CHAPTER 1

A Comparative Study of Delay Analysis Methods

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ABSTRACT

Delays in construction projects remain one of the most persistent challenges affecting timely completion and cost efficiency. Accurate delay analysis is therefore crucial for identifying the causes and for forming appropriate corrective action plan. This research aims to conduct a comparative evaluation of five principal delay analysis methods—Time Impact Analysis (TIA), Impacted As-Planned Analysis, Time Slice Window Analysis, As-Planned versus As-Built Analysis, and Collapsed As-Built (But-For) Analysis. The study utilizes a real-world case of an industrial shed construction project located in Pune, India, where baseline scheduling and actual progress data are inputted in Microsoft Project (MSP). Each delay analysis method will be systematically applied to the same dataset to assess its suitability, accuracy, and cost implications. Through comparative interpretation, the research seeks to identify the most appropriate delay analysis technique for projects of similar scale and complexity. The findings are expected to contribute toward establishing a structured framework for selecting delay analysis methodologies in the Indian construction industry, thereby improving dispute resolution, project monitoring, and time management practices.

Keywords: Delay analysis, Cost overrun, Cost efficiency.

1.0 Introduction

1.1 General

"Delays," in the current context, refer to any slowing or postponement in the project timeline that has a significant impact on the project schedule, budget, and, in many cases, the relationships among the stakeholders. This problem is common in the construction industry and has severe economic and managerial implications (Gurpreet Singh, 2024).

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It has been found that a substantial quota of projects in construction industry is prone to delays, which in some cases may be minor but, in other cases, may be critical, thereby posing a threat to the successful completion of projects (Gurpreet Singh, 2024). The rising complexity of projects, especially in infrastructure projects, further increases susceptibility to such problems (Kwame B. O. Amoah, 2024).

In this regard, delay analysis has emerged as an important tool for analyzing delay effects, assigning liability, resolving disputes, and avoiding future delays. It helps in assigning liability and ensuring just compensation by analyzing project schedules systematically (Choosing a Delay Analysis Methodology, 2021). This paper presents a comparative analysis of the most popular delay analysis techniques that are often employed in practice, such as As-Planned vs. As-Built, Impacted As-Planned, Time Impact Analysis, Windows Analysis and Collapsed As-Built.

1.2 Delay analysis methods classification

Delay analysis may be defined as the process of assessing and measuring delays to ascertain their causes and effects. The Society of Construction Law Delay and Disruption Protocol outlines the most commonly applied techniques for delay analysis; these are the ones considered in this section.

1.2.1 Time Impact Analysis (TIA)

Time Impact Analysis (TIA) is a technique that takes into account every single delay event as it happens. The essence of this analysis is in determining the impact of every delay event on the project completion date by comparing the schedule before and after the insertion of the delay event (Construction Delays Analysis Methods, n.d.). TIA, therefore, is a technique that analyses delays one after the other. The information needed for this technique includes the original project schedule, periodic project schedule updates reflecting the project status, and information on every single delay event, including the date of occurrence, duration, and type (Choosing a Delay Analysis Methodology, 2021).

1.2.2 Impacted As-Planned Analysis

The Impacted As-Planned approach requires the incorporation of delay events into the original project schedule, to theoretically assess the effect of the delay events on the project completion date (Construction Delays Analysis Methods, n.d.). The approach is founded on a theoretical representation of how the project would have happened (Choosing a Delay Analysis Methodology, 2021). The data needed for this approach includes a logically related project schedule and data about the delay events.

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1.2.3 Time slice window analysis (windows analysis)

Time Slice Window Analysis, also known as Windows Analysis, divides the project timeline into smaller units called windows. For each window, the analyst determines the amount of delay that happened to the critical path during the window. This method provides a detailed insight into the delays that happen throughout the life cycle of the project (Choosing a Delay Analysis Methodology, 2021)To implement this method, you require an as-built schedule, the original baseline schedule, and updates for each window (Choosing a Delay Analysis Methodology, 2021).

1.2.4 As-Planned vs. As-Built Analysis

The As-Planned vs. As-Built Analysis is a simple technique that compares the original as-planned schedule with the actual as-built schedule to determine activities that began or completed later than scheduled (Construction Delays Analysis Methods, n.d.) (Choosing a Delay Analysis Methodology, 2021),It is a simple observational comparison between planned and actual performance (Types of Delay Analysis in Construction, 2021). The only information needed is as-planned and as-built schedule (Construction Delays Analysis Methods, n.d.). It is very flexible and has been widely used for retroactive analysis (Michaud, 2022). Nevertheless, it is less reliable for large projects, does not treat concurrent delays effectively, and is very sensitive to errors in the schedule (Choosing a Delay Analysis Methodology, 2021) (Lenehan, 2023).

1.2.5 Collapsed As-Built method

The Collapsed As-Built method, also referred to as "But-For" Analysis, is a retrospective analysis method that starts with the as-built schedule of the project. This method is founded on the idea of "virtually subtracting" the impact of delay events from the as-built schedule to arrive at the theoretical completion date if the delay events had not occurred (Construction Delays Analysis Methods, n.d.). The main data required for this method include the as-built schedule and data about the delay events to be eliminated.

1.3 AIM

To critically compare and evaluate the suitability, cost implications, and effectiveness of various delay analysis methods in the construction industry, with the goal of identifying best practices that optimize cost and time management.

1.4 Research objectives

- To understand and perform a comprehensive study on various types of Delay Analysis Methods.

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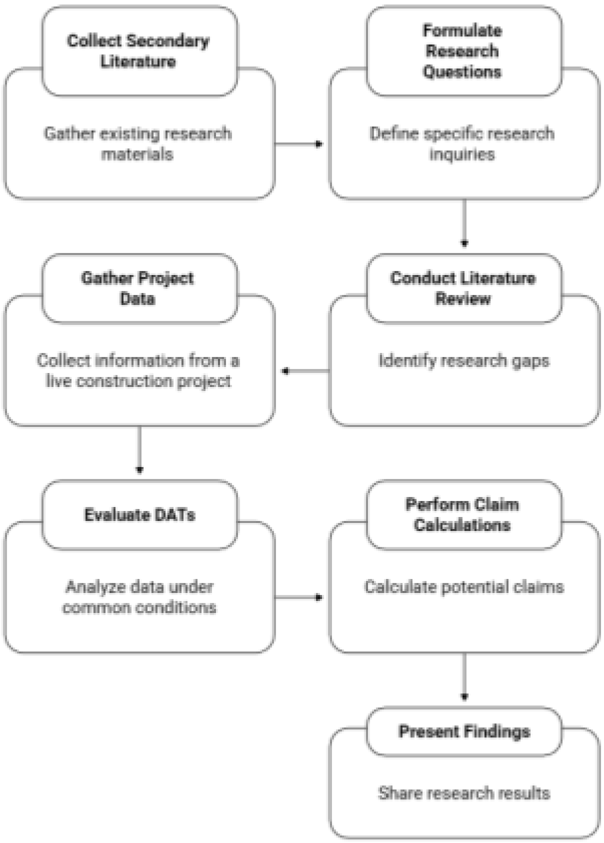
- Identifying commonly used delay analysis techniques in the Indian construction industry.
- To Identify best practices and offer practical recommendations for industry professionals.

2.0 Literature Review

Construction project delays remain an issue globally. Various studies have investigated the factors, impacts, and approaches for analyzing and solving construction project delays.

Figure 1*:* Flow Chart for Research Approach



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In India, (Hemanta Doloi, 2012) concluded that insufficient commitment, bad site management, substandard coordination, unclear scope, and poor communication were major factors, and regression analysis indicated that poor owner decisions, poor labor productivity, poor supervision, and rework were important contributors to delays (Hemanta Doloi, 2012).

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In Denmark, the absence of project funding was the most important factor influencing time performance, and consultant errors caused cost overruns (Larsen, Shen, Lindhard, & Brunoe, 2016). In Saudi Arabia and Malaysia, poor communication was an important factor that significantly impacted productivity and quality (Abdallah, Shaawat, & Almohassen, 2024) (Olanrewaju, Tan, & Kwan, 2017).

In developing countries, the issues of subcontractor performance, planning failure, and institutional issues are intricately linked. In Chile, case studies revealed that while issues with subcontractors were prevalent, planning failure had the most detrimental effects on critical activities (González, 2013) (Pablo González, 2014)This was also found to be true in Nepal and South Africa, where delays resulted in cost overruns, arbitration, and distress to the client (Koirala & Shahi, 2024) (Mukuka, Aigbavboa, & Thwala, 2015). In India, the treatment of concurrent delays is inconsistent, which is an indication that there are no standardized legal and analytical processes (Munvar, 2019). Comparisons have also been made between delay analysis methods. Cunningham (1998) showed that different methods can give very different results for the same project (Ndekugri, 2009; Ndekugri, 2009).

4.0 Project Data and Analysis

The project which is chosen is a single Pre-Engineered Building (PEB) structure, which is part of a larger industrial project located in Chakan MIDC. The infrastructure project comprises of many work packages, each awarded to a different contractor. The project which we have chosen is a PEB structure with a mezzanine floor. All the data collected regarding the activities, duration, relationships between activities, delays and who can the delay be attributed to is provided by the contractor firm responsible for that package.

