



Schedule Impact Assessment of Mumbai Metro Underground Project Using Primavera Software

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Abstract: The construction of any project such as Residential, Commercial, or Infra are usually complicated and requires time to complete the project. Even though with proper planning or resources the project lacks to complete on time due to some reasons. When the project lacks in any terms, the event is defined as a delay. These delays can happen at any period of the project and is very tough to predict occurrence of such delays. These delays can be due to conflicts between the stakeholders, unavailability of resources, legal issues, additional works, variation in the work, change in design or pandemic situations. However, in every project time management is very crucial so that such further delays can be avoided and project can be completed in time. Beside this, in every project delay analysis plays a vital role in understanding how the delays can affect the overall project in all terms.

Keywords – Stakeholders, Unavailability of resources, Legal issues

1.0 INTRODUCTION

Delay Analysis terms to analyze the causes of delays in the project. It helps to identify and manage the effects of the scheduled project. It also helps in determining how the delays occurred, what was the reason, who was responsible for that delay, etc. Delay Analysis helps in resolving the issues related to time by supporting the claim for extra time and compensation, additional work, etc. In addition, Delay Analysis is the process which helps to determine the difference of the progress between the planned project and actual project. In addition, delay analysis is the process of looking at differences between planned and actual project progress to find out the main reasons for delays, how they affect the overall timeline, and who is responsible for that delay. It helps all the people/team involved in the project, such as clients, contractors, consultants, and legal teams, to understand how delays developed and whether they excusable or non-excusable and also worth of compensation. The goal of delay analysis is not just to know the purpose of delays, but to justify the specific events or situations which are affecting the project's main path and changing the original plans. This is especially important when several delays happen at the same time and requires expert knowledge and tools to understand the overall effect. To do proper delay analysis, project managers and planners use scheduling tools and methods to outlook how delay events affect the critical path. The critical path is the sequence of activities that directly determines the earliest date the project can finish. Delays on the critical path are usually the most damaging and need the most attention. In today's fast-moving and complex project environments, having proper planning, scheduling, and resource management is key to successful project execution and delivery. As project expands with complexity, especially in construction of infrastructure and other engineering sectors, the need for strong project management tools becomes more important. There are various management tools used in all types of project sectors. The software's such as Primavera P6, Microsoft Project, SPSS, etc. are used for planning, scheduling, tracking, etc. of the respective project. It is based on the Critical Path Method (CPM) and enables project managers to create detailed schedules with logically connected activities, manage multiple projects, allocate resources efficiently, and monitor performance in real time.

2.0 SCOPE OF STUDY

The study determines the impact of time and cost of the project. It mainly focuses on baseline scheduling, updating progress with Actual dates and modeling delays through fragnets for Time Impact Analysis. Beside this, it specifies the causes of delays occurred in the project. Addition to this, the study evaluates how delays affect the project's timeline, critical path, and float. It also includes a cost analysis to assess the financial impact of schedule changes, considering direct and indirect costs. Finally, the work highlights how effective scheduling and resource management contribute to better project control and overall lifecycle efficiency.

3.0 METHODOLOGY

3.1 Collection of data and study :-

1. Data Collection and Baseline Development.
2. Schedule Updating and Delay Event Identification.
3. Delay Modeling Using Fragnets.
4. Rescheduling and Impact Analysis.
5. Development of Results and Graphical Analysis.
6. Cost and Time Impact Comparison and Conclusion.

3.2. Schedule Variation

3.2.1 Importing Project Schedule in Primavera P6

Importing a schedule into Primavera P6 is the first and most important step in making sure a project schedule is correct. Whether the schedule was made in Primavera or another tool like Microsoft Project or Excel, it needs to be moved into P6 using file types that are supported, such as .xer, .xml, or .xls/.xlsx. This process is important because if any data is lost or changed during the import, it can harm the whole project plan. The main goal when importing is to keep the schedule's structure and rules exactly as they were. That means keeping the Work Breakdown Structure (WBS), all activity names and numbers, how long each activity takes, how activities are connected, milestones, any time limits, and which calendar is used. For instance, if the type of activity connection, like Finish-to-Start or Start-to-Start, or the time gap between tasks is changed or lost during import, the schedule's logic and the critical path might not be right. Once the schedule is imported, it's important to check everything carefully to make sure it's exactly as planned. The WBS should be set up correctly, all activities and milestones must be there and in the right group, and the way activities are connected should match the original plan. Calendar settings are also important because changing them can shift the dates of activities and affect the project timeline.

