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Research Article

Earned Value Management of a Villa Construction project using Primavera P6

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Abstract

The Indian construction industry has still not recovered from the effects of demonetization and it has resulted in abrupt stoppage of construction work by many small and medium construction enterprises. Now the ensuing Covid-19 pandemic has brought the industry to a standstill and its impacts are yet to be analyzed. Effective project management is thus the need of the hour and the planning has to ensure the optimum use of budget and resources without compromising the quality of construction. Small construction enterprises in India solely depend on project managers to execute the design and do not invest in proper planning software. This sometimes can result in improper decision making, irregular scheduling, poor handling of the project which ultimately results in increased expenditure and wastage of available resources. To reduce such discrepancies, an effective tool called Primavera P6 is introduced to help optimize the planning and scheduling process for construction activities. This will help small construction enterprises accurately estimate the duration of completion, resource allocation and the budget associated with any activity and reduce cost outruns, thereby increasing the overall efficiency of the project completion process. This study aims to review the existing methods of construction management in small and medium construction firms by using Primavera P6 and perform Earned Value Management on a villa construction project.

Keywords: *Planning, Scheduling, Primavera P6, Resource allocation, Earned Value Management*

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Introduction

Construction project management is the process or science of controlling the planning, design and execution of construction projects from start till completion. The significance of proper and precise construction project management is immense and unbounded. To avoid cost overruns, delays and conflict between the client and the contractor, construction project management is to be accurately performed. This is very important in small and medium scale construction firms where they cannot afford cost overruns, especially at a situation - like now - where the entire industry is down.

The impact of the Covid-19 pandemic on the infrastructure and construction sector in India has been extensive and damaging. The restrictions imposed by the government of India and various other state governments to control the spread and impact of the virus have extensively stunted work on projects and adversely impacted supply chains, plants, equipment, materials and manpower.

Potential recovery of the capital and work lost is contractually obligated and work needs to get back underway as soon as possible. Stressful situations like these only serve to further the workload on construction planners who are already overworked in trying to utilize the resources available for the project effectively. Relying on intuition, like a lot of smaller construction firms in India do, during unprecedented times like this can be catastrophic and hence should be avoided.

The main objectives of this study are:

- To highlight the importance of proper planning and monitoring of the work to be done
- To highlight the versatility and deftness of Primavera P6 as a project management tool
- Perform Earned Value Analysis for a villa construction project to backup conclusions

Methodology

This study mainly focuses on performing Earned Value Management (EVM) on a villa construction project and in effect highlighting the compactness and fluidity of Primavera P6.

Earned value management is a project management technique used to monitor and measure project performance against planned and actual parameters. Integrated systems involving scope, cost and progress of the project help the management team assess and measure the performance of the project under consideration.

Earned value management involves a cost performance baseline against which the progress and scope of the project are measured and defined. The said baseline thus acts as a sort of measuring stick which helps in lending perspective to the management team. The resulting analysis is done via several work performance enhancements involving several project influencing parameters like projected cost, actual cost, project time, etc.

Project Management hierarchy in Primavera P6

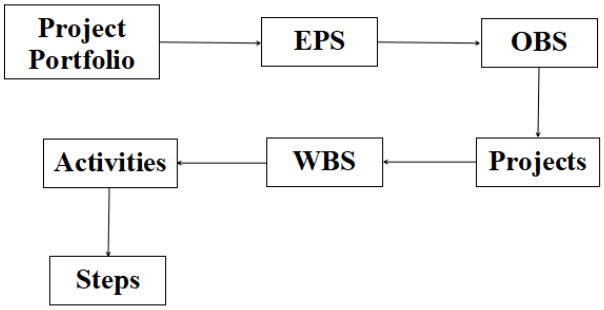


Fig 1. Hierarchy of project management

Project portfolio: is a collection of projects designed to facilitate viewing of multiple projects, one at a time. This helps in effective project management by grouping projects together to optimize the organizational output. Usually, a portfolio can be used to review the data and status information regarding organizational activities.

Enterprise Project Structure (EPS): represents the hierarchical structure of all projects in the organization. The EPS is the highest level of project management hierarchy and it can be subdivided into as many levels as needed to represent the entire work done by the organization.

Work breakdown structure (WBS): is an arrangement of the work to be done that divides the projects into discrete phases. This helps organize the project's total work into manageable sections.

Steps: are subsidiaries of project activities and are used to identify and report progress of an activity at different levels