Figure 2: External View of the PEB Structure

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We have used Microsoft Project software to carry out our delay analysis activity as it is now becoming popular due to easier interface when compared to its predecessor, Primera P6. Also, many small and medium firms use MSP and some of the bigger firms are also now adopting this software.

4.1 Activity schedule data

The activities along with their duration and predecessors are given below. These are provided by the contractor firm responsible for the construction of the PEB structure.

Table 1: Project Data

S. No.	Activity	Planned Duration	Duration after delay	Predecessors
	Foundation Works			
1	Excavation	70	76	-
2	PCC	65	65	1SS+13d
3	Footing	65	65	2SS+22d
4	Plinth	40	40	3
5	Pedestal	52	52	4
	PEB			
6	Supply of anchor bolt	3	3	3
7	Procurement & Fabrication	30	40	5,6
8	Supply - Primary & Secondary	21	21	7FS-14d
9	Supply of Liner Sheets, Roof Coil & Profile Machine	3	5	8
10	Supply of Cladding Sheet & Puff Panels	3	4	8
11	Supply of Misc. Work (Gutter, flashing, Down take & Etc)	7	12	8
12	Erection of Primary & Secondary	41	44	8SS+3d, 5
13	Roofing with Liner	14	14	12, 9
14	Cladding with Puff Panel	45	45	12SS+24d, 10
15	Misc. Work (Gutter, flashing, Down take & Etc)	14	14	11,13,14
	Superstructure			
16	Plinth Filling & Compaction	20	33	15
17	GSB with Compaction	18	18	16
18	Flooring	18	26	17FS-13d
19	Densification	19	21	18
20	Supply of Fire Door & Rolling Shutter	6	7	17SS+18d
21	Fixing of Fire Door & Rolling Shutter	7	7	19,20
22	Supply of Façade Materials	7	7	16
23	Fixing of Façade Frames	39	45	22
24	Fixing of Glass, Doors & Sealant	40	53	23SS+7d
25	Painting Work	9	12	24FS-10d,21

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4.2 Delay attribution matrix

Table 2: Table Indicating Delay Reason and Responsible Party

S. No.	Activity	Delay Event		Delay (days)	Attribution	Delay Percentage		Reason
		Client	Contractor			Client	Contractor	
Foundation Works								
1	Excavation		**D1**	**6**	**Contractor Responsible**	0%	**100%**	Site mobilization done late.
2	PCC			0	–	–	–	No delay.
3	Footing			0	–	–	–	No delay.
4	Plinth			0	–	–	–	No delay.
5	Pedestal			0	–	–	–	No delay.
	PEB							
6	Supply of anchor bolt			0	–	–	–	No delay.
7	Procurement & Fabrication	**D2**	**D3**	**10**	**Shared Delay**	**80%**	**20%**	Procurement delay as client-approved vendor delayed, contractor also delayed
8	Supply - Primary & Secondary			0	–	–	–	No delay.
9	Supply of Liner Sheets, Roof Coil & Profile Machine	**D4**		**2**	**Client Responsible**	**100%**	0%	Client-appointed vendor delayed.
10	Supply of Cladding Sheet & Puff Panels	**D5**		**1**	**Client Responsible**	**100%**	0%	Client-appointed vendor delayed.
11	Supply of Misc. Work (Gutter, flashing, Down take & Etc)	**D6**	**D7**	**5**	**Shared Delay**	**15%**	**85%**	Contractor placed late order.
12	Erection of Primary & Secondary		**D8**	**3**	**Contractor Responsible**	0%	**100%**	Poor site-execution.
13	Roofing with Liner			0	–	–	–	No delay.
14	Cladding with Puff Panel			0	–	–	–	No delay.
15	Misc. Work (Gutter, flashing, Down take & Etc)			0	–	–	–	No delay.
Superstructure								
16	Plinth Filling & Compaction		**D9**	**11**	**Contractor Responsible**	0%	**100%**	Poor site-execution.

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17	GSB with Compaction			0	–	–	–	No delay.
18	Flooring		**D10**	**8**	**Contractor Responsible**	0%	**100%**	Coordination issues between contractor and sub-contractor.
19	Densification	**D11**	**D12**	**2**	**Shared Delay**	**50%**	**50%**	Activity started late due to flooring delay and client delayed approvals.
20	Supply of Fire Door & Rolling Shutter	**D13**		**1**	**Client Responsible**	**100%**	0%	Procurement delay as client-appointed vendor delayed.
21	Fixing of Fire Door & Rolling Shutter			0	–	–	–	No delay.
22	Supply of Façade Materials			0	–	–	–	No delay.
23	Fixing of Façade Frames	**D14**	**D15**	**6**	**Shared Delay**	**33%**	**66%**	Delay due to late client approvals & installation inefficiencies
24	Fixing of Glass, Doors & Sealant	**D16**	**D17**	**13**	**Shared Delay**	**30%**	**70%**	Delay due to late client approvals & installation inefficiencies
25	Painting Work		**D18**	**3**	**Contractor Responsible**	0%	**100%**	Activity started late due delay in fixing of fire doors.

Source: Created by authors

This table lists out all the delays faced in the chosen activities of the WBS and who can these delays be attributed to. All the delays listed here are of Excusable Compensable (client responsible) and Non-Excusable- Non-Compensable (contractor responsible) category.

Total Delay days = 71 days

Client total = 8+2+1+1+1+1+2+4 = 20 days, i.e. client-attributable delay is approximately 28.16%

Contractor total = 6+2+4+3+11+8+1+4+9+3 = 51 days, i.e. contractor-attributable delay is approx. 71.83%

4.3 As planned schedule

This is the planned baseline schedule for the construction work. It acts as the blueprint for the contractor as to how the scope of work is to be achieved. As planned schedule is the original schedule. It allows us to compare the progress against itself to identify the discrepancies. Refer appendix A for MSP charts.

Total As-Planned duration=375 days

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4.4 As built schedule

This schedule states how the work was carried out by the contractor. It comprises of the real start and finish time of the activities along with the impacted durations of the activities due to delays. Refer appendix B for MSP charts.

Total As-built duration= 409 days

4.5 Analysis of data

4.5.1 As planned VS. As built

This technique compares the actual completion dates of activities with the planned (baseline) completion dates, considering all delaying events such as contractor-caused delays and owner/client-caused delays. The total delay for which extension of time or compensation is requested is the difference between the as-built duration and the as-planned duration.

Total As planned duration= 375 days. (Refer appendix A)

Total As-built duration= 409 days. (Refer appendix B)

Total project delay (As-Planned vs As-Built) = 409 - 375 = 34.0 days.

As discussed above, we have a total raw delay of 71 days, whereas, on adding all the delays in the as planned schedule, gives us the 34 days of net delay.

Hence, concurrent delays= 71-34 = 37 days

Total Delay days= 71 days

Sum of client caused delays = 8+2+1+1+1+1+2+4 = 20 days

Sum of contractor caused delays = 6+2+4+3+11+8+1+4+9+3 = 51 days

According to the min. Rule method, simultaneous delays caused by both entities is the value of the shorter delay duration, i.e., 20 days.

Hence, total project delay for whom the contractor is responsible= 51 – 20 = 31 days
Balance is client liability, 34 – 31 = 3 days

4.5.2 Collapsed as-built schedule

The Collapsed As-Built (CAB) Delay Analysis, also known as the *but-for method*, evaluates responsibility by starting with the actual as-built schedule and then removing the delays attributable to one party—either the owner or the contractor. By subtracting that party's delay events and recalculating the schedule, a hypothetical "but-for" completion date is produced: the date on which the project would have finished if that party had not caused any delay. The difference between the actual as-built completion date and the reconstructed but-for completion date represents the specific delay caused by the selected party. This makes the CAB method highly effective in disputes, as it clearly isolates each party's impact on the final project duration.

We will conduct the collapsed as-built analysis in two parts

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- Contractor's point of view

In this method, we will first adjust for the delays caused by client by not considering any delay caused by the client and only considering those delays which are due to the contractor. *The new duration comes out to be 401 days* (Refer appendix C) as compared to 409 days in the as-built schedule. This means the *client's liability is of 409 – 401 = 8 days.* When the adjusted schedule is compared to the original as-built schedule, it is found that *contractor is responsible for, 34 – 8 = 26 days* of delay causation.

- Client's point of view

Now, we will adjust to the delays caused by the contractor by not considering any delay caused by the contractor and only considering those delays which are due to the client. The *new duration came out to be 386 days* (Refer appendix C) as compared to 409 days in the as-built schedule. This means the *contractor's liability is of 409 – 386 = 23 days.* When the adjusted schedule is compared to the original as-built schedule, it is found that *client is responsible for, 34 – 23 =11 days* of delay causation.

4.5.3 Impacted as-planned analysis OR time impact analysis

The Impacted As-Planned analysis is used to evaluate how delay events affect the contractor's original CPM schedule. In this method, each delay is modelled as a separate activity and inserted into the baseline programme in chronological order. This helps illustrate how each delay event influences the critical path and the overall project timeline.