3.2.2 Verification of Baseline Logic, Calendar Accuracy, and Resource Assignments

This part is the most detailed and technical part of checking the schedule. It involves making sure the schedule makes sense logically, has the right time frames based in calendars and that the resources assigned are realistic, enough and do not go over the allowed limits.

a. Verification of Baseline Logic

The checking of basic logic, correct calendar dates, and right resource assignments is one of the most detailed parts of checking a schedule in Primavera P6. It makes sure that the schedule can be used as a dependable plan and control tool. First, the basic logic needs to be checked to make sure the order and connections between tasks are correctly set. These connections decide how the project moves forward and help P6 figure out when tasks start and end, how much time is extra, and which tasks are on the critical path. Mistakes like missing links, tasks going in the wrong order, connections that loop back, or tasks that do not have a proper end can mess up the schedule. This can create wrong extra time values or a messed-up critical path. Making sure the logic is correct helps in finding the critical path clearly, which is important to know which tasks affect the total time of the project.

b. Calendar Accuracy

Calendars in Primavera P6 help manage how time is used across all project tasks. They show which days are workdays, which are not (like weekends, holidays, or planned shutdowns), and how many hours are worked each day. P6 lets you use a few types of calendars: - Global Calendars: Used in all projects in the database. - Project Calendars: Made for a specific project. - Resource Calendars: Assigned to individual resources and can overwrite the activity calendar in some setups. When checking a schedule, it is important to make sure that each task is linked to a calendar that matches the real working environment. For example, if a project is meant to work 6 days a week with 10-hour shifts, using a standard 5-day, 8-hour calendar will cause wrong start and end dates, incorrect time lengths, and wrong extra time values. Calendars also need to include non-working days like national holidays, religious holidays, planned factory stops, or environmental limits (such as not working during monsoon season or freezing weather). If these are not included, tasks might be scheduled during times when they can't be done, which gives unrealistic timelines. One thing to check is calendar consistency. If some tasks use a 7-day calendar and others use a 5-day calendar without reason, it can mess up the whole schedule. This might cause uneven extra time, wrong early and late dates, or change the project's total time unnaturally. So, calendars need to not just be right on their own, but also match each other across the whole project to keep the schedule accurate and dependable.

c. Resource Assignments

Resources in Primavera P6 are important parts that make a schedule workable, not just a theory. Resources are divided into three types: - Labor: People like electricians, welders, or project managers. - Non-Labor: Tools like cranes or generators. - Material: Things like steel or concrete. Each task should be checked to make sure the right type of resource is assigned. For instance, a task named "Electrical Rough-In" should have electricians, not general workers or equipment operators. One key part of checking resources is making sure there is no over-allocation. Over-allocation happens when a resource is scheduled to work more hours than they are available in a period. P6 gives charts and graphs to find these overloads. If not fixed, over-allocation can lead to impossible

schedules, delays, and overworked staff. It can also raise costs due to overtime, extra shifts, or hiring more workers. Also, resource availability must match the calendar for the task. If a resource uses a 5-day calendar but the task has a 7-day one, the system might plan unrealistic progress. It is also important to include known absences, leave days, or maintenance times for equipment when assigning resources.

3.3. Schedule Updating

Schedule updating is a critical component of project schedule management, ensuring that the project timeline remains accurate and reflects the actual progress of work. This step involves incorporating real-time data into the project schedule, which enables effective monitoring, forecasting, and decision-making.