Project methodology/Work plan

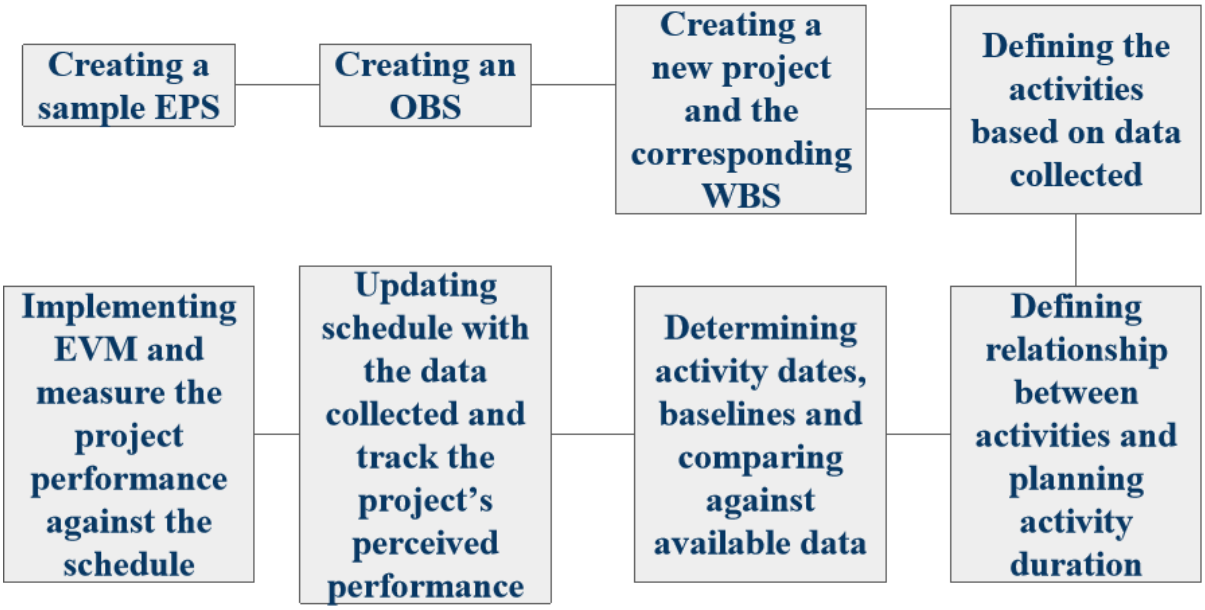


Fig 2. Work plan

Advantages of Earned Value Management system

- Helps clearly define scope of work to be done
- Establishes hierarchy of responsibility ensuring minimal missteps
- Provides novel method of integrating schedule, cost and scope
- Acts as a warning system in identifying potential problems
- Analyzes impact of known problems and helps manifest them in terms of cost and scope
- Establishes clear lines of communication across the managerial hierarchy
- Adds several welcome layers to project visibility

Case Study: Villa at ECR

This case study serves a purpose in substantiating our observations and further helped us understand the workings of project managers in medium industries. The structure under consideration is a villa located on the East Coast Road.

The villa was constructed from around April of 2019 to February of 2020 and just missed the pandemic by a month. The structure is a RCC framed structure with the roof around 11 feet tall and 5 inches thick and the lintel beam around 8 feet high. The type of foundation used was an isolated footing and 11 such trapezoidal column footings were used.

The land area of the plan is around 1580 sq-ft and the subsequent built-up area is around 3000 sq-ft.

Project	**Construction of a villa**
Location of site	**East Coast Road, Chennai**
Type of building	**Residential 4BHK**
Additional features	**Modular Kitchen**
Land area	**1580 sq-ft**
Built-up area	**3000 sq-ft**
Main wall	**9.5” thick**
Partition wall	**4.5” thick**