Table 3: Impact as Planned Table

Delay Event	Delay	Delay Duration	Delay Days		Delay Impact
			Client	Contractor	
D1	6	375	0.00	6.00	0
D2+D3	10	385	8.00	2.00	10
D4	2	385	2.00	0.00	0
D5	1	385	1.00	0.00	0
D6+D7	4	385	0.60	3.40	0
D8	3	385	0.00	3.00	0
D9	11	396	0.00	11.00	11
D10	8	404	0.00	8.00	8
D11+D12	2	406	1.00	1.00	2
D13	1	406	1.00	0.00	0
D14+D15	6	406	2.40	3.60	0
D16+D17	12	406	3.60	8.40	0
D18	3	409	0.00	3.00	3
	Total Impact=		**9.00**	**25.00**	**34**

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The resulting delay is determined by comparing the original planned completion date with the updated schedule that includes the inserted delay activities. This approach provides a clearer and more comprehensive understanding of how individual delays altered the baseline schedule and contributed to the project overrun. Refer appendix D for MSP charts.

On conducting this analysis on our activities, it is established that delay events 2,3 and 9 cause the most delay, and some events cause no impact on the schedule.

Hence, the *client is liable for 9 days* of delay for this project, and the *contractor is liable for 25 days of delay*.

4.5.4 Window analysis

For this project, the Window Analysis technique was used to evaluate how delays affected the work sequence over time. The total construction period was divided into smaller, sequential time windows, each representing a distinct phase of progress. Within each window, the schedule was updated to reflect the actual durations, actual start/finish dates, and delay events that occurred during that period, while the remaining future activities retained their as-planned logic. By examining the critical path movement and the revised completion date within each window, the specific delay impact of that time slice was determined. This was done by comparing the new completion date at the end of the window with the planned completion date immediately prior to the analysis. The schedule was divided into eight windows based on key activity groupings such as earthwork, flooring, densification, façade works, and finishing. The analysis was then performed successively for each window to identify how delays accumulated and shifted the critical path throughout the project duration. Refer appendix E for MSP data.

Table 4: Window Analysis Table

Window No.	Window Range	Project Duration	Delay in window slice	
			Client	Contractor
1	17 May, 24 - 1 Aug, 24	375	0	0
2	2 Aug, 24 - 15 Oct, 24	375	0	0
3	16 Oct, 24 - 31 Dec, 24	375	0	0
4	1 Jan, 25 - 15 Mar, 25	375	0	0
5	16 Mar, 25 - 31 May, 25	385	8	2
6	1 Jun, 25 - 15 Aug, 25	385	0	0
7	16 Aug, 25 - 31 Oct, 25	404	0	19
8	1 Nov, 25 - 10 Dec, 25	409	1	4
		Total Delay =	9	25

Source: Created by authors

From window slice analysis, we conclude that the *client is responsible for* ***9 days*** of delay and *contractor is responsible for* ***25days*** of delay.

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5.0 Result and Discussion

The results of all applied delay analysis techniques show that contractor is responsible for majority of the delay, with values ranging between 3 to 31 days, while the owner's contribution remains comparatively lower across all methods. Techniques that incorporate actual progress and critical path evolution—like Window Analysis and Time Impact Analysis—produce the most reliable and consistent results, both identifying the owner's liability at 9 days and the contractors at 25 days.

Table 5: Results Obtained in all Analysis Methods

Delay Analysis Techniques	Delay (in days)	
	Client	Contractor
As-Planned vs. As-Built Analysis	3	31
Impacted As-Planned / Time Impact Analysis	9	25
Collapsed As-Built – *Contractor's point of view*	8	26
Collapsed As-Built – *Owner's point of view*	11	23
Window Analysis (approx. 60-day windows)	9	25

Source: Created by authors

6.0 Conclusion

Based on industry best practices and international standards (AACE, SCL Protocol), both Time Impact and Window Analysis are considered the most accurate and defensible methods, as they reflect contemporaneous updates, actual delays, and real critical path shifts throughout the project lifecycle. These methods provide the strongest basis for determining responsibility and supporting delay claims.

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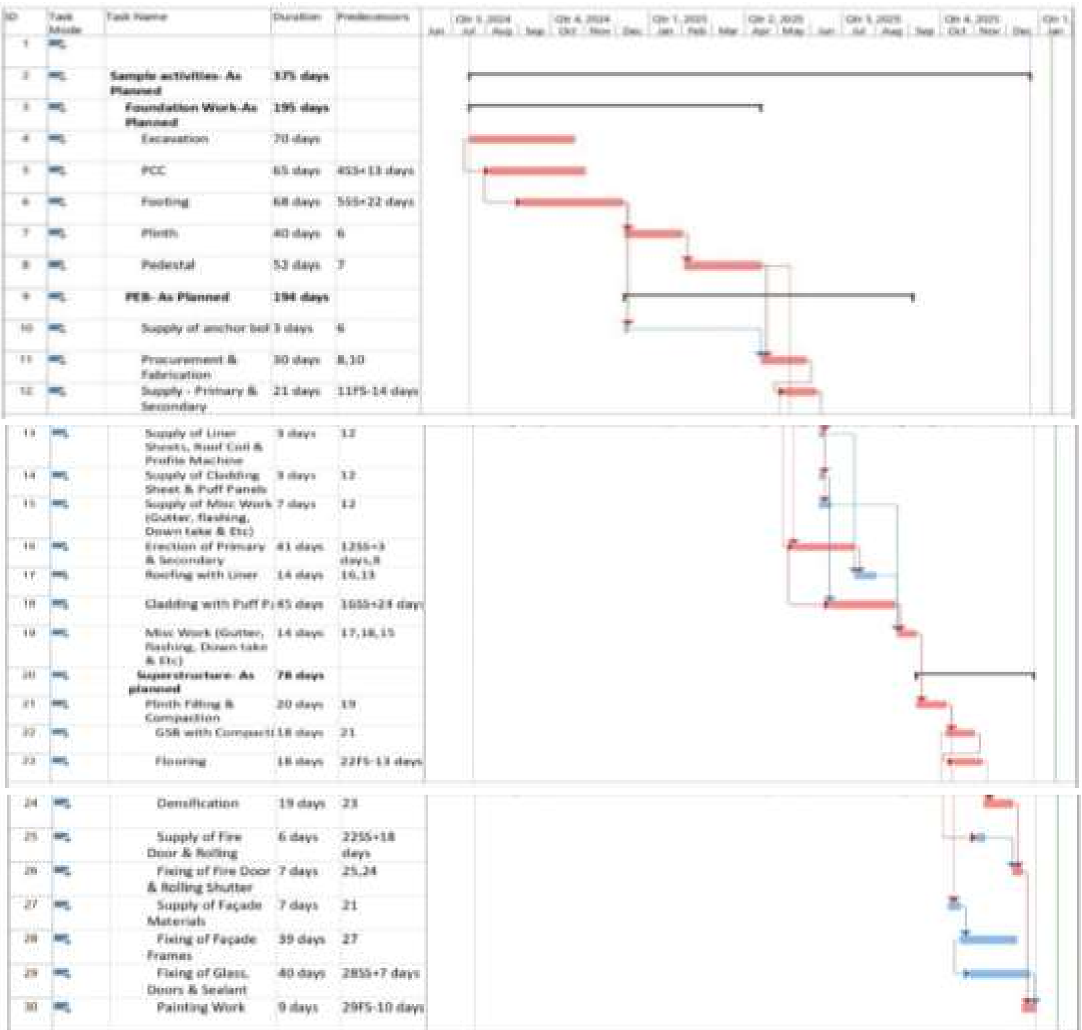
APPENDICES