3.4. Delay Event Modelling (Fragnet Creation)

Identifying the main reasons for delays is the first important step in creating a fragnet—a specific part of the project schedule used to look at how certain delays affected the project. This step helps create a clear and strong delay analysis by finding out the real causes and types of problems that slowed things down. It needs a team effort from several people involved in the project, like the project controls team, construction management, and those handling contracts. Delays can come from many different sources, and each has different effects on who is responsible and how much damage was done. Owner-related delays are quite common and can include things like late design approvals, slow decisions, changes to the work plan, or delays in getting important documents. These delays usually have legal effects and might give the project team a chance to get more time or extra money. On the other hand, delays from the contractor can be because of not enough workers, broken equipment, poor planning, or bad coordination on the job site. It is very important to know if delays were under the contractor's control, especially when deciding who is to blame. Another type of delay can come from third parties, such as subcontractors, suppliers, or service providers. For example, a delay in connecting utilities because of problems coordinating with a local authority, or a supplier not delivering materials on time, can affect many parts of the project. Force majeure events like heavy weather, pandemics, or sudden new rules can also cause big, unexpected delays that neither the owner nor the contractor can control. To properly find and prove these delay events, a lot of project records need to be reviewed. These include daily site logs, which keep track of what is happening on the job each day; progress reports, which give updates on the project's status; and RFIs (Requests for Information), which can show communication problems or unclear design details. Change orders and non-conformance reports (NCRs) show where the project strayed from the original plan, while meeting minutes can show decisions or discussions that slowed the project down. By looking at all these documents, the team can make clear timeline of when delays happened, what caused them, and how they affected the project.

3.4. Time Impact Analysis

Time Impact Analysis (TIA) is a method used in project planning that helps understand how delays affect when a project finishes and which activities are most important. It is commonly used in construction and project management and is supported by groups like AACE International and the Society of Construction Law. TIA is considered reliable and helpful, especially when proving delays or asking for more time. To start, you pick a project schedule that shows the project's state right before the delay happened. This helps set a clear starting point for the analysis, so changes after the delay do not affect the results. This point in time lets you focus only on the delay's effects. Next, you add a fragnet to the schedule. A fragnet is a group of activities that show what caused the delay, how long it lasted, and how it disrupted the project. These activities are linked to the existing tasks in the schedule, showing how the delay affects ongoing and future work. This makes the impact of the delay clear in the overall plan. Then, the schedule is recalculated using the Critical Path Method in Primavera P6. This process updates the start and end dates of all tasks, the amount of float, and the critical path. This helps show how the delay affects the project timeline and changes the finish date. After the schedule is adjusted, the analyst compares the original finish date with the new one. This shows how much the delay has pushed back the project or changed the float. It also shows how important milestones are affected, which helps understand the risk and flexibility of the schedule.

3.5. Rescheduling and Impact Analysis

This stage focuses on doing a detailed Time Impact Analysis (TIA) in Primavera P6 to see how certain delay events affect the whole project schedule. The process starts after the delay events, which are shown as fragnets or extra activities, are added to the project timeline. The main job here is to reschedule the whole project using the Critical Path Method (CPM). This method recalculates all the activity dates and related schedule information to include the new delays. In Primavera P6, you do this by pressing the F9 key or choosing the Schedule option, which starts the software's scheduling engine.

3.6. Cost Impact

Once the delay events have been identified and modeled into the schedule (as fragnets), and the impacted schedule has been rescheduled using the Critical Path Method (CPM), it becomes possible to quantitatively assess the time impact. This involves comparing Baseline Project Duration (unimpacted schedule) and Revised/Impacted Duration (after inserting delay events). The difference in project completion dates reflects the actual time delay due to disruptions such as labour strikes, material shortages, weather events, or design changes. This delay is then evaluated in terms of cost implications, which may include Direct Costs i.e. Additional labour wages, extended equipment rentals, site overheads, and supervision costs for the extended period. Indirect Costs means Loss of productivity, inflationary effects on materials, penalty clauses, or opportunity costs due to late project handover and Client and Contractor Costs are Delay-related claims from contractors or liquidated damages applied by clients.

