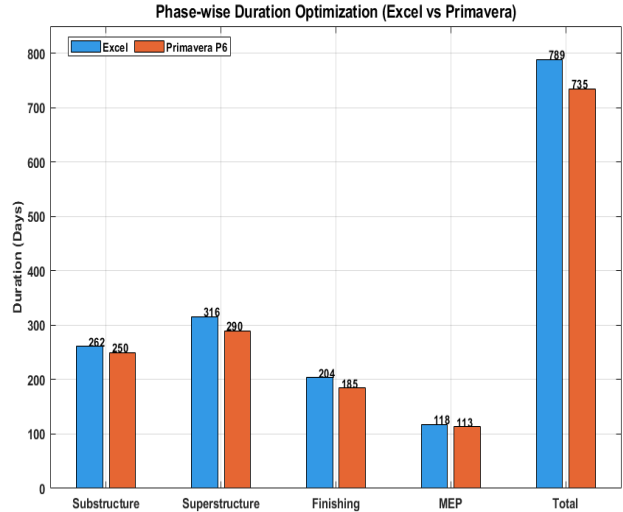


Fig 11. Phase-wise Duration Optimization

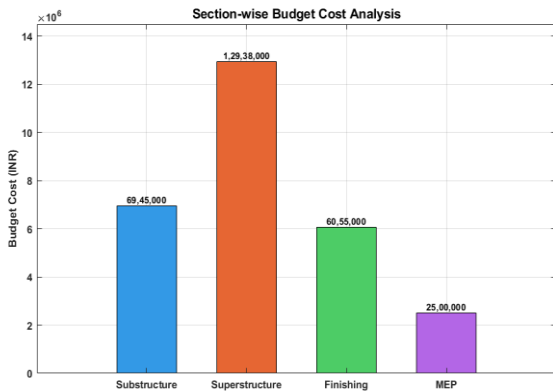


Fig 12. Section-wise Cost and Efficiency Analysis

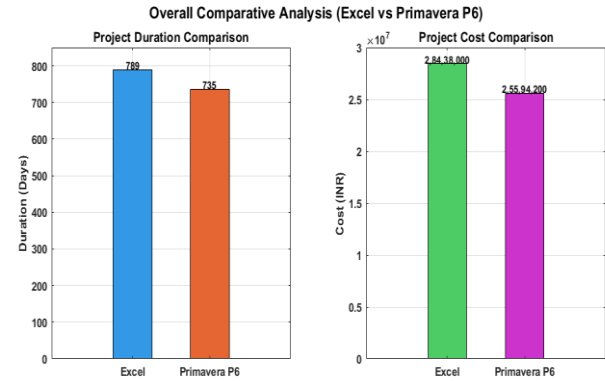


Fig 13. Overall Comparative Analysis (Excel vs Primavera)