9.1 APPENDIX A: As planned schedule (MSP data chart)

Figure 3: As Planned Schedule MSP Chart



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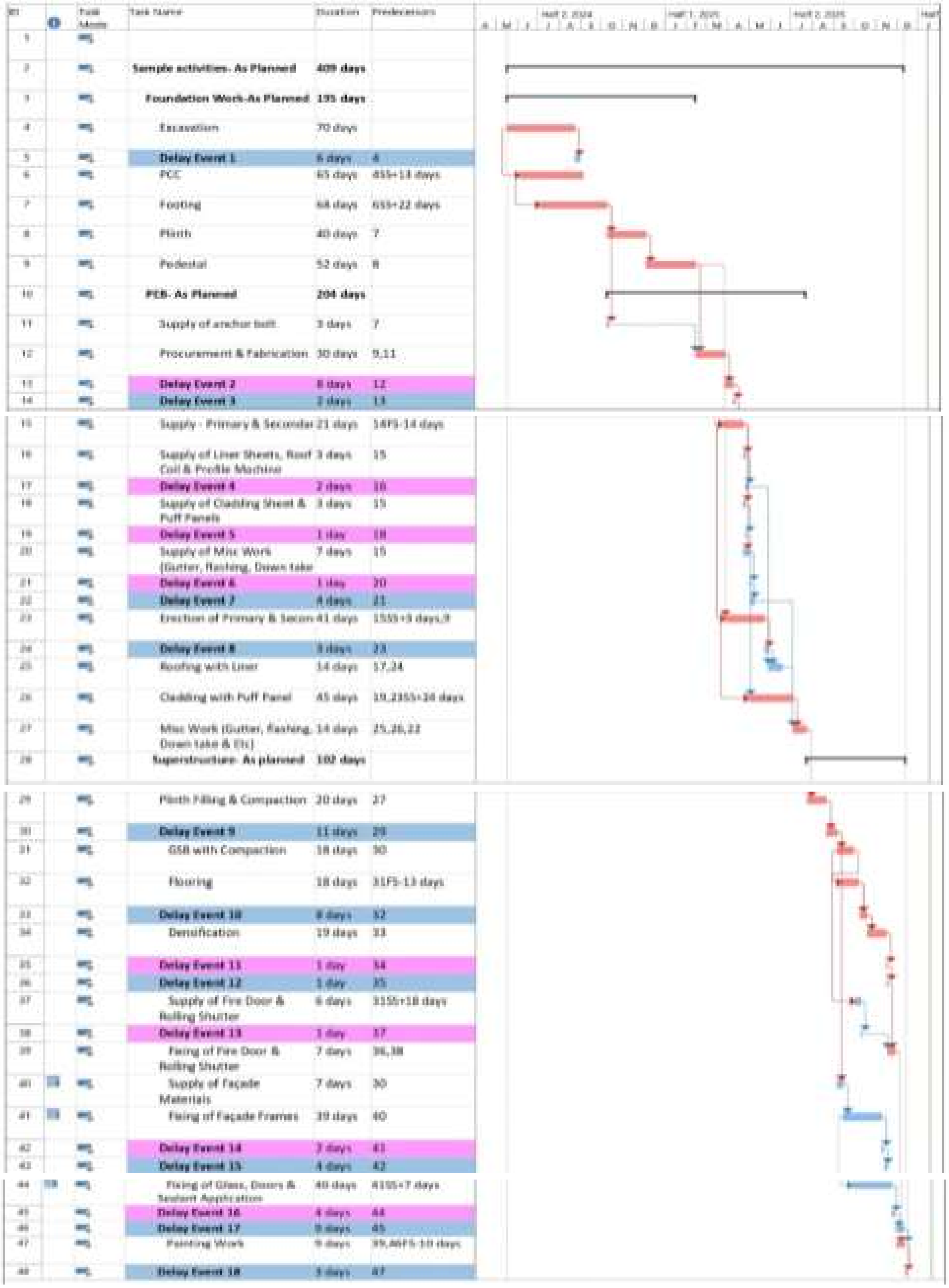
Appendix B: As built schedule (MSP Data Chart)

Figure 4: As Built Schedule MSP Chart



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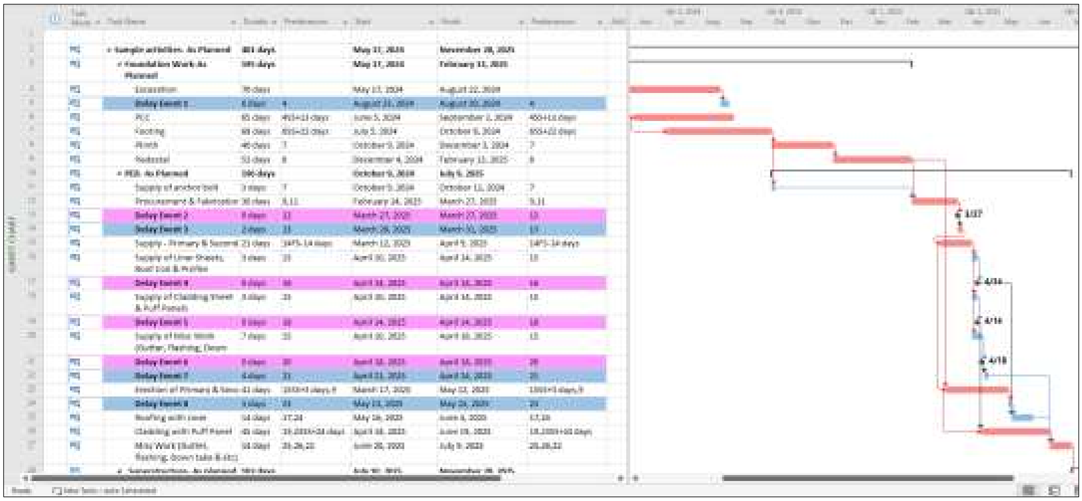
Appendix C: Collapsed as built schedule (MSP data chart)

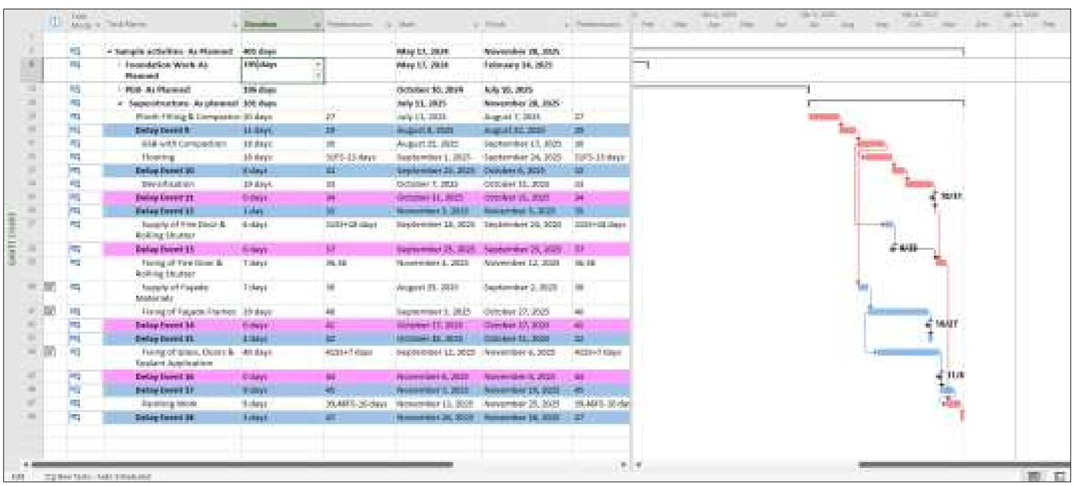
9.3.1 Contractor's POV

Figure 5: Collapsed As- Built Analysis where Delay Events by Client are Considered '0' in Events 2,4,5 and 6



Source: Created by authors

Figure 6: Collapsed As- Built Analysis where Delay Events by Client are Considered '0' in Events 11,13,14 and 16



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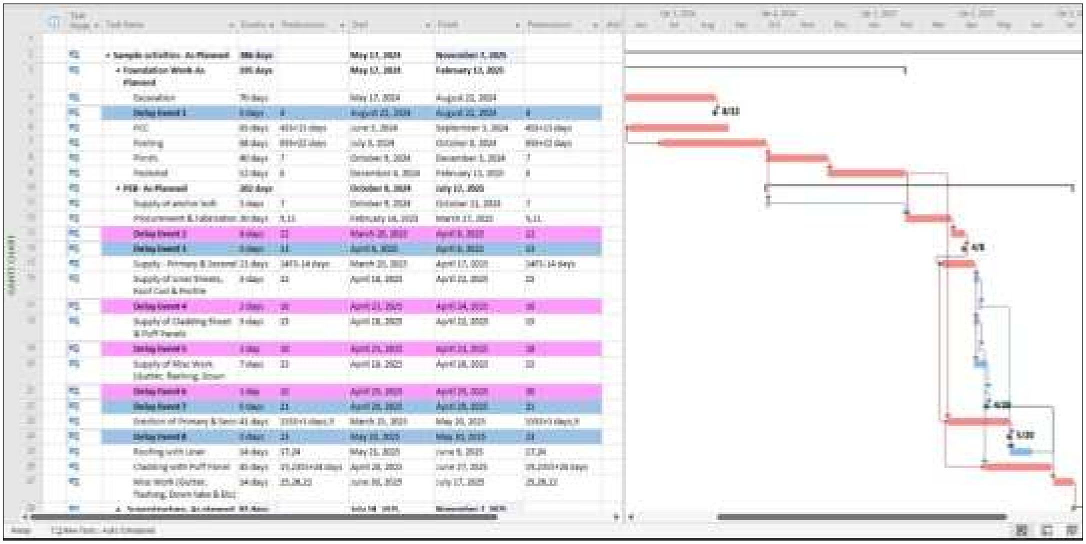
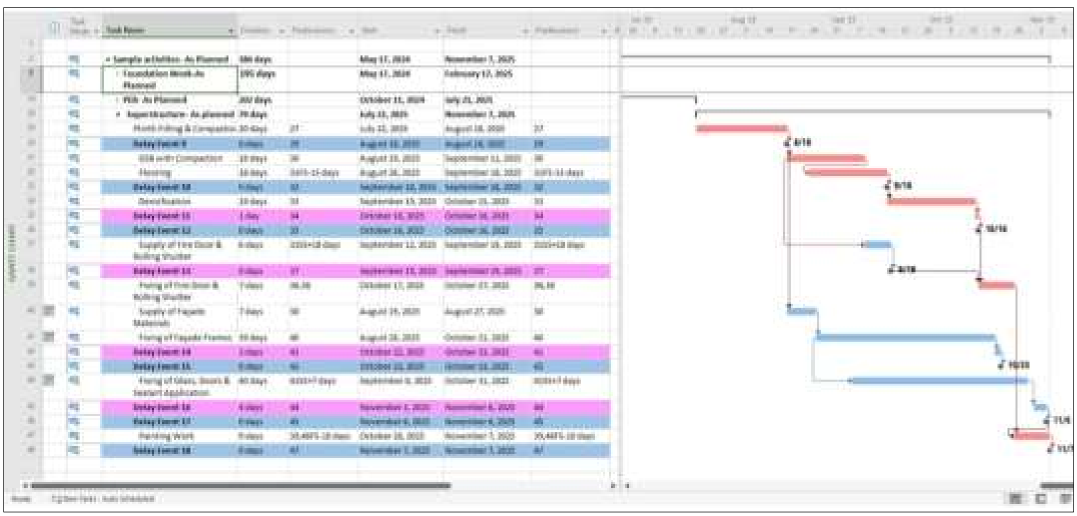
9.3.2 Client's POV