4.0 Experiments

4.1 Create a Copy of the Main Project:

- Go to the Enterprise option and select projects. The list of all the projects will appear.
- Copy the main project and paste all the contents such as WBS, Resources, Calendar, etc.
- Rename the copied project.as Time Impact.



Fig 4.1- Creating Copy of Main Project

4.2. Maintain and Assign a Baseline:

- For newly copied project it is must to create a baseline. For that:
- Go to: Project and select Maintain Baseline By clicking on Maintain baseline a wizard will pop-up which indicates to create a new baseline
- By clicking on Maintain baseline a wizard will pop-up which indicates to create a new baseline.
- Now click on add button and another window will appear upon which a copy should be saved as the current project for new Baseline.
- Now Assign the Project Baseline Primary Baseline as Time Impact Analysis B1 and then click Ok.

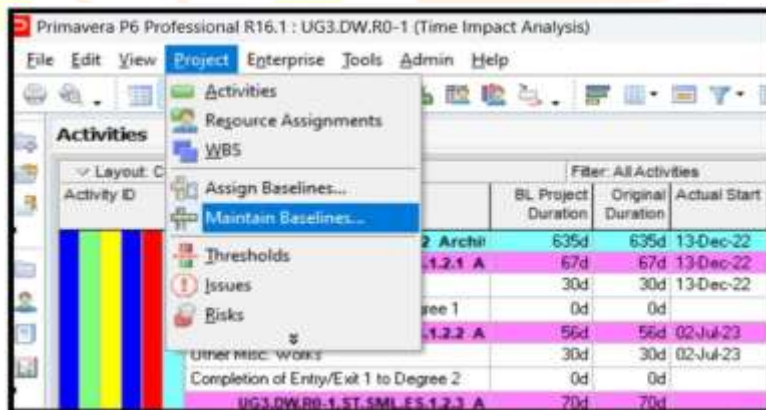


Fig 4.2- Maintaining Baseline

4.3. Create Fragnets:

- Go to Enterprise Option and Select User Defined Fields
- Now click add button for User Defined Field and rename the title as Contractor delay and select data type as Start date.
- Now create another User Defined Field and rename it as Contractor Delay and select data type as Finish date.



Fig. No. 4.3-User Defined Fields

4.4 Customization of Columns:

Customization of Column means to add the columns in the activity table to schedule the delayed dates.

- Select the Column Tab in the tool bar and a window will be displayed. Select User Defined in Available options.
- Now add the Contractor Delay Start and Finish to the right side i.e. to the selected options by moving the arrows given in the middle of both the tables. Then select Apply and click OK.

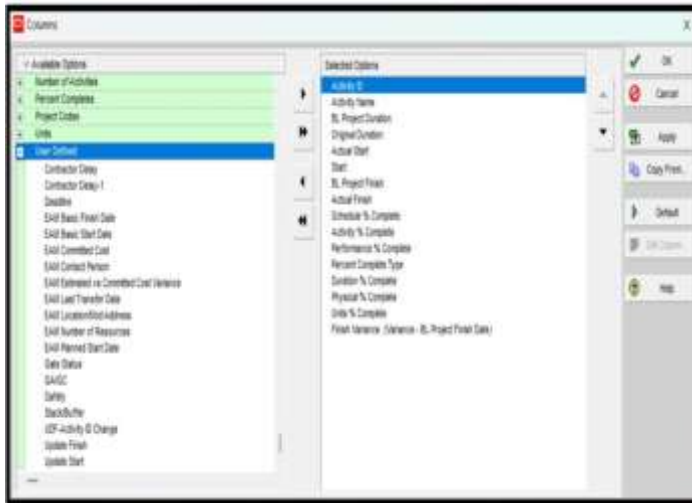


Fig. 4.4- Customization of Columns in Activity Table

4.5 Addition of Bars in Gantt Chart:

- To add a Bar in the Gantt Chart, go to Bars tab in the Tool bar.
- A window will be displayed upon which click Add button placed on the right side of the window.
- Now add a bar and rename the title of Bar as Contractor Delay.
- In Timescale select User date, with that it will automatically select User Start date and User Finish date.
- Now in preview change the colour of the bar so that the fragnets can be easily visible in the Gantt chart.
- Select Apply and then click OK.