Table 1. Villa at ECR - Case study details

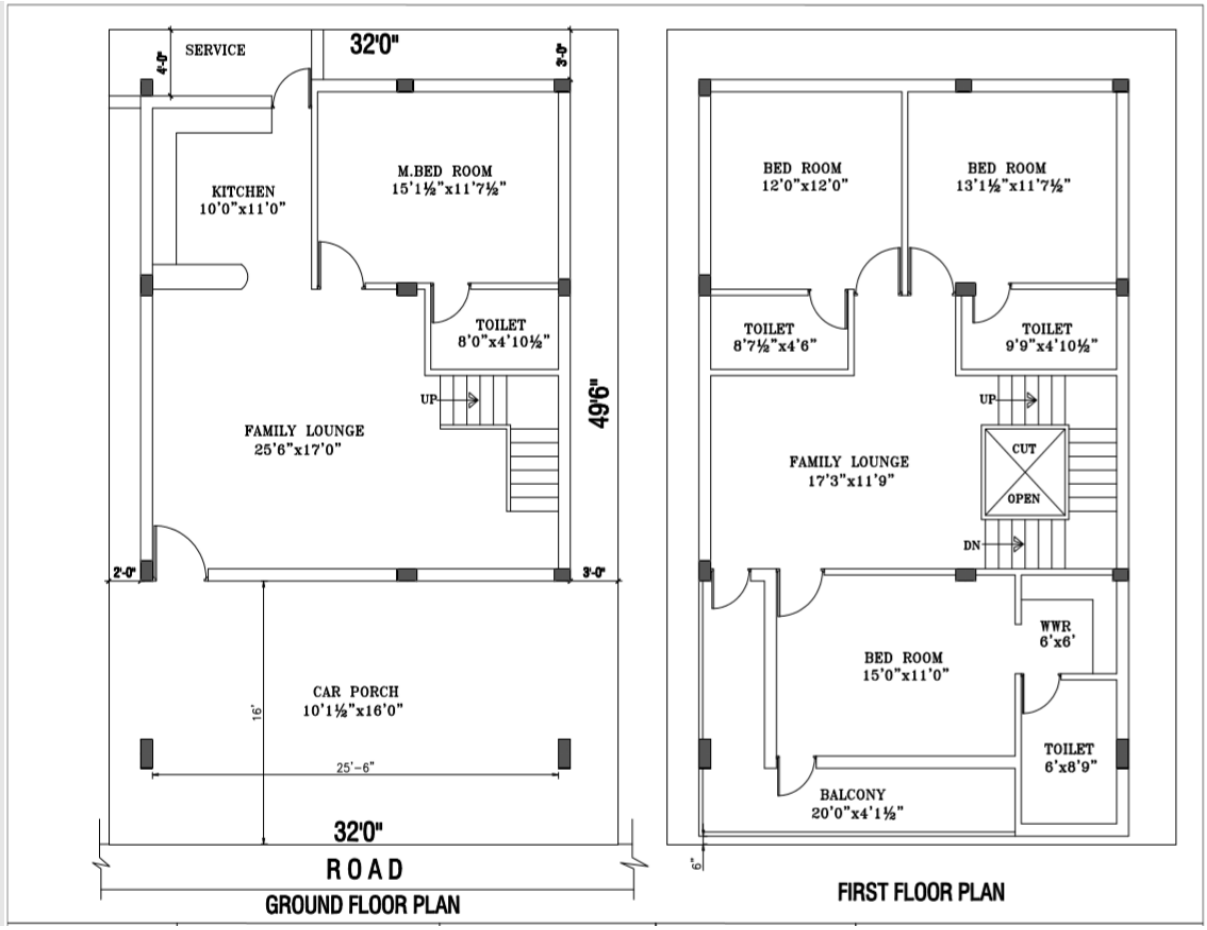


Fig 3. Floor plan of the Villa

Work done and results

- A *schedule* is first created to facilitate monitoring and reviewing of project activities
- To emulate structure of the contactor company, a temporary *EPS* was created in Primavera
- A corresponding *OBS* was then created to represent the hierarchy of responsibility for the project
- A *calendar* was then created which is assigned to the activities and resources to provide a timeline of the work to be done. Primavera P6 offers three types of calendars: g*lobal calendar, project calendar* and *resource calendar*. For this particular study we used the *6x9 global calendar,* which represents a 6-day week with 9 hours of work per day

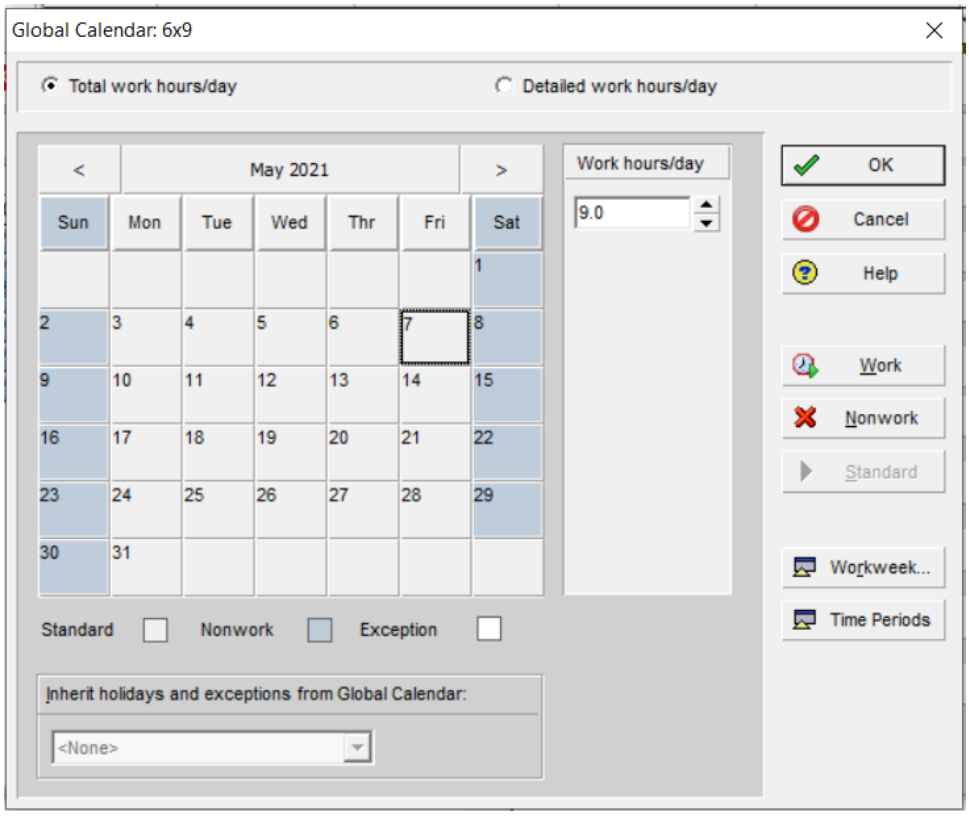


Fig 4. 6X9 Global calendar

- Then project itself was created with a *WBS* attached to it. Similarly, several WBS elements were created each providing its own depth in the form of activities and steps

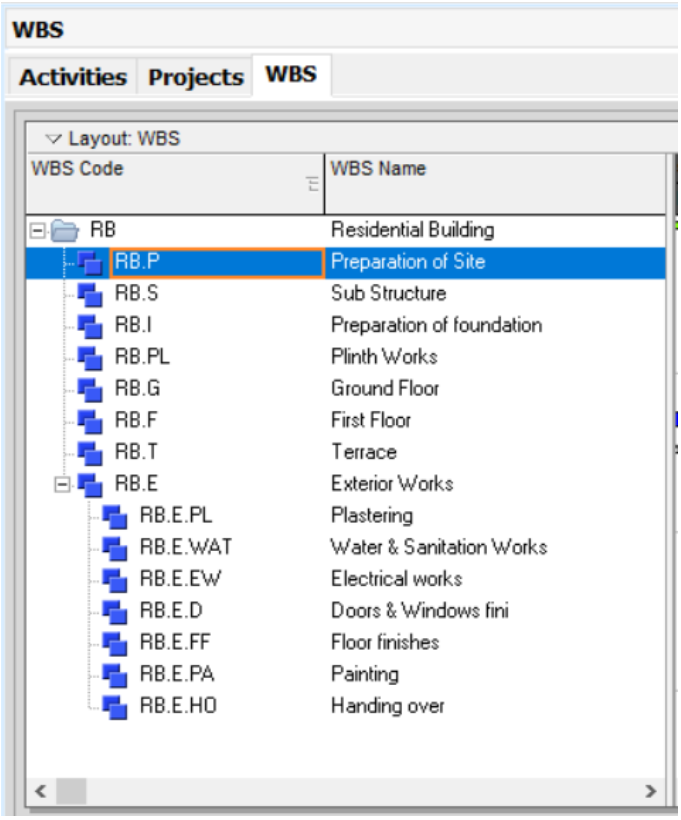


Fig 5. Project Work Breakdown Structure

- The aforementioned *activities* were then defined to represent the fundamental working elements of the WBS. Each activity comprised of an *activity name, activity ID, start* and *finish dates* and the corresponding *duration*, constraints in the form of *successor/predecessor relationships, resource values*, etc.