Figure 7: Collapsed As- Built Analysis where Delay Events by Contractor are Considered '0' in Events 1,3,7 and 8



Source: Created by authors

Figure 8: Collapsed As- Built Analysis where Delay Events by Contractor are Considered '0' in Events 9,10,12,15,17 and 18



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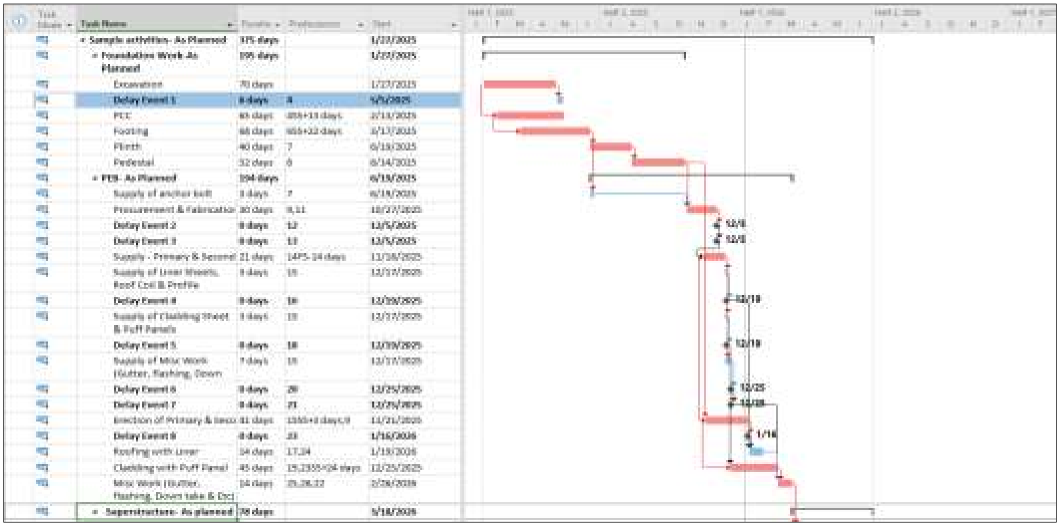
APPENDIX D: Impacted as Planned/ Time Impact Analysis (MSP Data Chart)

Figure 9: Impacted as Planned Analysis, where Delay Event 1 is Inserted and its Impact on as Planned Schedule is Studied. DE 1 has no Impact on Completion Date



Source: Created by authors

Figure 10: Inserting Delay Events 2&3 Impacts the Schedule and Delay the Project by 10 Days

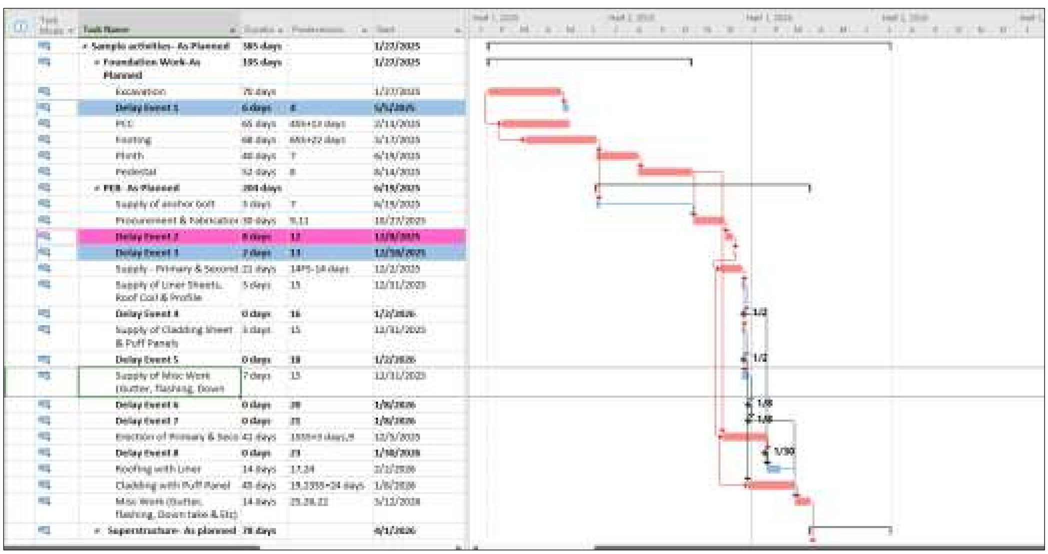


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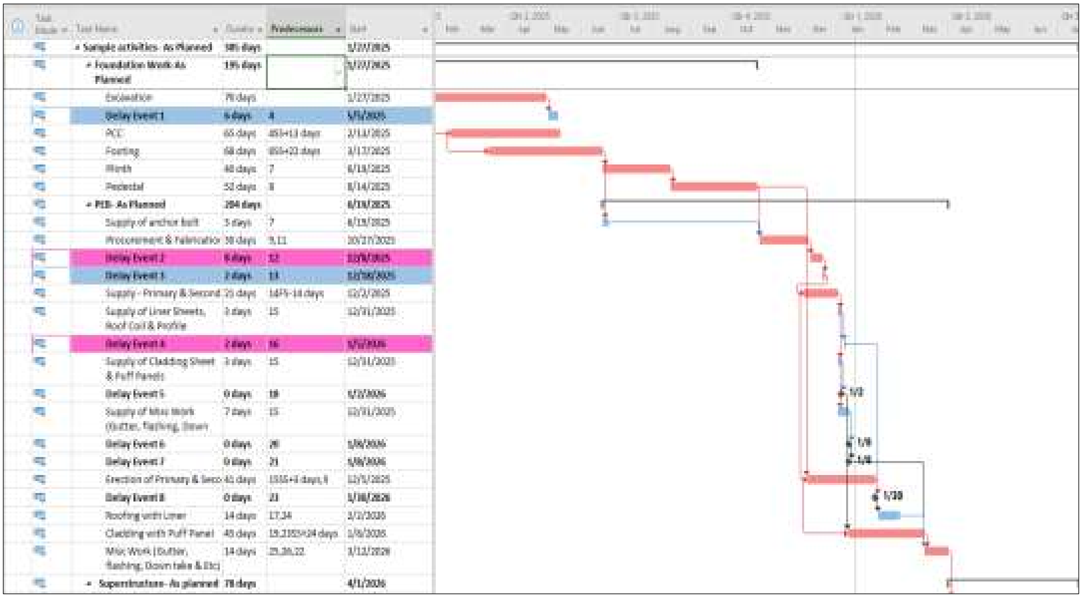
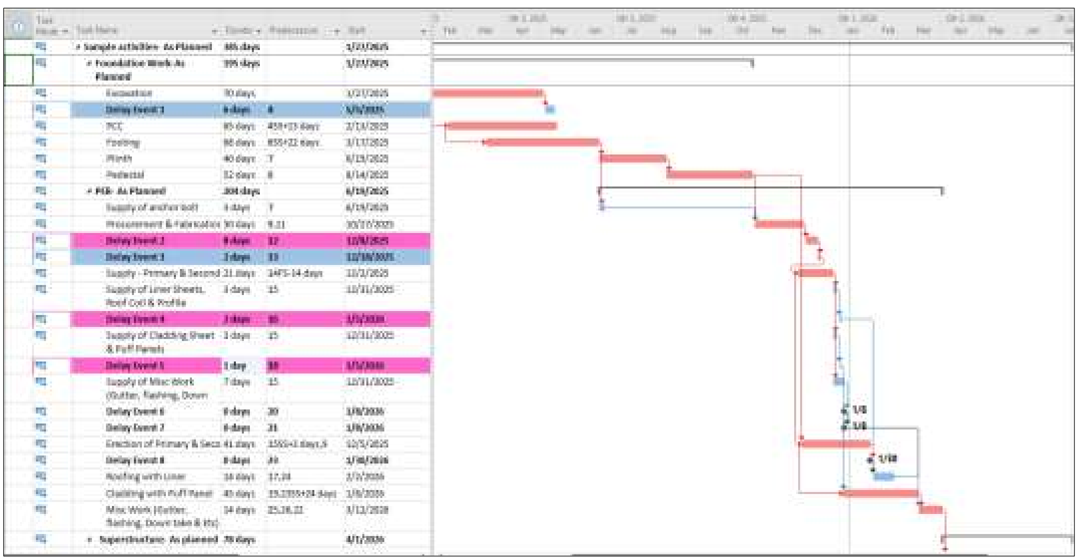
Figure 11: Delay Event 4 has no Impact on Schedule