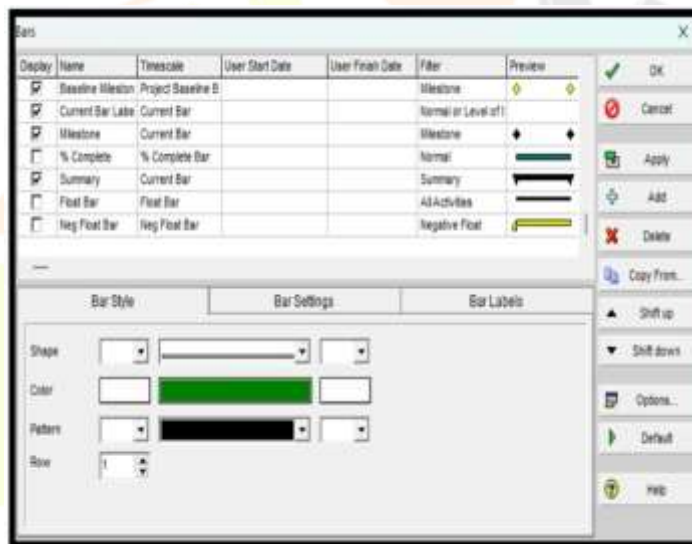


Fig no. 4.5- Addition of Bars in the Gantt Chart.

4.6 Addition of Fragnets:

- To add fragnets to the current activities, go to View tab and select show on bottoms and click on Detail tab.
- Now select the activity and go to detail tab. In detail tab select status button and go to start dates and finish dates.
- Now select the actual start date and finish date of the specific activity.
- Now set the dates for delay event such as Delay Start and Delay finish.
- By doing so the fragnet will appear on the Gantt Chart.

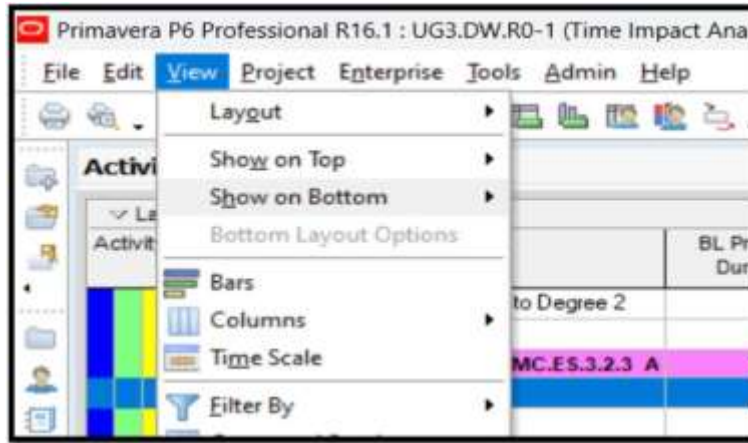


Fig no. 4.6- View option in Tool Bar.

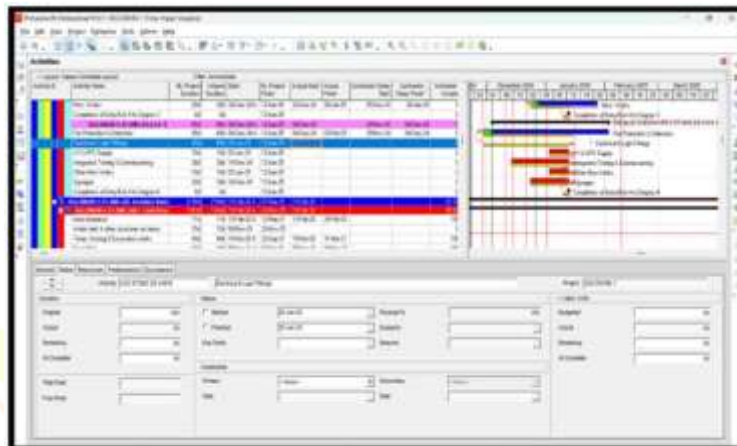


Fig no. 4.7- Addition of Fragment.