Activities

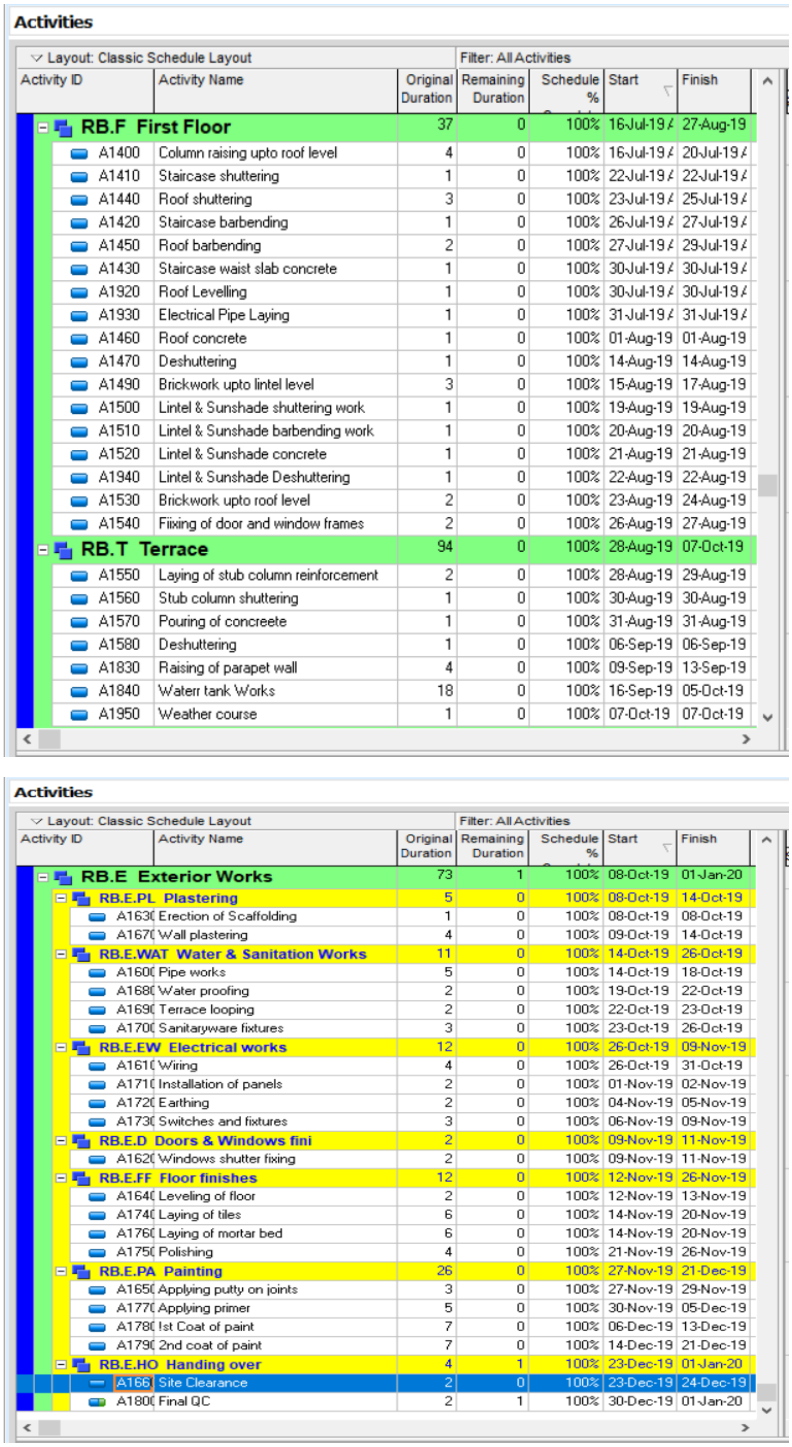
Layout: Classic Schedule Layout — Filter: All Activities

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule %	Start	Finish
RB	**Residential Building**	233	193	100%	04-Apr-19	01-Jan-20
RB.P	**Preparation of Site**	8	0	100%	04-Apr-19.	12-Apr-19.
A1000	Surveying	2	0	100%	04-Apr-19.	05-Apr-19.
A1010	Marking Boundaries	1	0	100%	06-Apr-19.	06-Apr-19.
A1170	Temporary Connection	2	0	100%	08-Apr-19.	09-Apr-19.
A1030	Temprorary Main gate and fencing	1	0	100%	10-Apr-19.	10-Apr-19.
A1020	Borewell	2	0	100%	11-Apr-19.	12-Apr-19.
RB.S	**Sub Structure**	6	0	100%	13-Apr-19.	19-Apr-19.
A1040	Column layout marking	2	0	100%	13-Apr-19.	15-Apr-19.
A1050	Excavation	3	0	100%	16-Apr-19.	18-Apr-19.
A1060	Preparation of PCC works	1	0	100%	19-Apr-19.	19-Apr-19.
A1070	Soiling	1	0	100%	19-Apr-19.	19-Apr-19.
A1090	Pouring of PCC	1	0	100%	19-Apr-19.	19-Apr-19.
RB.I	**Preparation of foundation**	9	0	100%	23-Apr-19.	02-May-19
A1110	Layout Marking	1	0	100%	23-Apr-19.	23-Apr-19.
A1120	Laying of reinforcement	1	0	100%	24-Apr-19.	24-Apr-19.
A1130	Shuttering for Matt foundation and pou	1	0	100%	25-Apr-19.	25-Apr-19.
A1140	Shuttering for column	1	0	100%	26-Apr-19.	26-Apr-19.
A1150	Pouring of concrete	1	0	100%	27-Apr-19.	27-Apr-19.
A1810	Deshuttering	1	0	100%	29-Apr-19.	30-Apr-19.
A1860	Foundation column	2	0	100%	30-Apr-19.	01-May-19
A1870	Soil refilling	1	0	100%	02-May-19	02-May-19