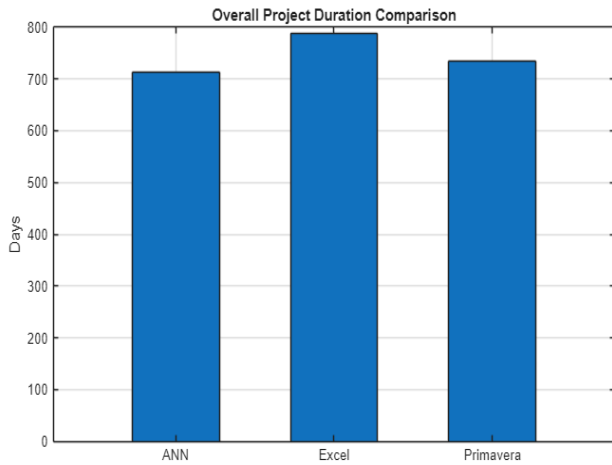


Fig 14 Overall Project Duration Comparison

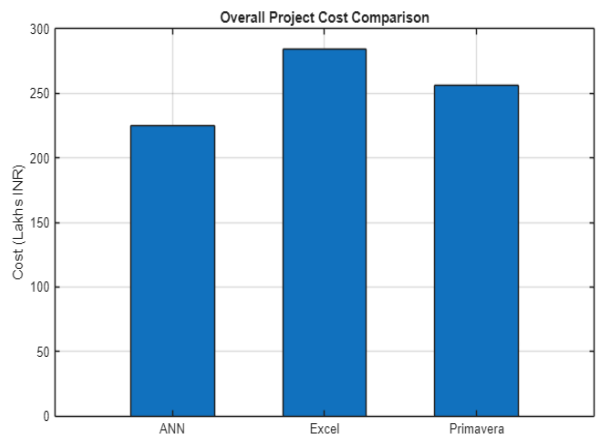


Fig 15. Overall Project Cost Comparison

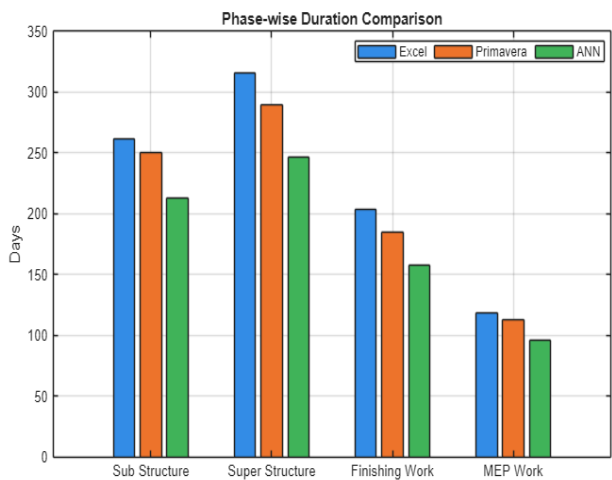


Fig 16. Phase-Wise Duration Comparison

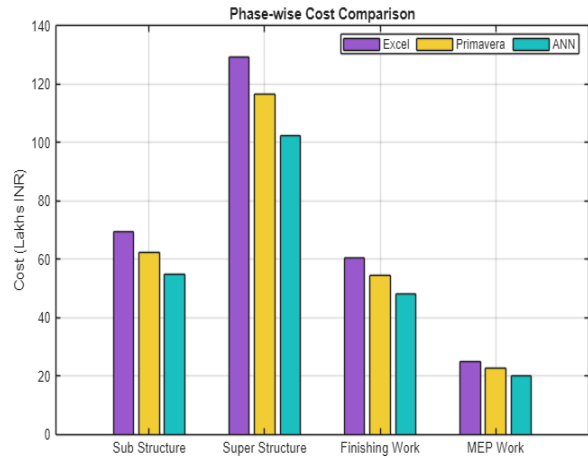


Fig 17. Phase-Wise Cost Comparison

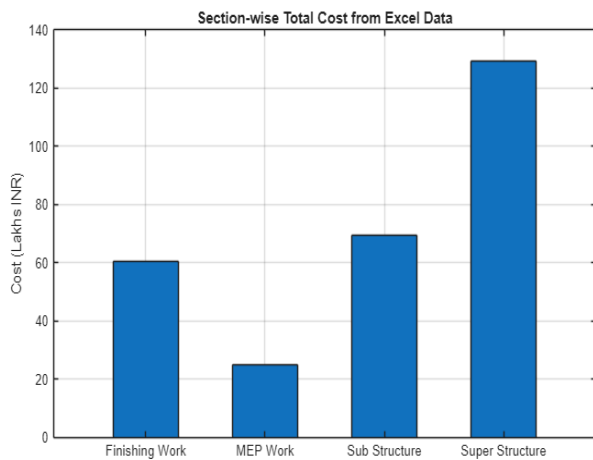


Fig 18. Section-Wise Total Cost from Excel Data

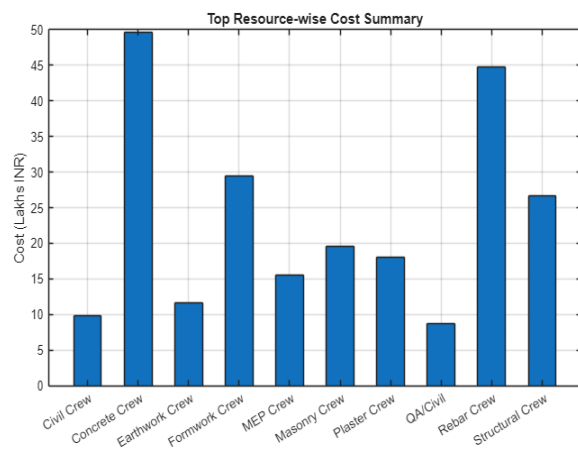


Fig 19. Top Resource-Wise Cost Summary

CONCLUSION

The present study confirms the effectiveness of MATLAB- and Primavera-supported optimization in improving the scheduling and cost performance of the Belmont Skyverse project when compared with traditional Excel-based planning. The baseline Excel schedule shows a total project duration of 789 days and a total project cost of ₹2,84,38,000, indicating higher time and financial requirements under the conventional planning approach. After applying Primavera P6, the total project duration is reduced to 735 days, resulting in a saving of 54 days, while the total project cost decreases to ₹2,55,94,200, giving a cost reduction of ₹28,43,800, or approximately 10%. These results demonstrate that logical sequencing, better dependency tracking, and resource leveling significantly improve project execution efficiency. The phase-wise analysis also supports this finding, where Primavera reduces the duration of Sub Structure from 262 to 250 days, Super Structure from 316 to 290 days, Finishing Work from 204 to 185 days, and MEP Work from 118 to 113 days. The ANN-based optimization model demonstrates an additional improvement over Primavera by producing a total project duration of 712.30 days and a total project cost of ₹2,25,23,000. This reflects a total saving of 76.70 days and ₹59,15,100 compared with the Excel baseline. Similarly, phase-wise ANN results show reduced durations of 212.50 days for Sub Structure, 246.50 days for Super Structure, 157.25 days for Finishing Work, and 96.05 days for MEP Work, all of which are lower than both Excel and Primavera values. The cost pattern also improves across all phases, with ANN reducing the Super Structure cost to ₹102.31 lakhs, Sub Structure to ₹54.88 lakhs, Finishing Work to ₹48.10 lakhs, and MEP Work to ₹19.95 lakhs.

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