4.7 Time Impact Analysis:

- For Time impact go to the Column bar and select Schedule % complete, Performance % complete, Unit % complete, Activity percentage complete, etc.
- Now the actual duration, variance can be determined from the table.
- Also, the delay or time impacted on the project can be clearly seen from the activity table.

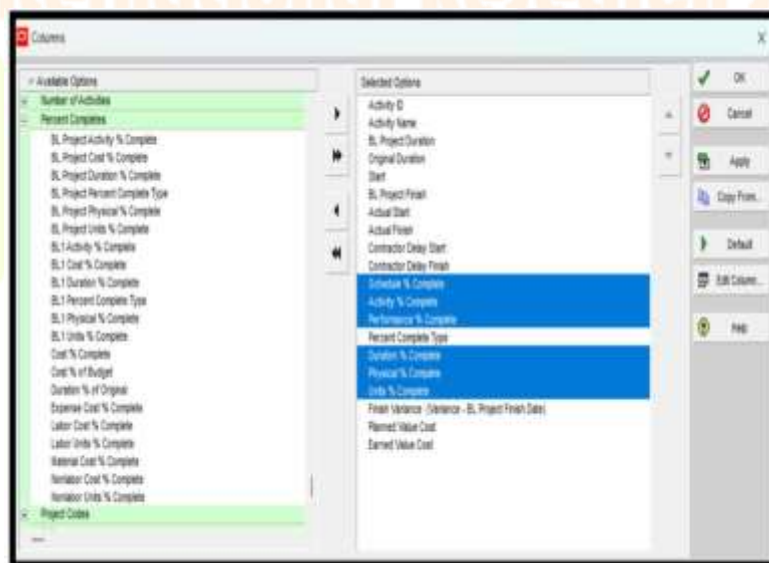


Fig no. 4.8- Addition of Percent Completes in Columns.

4.8 Cost Impact Analysis:

- For Cost Impact analysis go to the Column bar and select Earned value.
- From Earned Value list select Earned Value Cost and Planned Value Cost and then apply and click Ok.
- Now both the columns will be added in the activity table. And both the costs can be determined from the table.

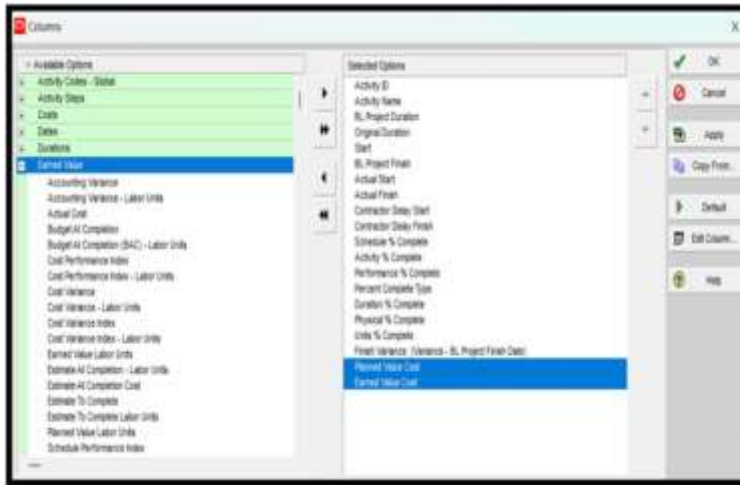


Fig no. 4.9- Addition of Planned Value and Earned Value in the Columns.

4.9. Comparison of Planned value and Earned Value:

- To compare the cost go to view tab select show on bottom and click on Activity Usage.
- A line graph will appear on the bottom layout from which the increased cost will be determined.