Source: Created by authors

Figure 12: Delay Event 5 has no Impact on Schedule



Source: Created by authors

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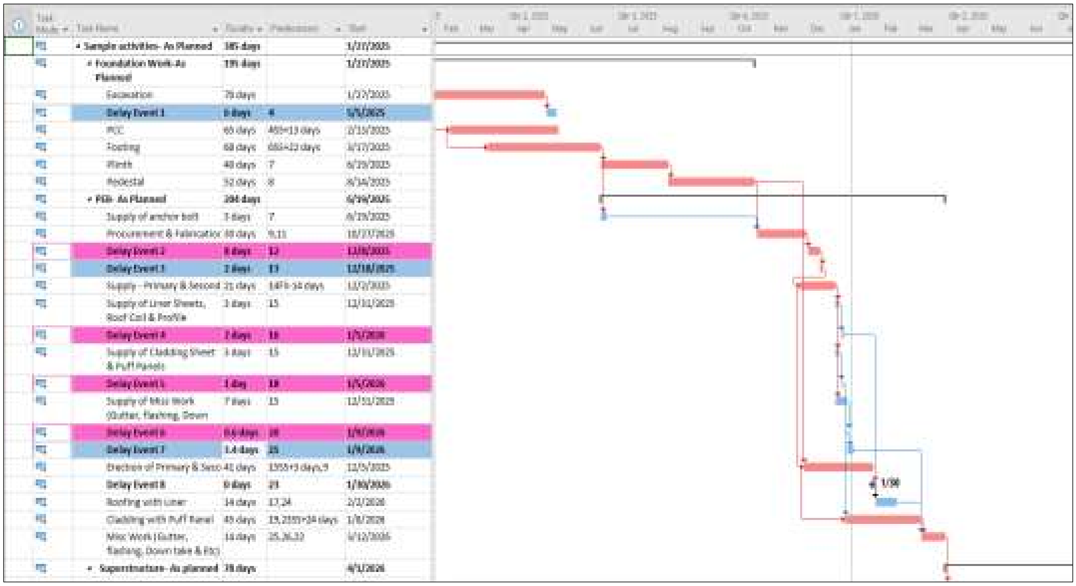
Figure 13: Delay Event 6&7 have no Impact on Schedule



Source: Created by authors

Figure 14: Delay Event 8 has no Impact on Schedule

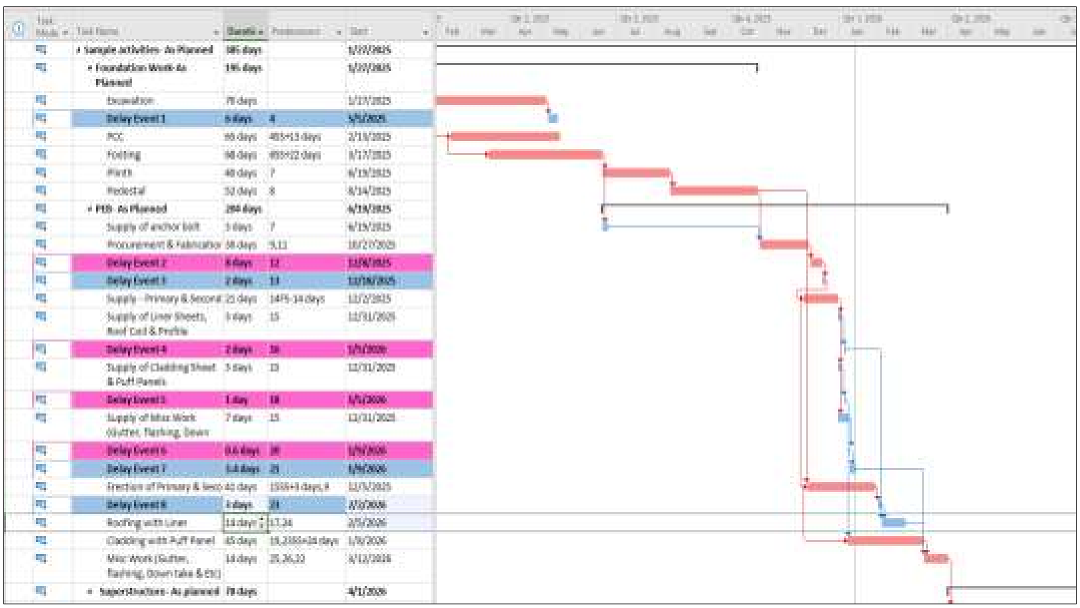


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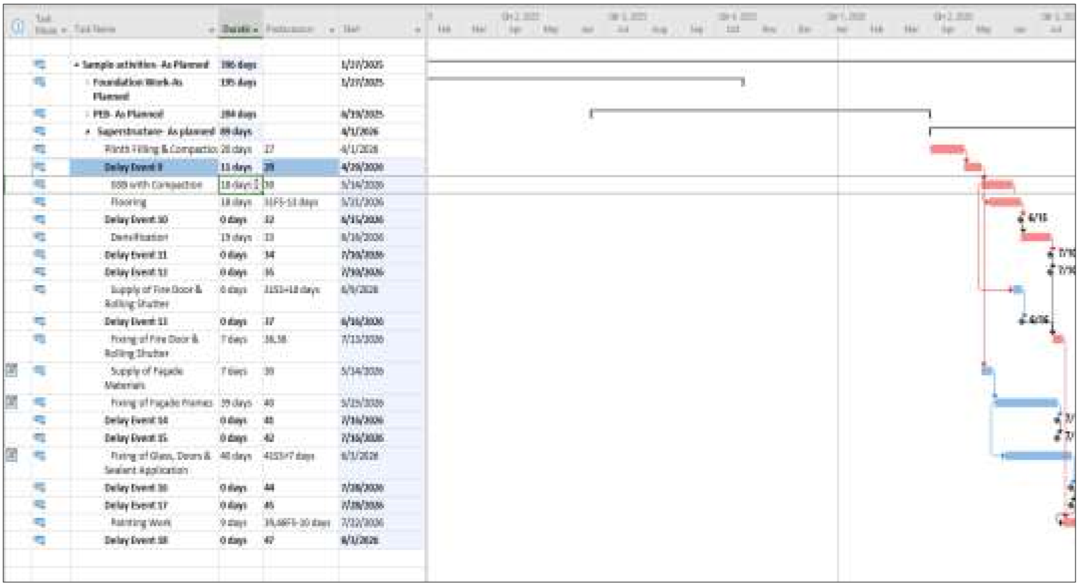
Figure 15: Delay Event 9 Increases the Schedule by 11 Days