Activities

Layout: Classic Schedule Layout — Filter: All Activities

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule %	Start	Finish
RB.PL	**Plinth Works**	26	0	100%	03-May-19	01-Jun-19
A1160	Setting up level for plinth	1	0	100%	03-May-19	03-May-19
A1180	Laying of PCC	1	0	100%	04-May-19	04-May-19
A1190	Laying of reinforcement	2	0	100%	06-May-19	07-May-19
A1200	Side shuttering for beams	2	0	100%	08-May-19	09-May-19
A1210	Pouring of concrete	1	0	100%	10-May-19	10-May-19
A1220	Deshuttering	1	0	100%	17-May-19	17-May-19
A1230	Rising brickwork till floor level	2	0	100%	18-May-19	20-May-19
A1240	Backfilling upto plinth beam bottom	1	0	100%	21-May-19	22-May-19
A1250	Compaction of soil	3	0	100%	22-May-19	24-May-19
A1260	Laying of PCC	1	0	100%	25-May-19	25-May-19
A1880	Septic tank and sump works	6	0	100%	27-May-19	01-Jun-19
RB.G	**Ground Floor**	37	0	100%	03-Jun-19	15-Jul-19 A
A1300	Column raising upto roof level	4	0	100%	03-Jun-19	06-Jun-19
A1270	Staircase shuttering	1	0	100%	07-Jun-19	07-Jun-19
A1310	Roof shuttering	3	0	100%	08-Jun-19	11-Jun-19
A1280	Staircase barbending	1	0	100%	12-Jun-19	12-Jun-19
A1320	Roof Barbending	2	0	100%	13-Jun-19	14-Jun-19
A1290	Staircase waist slab concrete	1	0	100%	14-Jun-19	14-Jun-19
A1890	Roof levelling	1	0	100%	15-Jun-19	15-Jun-19
A1900	Eletrical pipe laying	1	0	100%	15-Jun-19	15-Jun-19
A1330	Roof Concrete	1	0	100%	17-Jun-19	17-Jun-19
A1340	Deshuttering	1	0	100%	01-Jul-19 A	01-Jul-19 A
A1360	Brickwork upto lintel level	3	0	100%	02-Jul-19 A	04-Jul-19 A
A1370	Rubble leveling	1	0	100%	05-Jul-19 A	05-Jul-19 A
A1380	Lintel & Sunshade shuttering work	1	0	100%	06-Jul-19 A	06-Jul-19 A
A1390	Lintel & Sunshade barbending work	1	0	100%	08-Jul-19 A	08-Jul-19 A
A1480	Lintel & Sunshade concrete	1	0	100%	09-Jul-19 A	09-Jul-19 A
A1850	Lintel & Sunshade deshuttering	1	0	100%	10-Jul-19 A	10-Jul-19 A
A1820	Brick work till roof level	2	0	100%	11-Jul-19 A	12-Jul-19 A
A1910	Fixing of door and window frames	2	0	100%	13-Jul-19 A	15-Jul-19 A



Activities

Layout: Classic Schedule Layout — Filter: All Activities

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule %	Start	Finish
RB.F	First Floor	37	0	100%	16-Jul-19 A	27-Aug-19
A1400	Column raising upto roof level	4	0	100%	16-Jul-19 A	20-Jul-19 A
A1410	Staircase shuttering	1	0	100%	22-Jul-19 A	22-Jul-19 A
A1440	Roof shuttering	3	0	100%	23-Jul-19 A	25-Jul-19 A
A1420	Staircase barbending	1	0	100%	26-Jul-19 A	27-Jul-19 A
A1450	Roof barbending	2	0	100%	27-Jul-19 A	29-Jul-19 A
A1430	Staircase waist slab concrete	1	0	100%	30-Jul-19 A	30-Jul-19 A
A1920	Roof Levelling	1	0	100%	30-Jul-19 A	30-Jul-19 A
A1930	Electrical Pipe Laying	1	0	100%	31-Jul-19 A	31-Jul-19 A
A1460	Roof concrete	1	0	100%	01-Aug-19	01-Aug-19
A1470	Deshuttering	1	0	100%	14-Aug-19	14-Aug-19
A1490	Brickwork upto lintel level	3	0	100%	15-Aug-19	17-Aug-19
A1500	Lintel & Sunshade shuttering work	1	0	100%	19-Aug-19	19-Aug-19
A1510	Lintel & Sunshade barbending work	1	0	100%	20-Aug-19	20-Aug-19
A1520	Lintel & Sunshade concrete	1	0	100%	21-Aug-19	21-Aug-19
A1940	Lintel & Sunshade Deshuttering	1	0	100%	22-Aug-19	22-Aug-19
A1530	Brickwork upto roof level	2	0	100%	23-Aug-19	24-Aug-19
A1540	Fiixing of door and window frames	2	0	100%	26-Aug-19	27-Aug-19
RB.T	Terrace	94	0	100%	28-Aug-19	07-Oct-19
A1550	Laying of stub column reinforcement	2	0	100%	28-Aug-19	29-Aug-19
A1560	Stub column shuttering	1	0	100%	30-Aug-19	30-Aug-19
A1570	Pouring of concreete	1	0	100%	31-Aug-19	31-Aug-19
A1580	Deshuttering	1	0	100%	06-Sep-19	06-Sep-19
A1830	Raising of parapet wall	4	0	100%	09-Sep-19	13-Sep-19
A1840	Waterr tank Works	18	0	100%	16-Sep-19	05-Oct-19
A1950	Weather course	1	0	100%	07-Oct-19	07-Oct-19