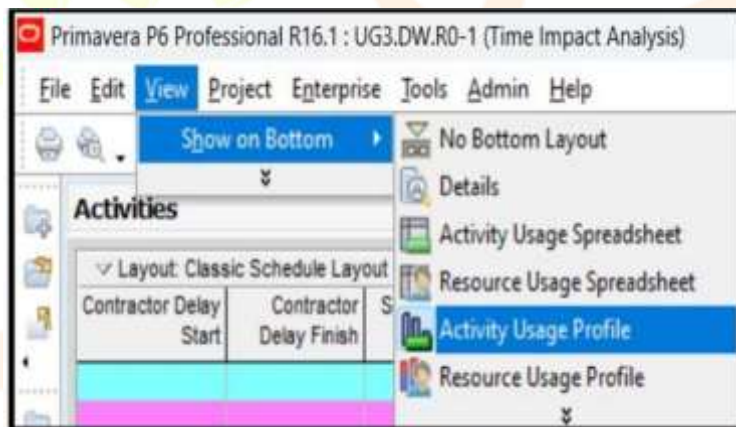


Fig no. 4.10 -Activity Usage Profile for Earned Value

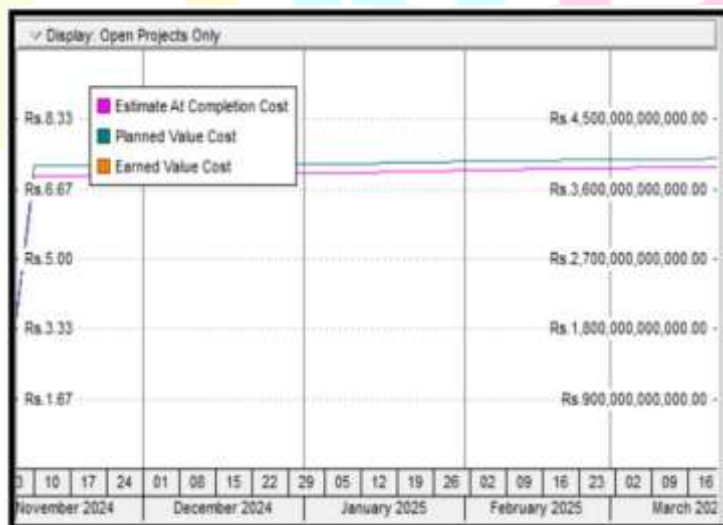


Fig no. 4.11- Earned Value Graph

5.0 RESULTS AND DISCUSSION

The use of Primavera P6 in a construction project gave valuable lessons on how modern project management tools can improve schedule control, delay analysis, and cost prediction. At first, the project schedule was imported and checked in Primavera, keeping all the details like the Work Breakdown Structure, logic links, calendars, and resource information. This careful check set up the project for accurate tracking and future analysis. As the project moved forward, real data such as start and finish dates and how much work was done was regularly added.

These updates showed differences between what was planned and what happened. This monitoring showed that several delays, both from outside and inside the project, were causing problems. These delays, like waiting for permits, missing materials, and bad weather, were handled by using fragnets. Fragnets are small parts of a schedule added right before a delay happens to show how it affects the timeline. Once the fragnets were added, the schedule was changed again using the Critical Path Method (CPM) to see how each delay affected the project.

This analysis found that the total delay added, pushing the project forward its original finish date. The critical path was also changed, and some activities had much float time. This showed not only how the delays affected the schedule but also pointed out possible risks in other parts of the project. Overall, using Primavera P6 was a strong way to manage complex construction schedules, especially when delays are common. It helped with better planning and tracking, and gave clear, backed-up information on delays and their effects on time and cost. The study shows that using Primavera P6 and Time Impact Analysis can improve transparency, help make better decisions, and support discussions about claims and time extensions in contracts.