Source: Created by authors

Figure 16: Delay Event 10 Increases the Schedule by 8 Days

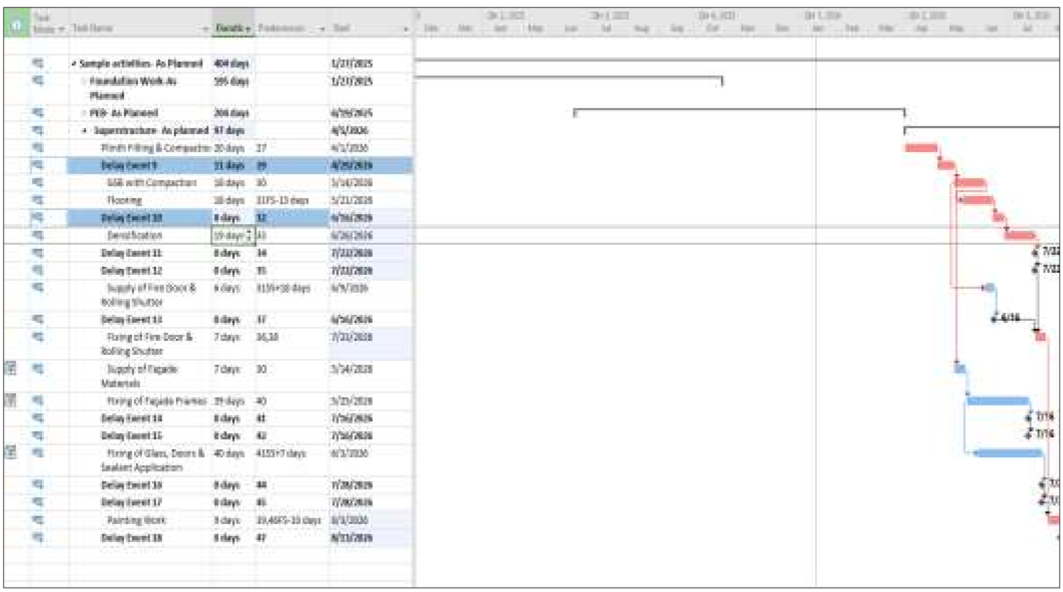


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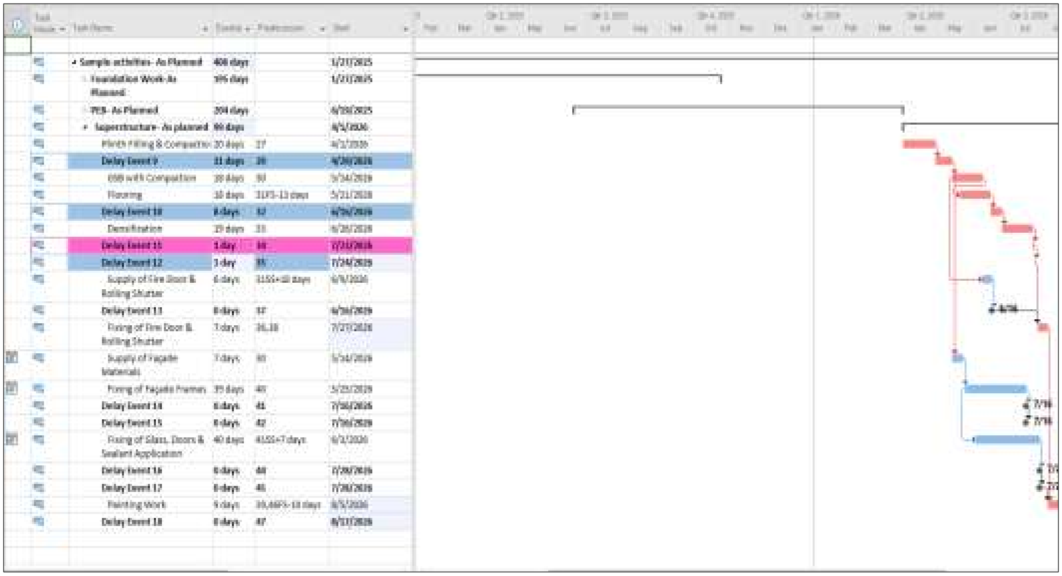
Figure 17: Delay Event 11&12 Impact the Schedule by 2 Days



Source: Created by authors

Figure 18: Delay Event 13 has no Impact on the Schedule

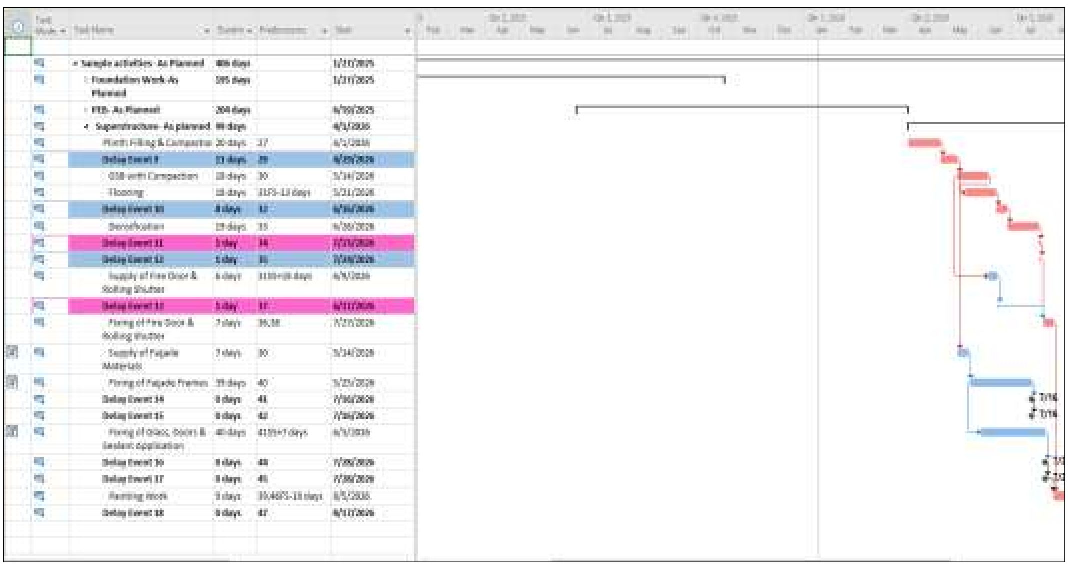


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Figure 19: Delay Event 14&15 have no Impact on the Schedule

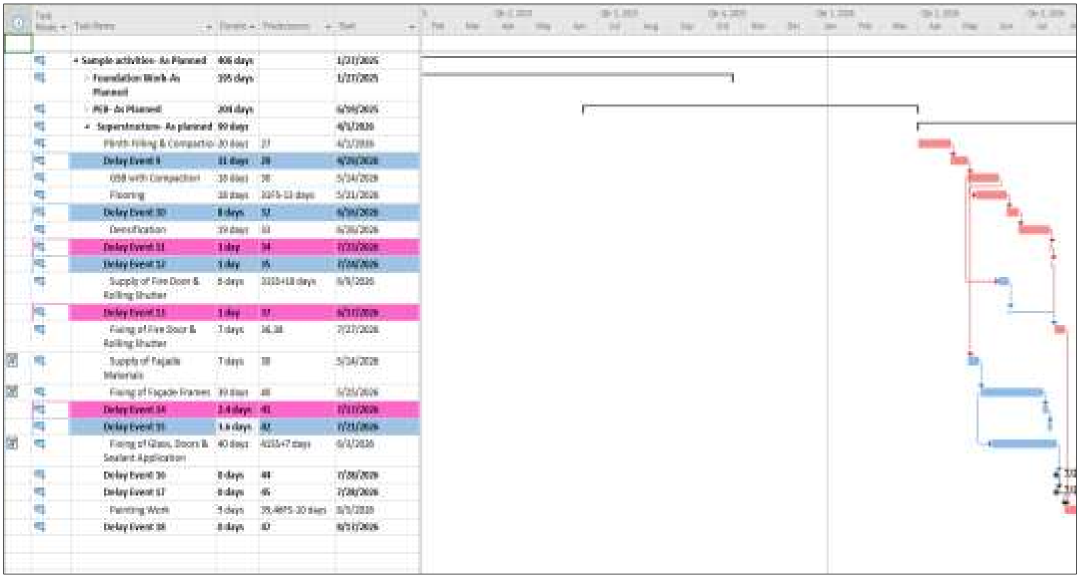

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Figure 20: Delay Event 16&17 have no Impact on the Schedule

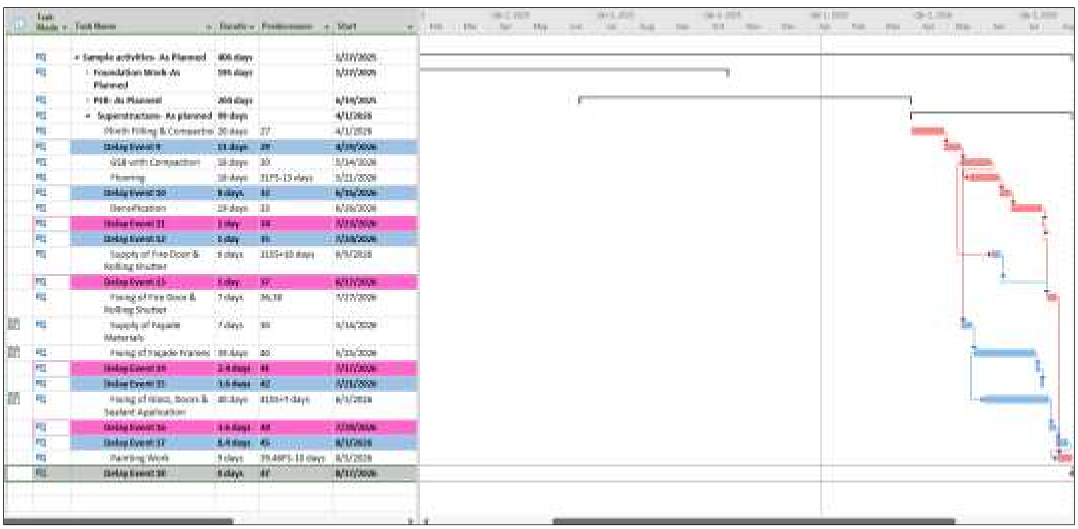

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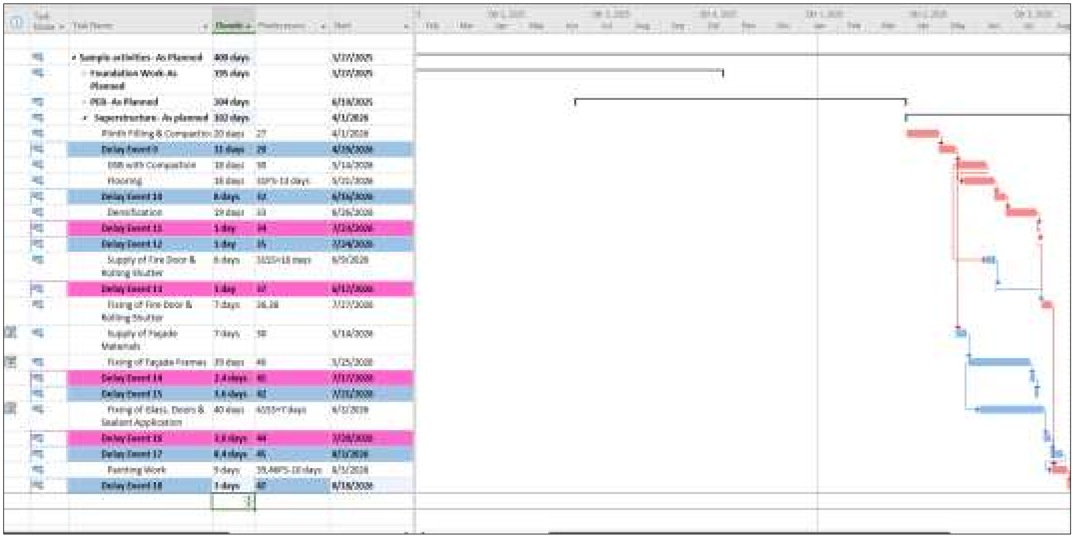
Figure 21: Delay Event 18 Impact the Schedule by 3 Days