Activities

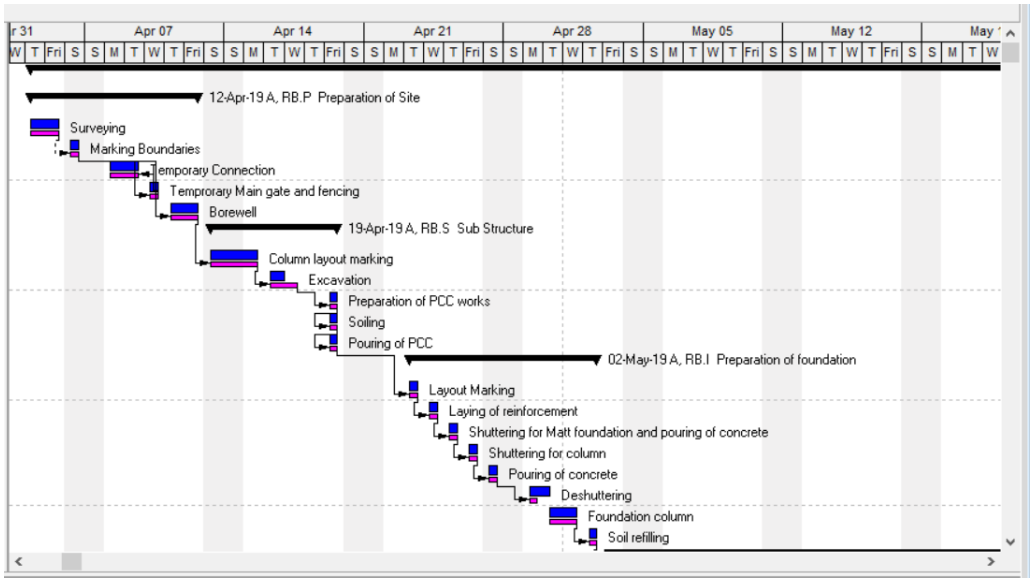
Layout: Classic Schedule Layout — Filter: All Activities

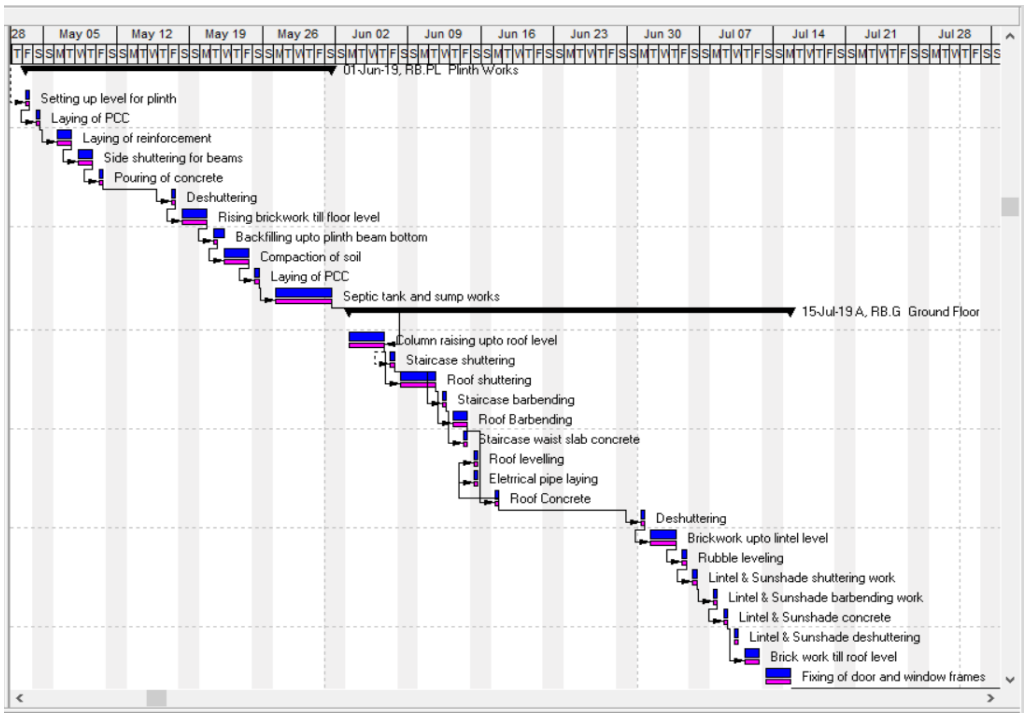
Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule %	Start	Finish
RB.E	Exterior Works	73	1	100%	08-Oct-19	01-Jan-20
RB.E.PL	Plastering	5	0	100%	08-Oct-19	14-Oct-19
A163(	Erection of Scaffolding	1	0	100%	08-Oct-19	08-Oct-19
A167(	Wall plastering	4	0	100%	09-Oct-19	14-Oct-19
RB.E.WAT	Water & Sanitation Works	11	0	100%	14-Oct-19	26-Oct-19
A160(	Pipe works	5	0	100%	14-Oct-19	18-Oct-19
A168(	Water proofing	2	0	100%	19-Oct-19	22-Oct-19
A169(	Terrace looping	2	0	100%	22-Oct-19	23-Oct-19
A170(	Sanitaryware fixtures	3	0	100%	23-Oct-19	26-Oct-19
RB.E.EW	Electrical works	12	0	100%	26-Oct-19	09-Nov-19
A161(	Wiring	4	0	100%	26-Oct-19	31-Oct-19
A171(	Installation of panels	2	0	100%	01-Nov-19	02-Nov-19
A172(	Earthing	2	0	100%	04-Nov-19	05-Nov-19
A173(	Switches and fixtures	3	0	100%	06-Nov-19	09-Nov-19
RB.E.D	Doors & Windows fini	2	0	100%	09-Nov-19	11-Nov-19
A162(	Windows shutter fixing	2	0	100%	09-Nov-19	11-Nov-19
RB.E.FF	Floor finishes	12	0	100%	12-Nov-19	26-Nov-19
A164(	Leveling of floor	2	0	100%	12-Nov-19	13-Nov-19
A174(	Laying of tiles	6	0	100%	14-Nov-19	20-Nov-19
A176(	Laying of mortar bed	6	0	100%	14-Nov-19	20-Nov-19
A175(	Polishing	4	0	100%	21-Nov-19	26-Nov-19
RB.E.PA	Painting	26	0	100%	27-Nov-19	21-Dec-19
A165(	Applying putty on joints	3	0	100%	27-Nov-19	29-Nov-19
A177(	Applying primer	5	0	100%	30-Nov-19	05-Dec-19
A178(	1st Coat of paint	7	0	100%	06-Dec-19	13-Dec-19
A179(	2nd coat of paint	7	0	100%	14-Dec-19	21-Dec-19
RB.E.HO	Handing over	4	1	100%	23-Dec-19	01-Jan-20
A166	Site Clearance	2	0	100%	23-Dec-19	24-Dec-19
A180(	Final QC	2	1	100%	30-Dec-19	01-Jan-20