6.0 ECONOMIC AND LIFE CYCLE ASSESSMENT

In the realm of construction project management, the assessment of economic performance and lifecycle implications is critical not only for evaluating immediate project costs but also for understanding the long-term value, efficiency, and sustainability of the project. This thesis, using Primavera P6, facilitated not only detailed scheduling and delay analysis but also provided a framework to assess the economic efficiency and lifecycle considerations of the construction process. From an economic standpoint, the analysis revealed the direct and indirect financial impacts of project delays. As delay events were modeled and integrated into the schedule, it became evident that time overruns carried substantial cost implications. These included extended labour charges, prolonged equipment rentals, increased site management costs, and potential penalties due to breach of contractual deadlines. Primavera P6's cost-loading and resource analysis capabilities allowed for a quantifiable assessment of these financial burdens. As delay durations increased, the extended overhead costs and inflationary effects on material and labour rates significantly affected the overall project budget, proving that time management is inherently tied to economic performance. Furthermore, the study examined mitigation strategies such as crashing and fast-tracking. These options, while successful in recovering time, came with additional costs in the form of overtime pay, expedited procurement, and reduced productivity. Thus, the economic assessment clearly showed that while mitigation may provide schedule relief, it requires careful financial justification. Primavera P6 allowed these scenarios to be simulated and evaluated before implementation, offering stakeholders data-driven insights into the cost benefit trade-offs of corrective measures.

In terms of lifecycle assessment, the project was viewed not merely as a set of activities to be completed, but as part of a broader system that includes design, construction, operation, maintenance, and eventual decommissioning. The scheduling and resource planning functions in Primavera P6 supported this view by emphasizing long-term project structure and resource allocation. Accurate scheduling contributed to improved build quality by ensuring that critical construction phases were not unduly rushed or compromised due to delays. This, in turn, has implications for the lifecycle durability of the built asset, as quality during construction directly affects future maintenance costs and operational efficiency.

In summary, the economic and lifecycle assessment conducted through this Primavera P6-based analysis demonstrated that effective schedule management is deeply intertwined with financial health and the long-term viability of construction projects. Delays introduce not only immediate cost implications but also compromise quality, increase lifecycle costs, and potentially disrupt future stages of asset use. Primavera P6 proved to be a valuable platform not only for short-term schedule control but also for long-range planning that considers the broader lifecycle and economic implications of every decision made during construction.

7.0 CONCLUSION

This study demonstrates the practical application and effectiveness of Primavera P6 as a powerful tool for planning, scheduling, monitoring, and analyzing delays in construction projects. From the initial phase of baseline development and validation, through ongoing progress updates, and ultimately to the modeling and assessment of delays using Time Impact Analysis (TIA), the study systematically applied a structured project management methodology grounded in industry standards. The process began with importing and validating a detailed project schedule in Primavera P6, ensuring the integrity of activity sequences, logical relationships, calendars, and resource assignments. Establishing a sound baseline was critical, as it became the benchmark against which all future progress and deviations were measured. The ability to set and manage this baseline within P6 allowed for clear comparisons between planned and actual performance, which is essential for accurate reporting and control.

As the project advanced, actual performance data was consistently fed into the system—recording activity start and finish dates, updating percentages complete. These updates enabled real-time visibility into project performance and allowed for early detection of variances. When delays occurred, they were carefully modeled using fragnets, which were inserted logically into the project schedule to simulate their impact on subsequent activities and overall project completion. This modeling provided a transparent and defensible method for understanding the specific cause-effect relationships between delay events and project outcomes.

Ultimately, the findings confirm that Primavera P6 is not only suitable for basic scheduling functions but is also highly effective for advanced delay analysis and decision support in construction project management. Its ability to integrate time, cost, and resource dimensions makes it a critical tool in managing complex projects. The study concludes that, when properly implemented, Primavera P6 significantly enhances a project team's ability to manage uncertainty, respond to delays proactively, and maintain control over both schedule and budget. Therefore, it is strongly recommended that construction firms adopt Primavera P6 as a standard part of their project planning and control toolkit. Its structured approach to delay analysis, supported by industry-recognized methods such as TIA, provides both operational and contractual advantages, making it an essential asset in modern construction project management.

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