Fig 6. Project activities

- Relationship between activities then need to be assigned to form a project network which represent the flow of work to be done. Relationships can either be *finish to start*, *finish to finish*, *start to start* or *start to finish*, depending on the level of importance of each activity. Doing so helps identify *critical activities* and the *critical path* for the project
- A gantt chart is generated to represent the timeline of work to be done in the project. The Primavera P6 gantt chart helps us visualize the project's schedule and helps us

tabulate the start and finish time of the activities. This makes the schedule more flexible to work with





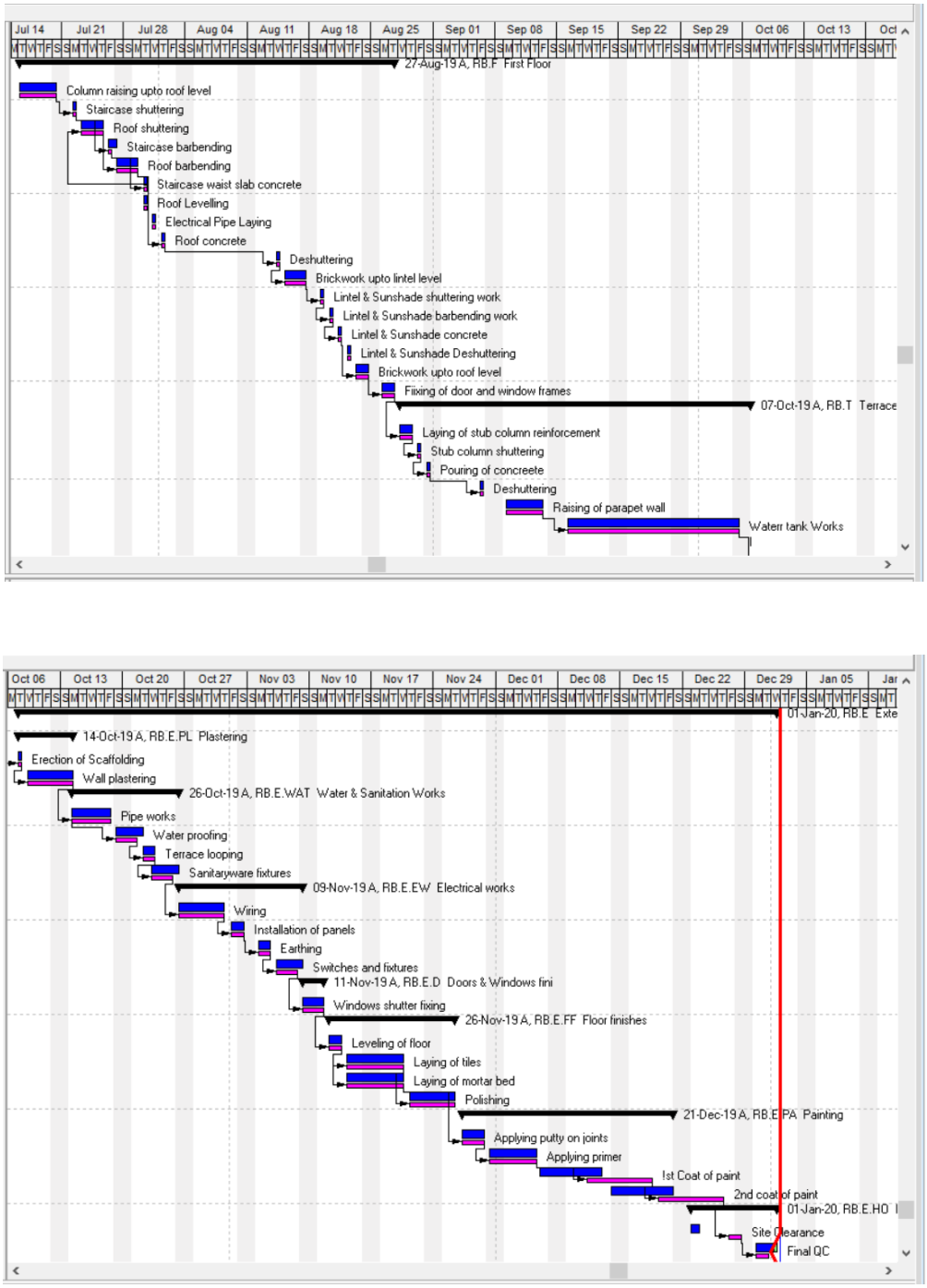


Fig 7. Project baseline

- Critical activities represent the activities which are mandatory to prevent the delay of the project. These activities must start and finish on time to ensure that the work stays on schedule
- The *planned duration* of the activities then needs to be entered. This usually depends on the activity and amount of the work represented by it. The *actual duration* will then be determined after the activity actually get completed
- This duration is dependent on the start and finish dates of the activity. Primavera offers four types of activity dates: *actual start*, *actual finish*, *planned start* and

planned finish. These also govern the relationship between various activities and interlink them together

- Primavera also offers *activity cost* parameters which define the costs incurred over the course of the completion of the activity
- Each activity further needs to have *resources* allocated to it to determine activity cost. In our study we divided known available resources into two types: labor and non-labor
- For example, a mason is a labor resource whereas a concrete vibrator is a non-labor resource
- Each of these resources have fixed rates of pay which determine the non-material cost incurred by the activity.

RESOURCE NAME	RESOURCE TYPE	RATE (COST/DAY)
MASON	LABOUR	RS. 850
MAZDOOR	LABOUR	RS. 700
MATE	LABOUR	RS. 650
BARBENDER	LABOUR	RS. 700
PAINTER	LABOUR	RS. 750
BHISTI	LABOUR	RS. 600
CARPENTER	LABOUR	RS. 700
PLUMBER	LABOUR	RS. 750
PLUMBER ASSISTANT	LABOUR	RS. 650
MIXER	NON LABOUR	RS. 1300
ELECTRICIAN	LABOUR	RS. 750
ELECTRICIAN ASSISTANT	LABOUR	RS. 650
MIXER OPERATOR	LABOUR	RS. 650
VIBRATOR	NON LABOUR	RS. 500

Table 2. Rate of allocated resources as per IS 7272:1974 and Delhi Analysis of Rates

- The resources were assigned to each activity based on the work done and in accordance with *IS 7272:1974* and *Delhi Analysis of Rates*. The structural details were procured from the firm and were used for assigning resources to each activity.
- As an example, during excavation the measurements are done in cubic meter where the length and breadth are taken from the structural drawings and a mean value of depth is used to calculate volume of excavations needed to analyze rate of resource

allocation. In the study under consideration five excavations of dimensions 1'x9" were done, four excavations of dimensions 1'3"x9" were done and finally two excavations of dimensions 1'9"x9" were done. Similarly, such calculations were done for estimating and assigning of resources to all other activities

- *Earned Value Analysis* is then performed where the actual cost of the project is compared against the budgeted cost with both time and scope as governing parameters. Performing EVM on a project can give us details on the budgeting and resource usage of the work done and analyze whether or not the work done is cost effective
- Schedule variance (SV): determines whether a project is behind or ahead of the schedule and is calculated by subtracting planned value from the earned value.

  Schedule variance = Earned value (EV) -Planned value (PV)
- Schedule performance index (SPI): indicates the efficiency with which the project team is using its time

  Schedule performance index = Earned value / Planned value
- Time estimates at completion (EAC): generates a rough estimate of when project will be completed

  Estimate at complete (EAC) = (BAC/SPI)/ (BAC/months)

  BAC = Budget at completion
- Cost variance (CV): indicates whether a project is under or over its planned budget

  Cost variance (CV) = Earned value (EV) - Actual cost (AC)
- Cost performance index (CPI): gives a clear indicator of the cumulative cost efficiency of the project

  Cost performance index (CPI) = Earned value (EV) / Actual cost (AC)

Conclusions

The progress of work done during the course of completion of a construction project can be measured and tracked by means of proper planning and scheduling. This allows project managers to assess the initial scope of the project and also measure the change in scope in case of any setbacks. Further a proper management system helps mitigate risks and ensures that the management team is always able to plan around any obstacle encountered.

The main focus of the study was to highlight the importance of said planning in construction projects and offer up Primavera P6 as an effective tool for project managers to exploit. This was achieved through extensive literature surveys and then a practical problem was undertaken using the software to show its versatility. Results of this report highlight the disadvantages of improper management systems (in SMEs) and the importance of efficient management software like Primavera.

Summary of results derived

- A total of 92 activities were mapped under work to be done for the project
- The project completion date according to the planned schedule was on 31st December, 2019
- The actual project was delayed for around 2 months and wrapped up on the 7th of February, 2020
- The budget allocated for one standalone 4BHK villa was valued around Rs. 60,00,000 as of 2019
- The cost of labour was calculated at around Rs. 13,11,933
- The Cost Performance Index of the project was around 0.46 indicating that the project was under budgeted. This is a direct consequence of lack of planning, monitoring and lack of consideration of miscellaneous constraints
- Proper delay analysis considerations were not under order and the ensuing delays are subject to proof. The team appears to have severely underestimated the unpredictability of the Chennai monsoon cycle thus resulting in overtime work
- Primavera P6 proves to be an efficient tool in aiding management of construction projects and helps immensely in monitoring and controlling the scope of work to be done

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