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9.5 Appendix E: Window analysis (MSP data chart)

Figure 22: Window 1: 17 May, 24 - 1 Aug, 24
There are no Delay Events in this Window

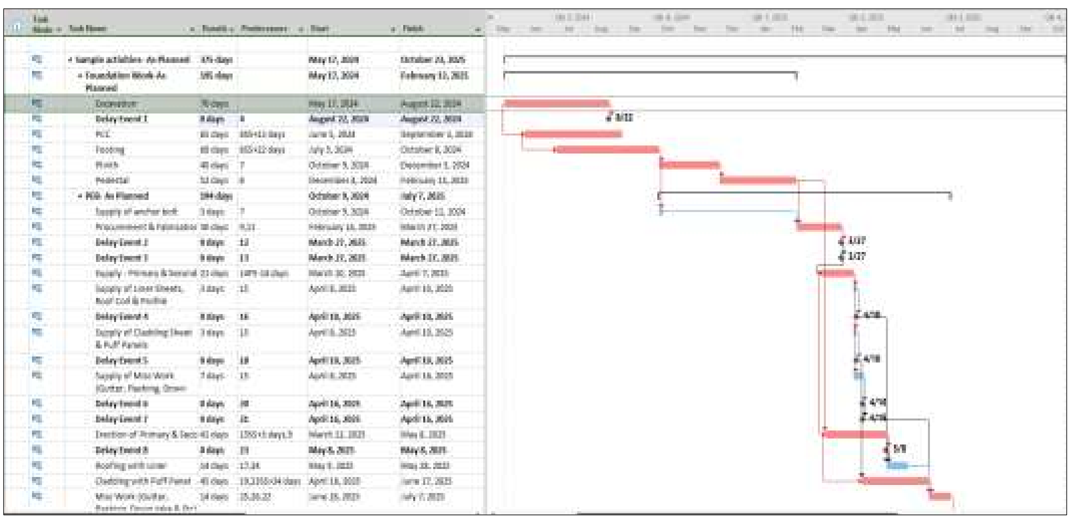

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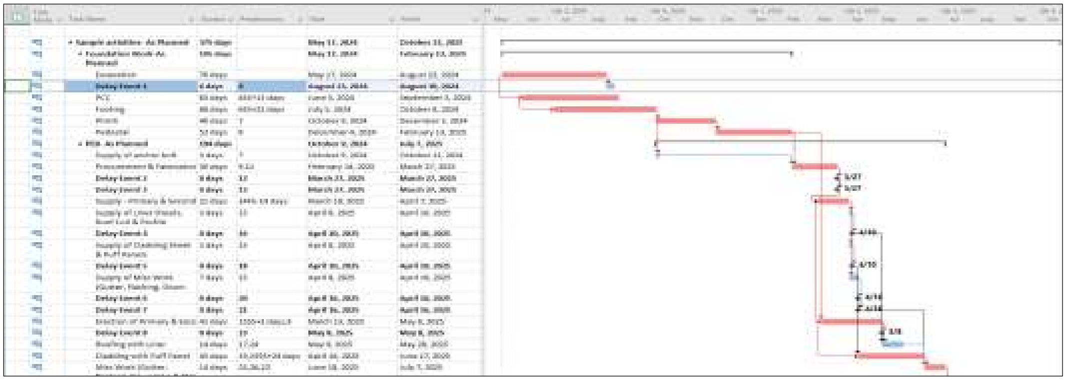
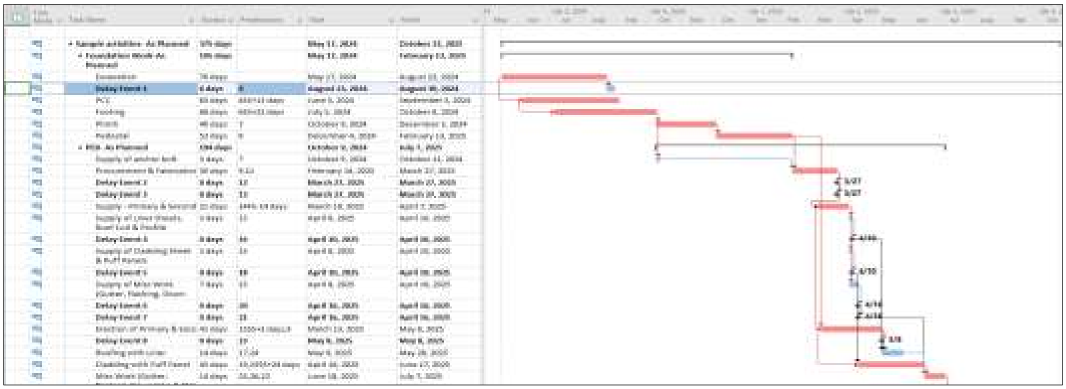
Figure 23: Window 2: 2 Aug, 24 - 15 Oct, 24 – Delay Event 1 has no Effect on the Completion Date



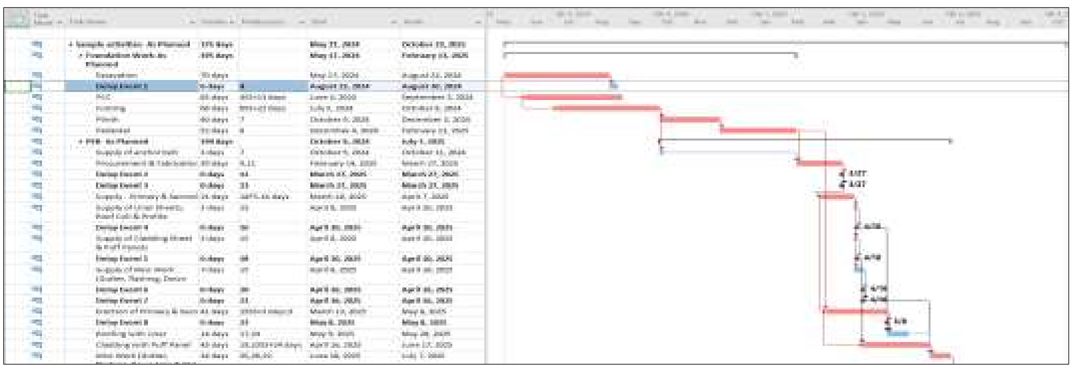
Source: Created by authors

Figure 24: Window 3: 16 Oct, 24-31 Dec, 24-There are no Delay events in this Window



Source: Created by authors

Figure 25: Window 4: 1 Jan, 25-15 Mar, 25-There are no Delay Events in this Window



Source: Created by authors

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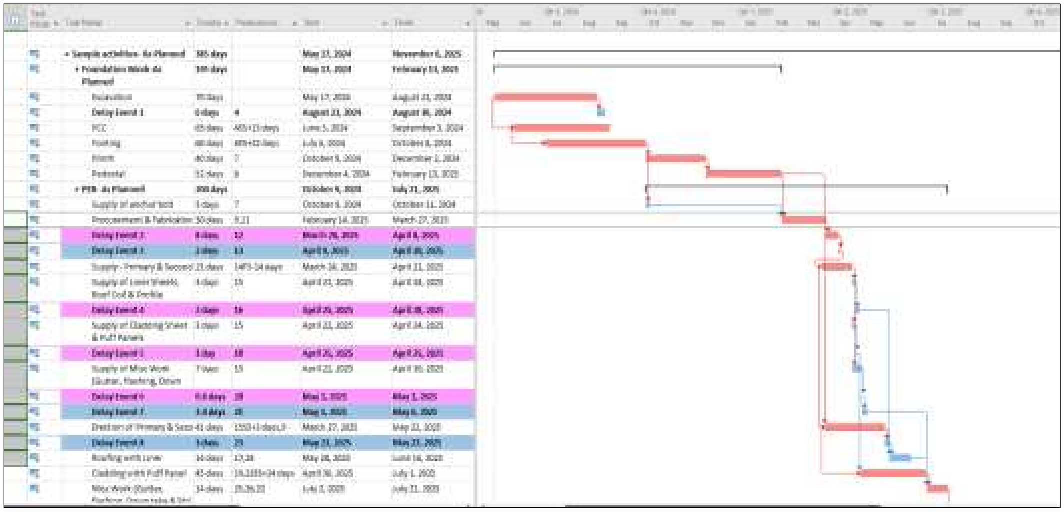
Figure 26: Window 5: 16 Mar, 25-31 May, 25 – Delay Events 2,3,4,5,6,7 and 8 Occur in this Window and the Impact the Project with a Delay of 10 Days



Source: Created by authors

Figure 27: Window 6: 1 Jun, 25-15 Aug, 25 – Zero delay Occurrence in this Window

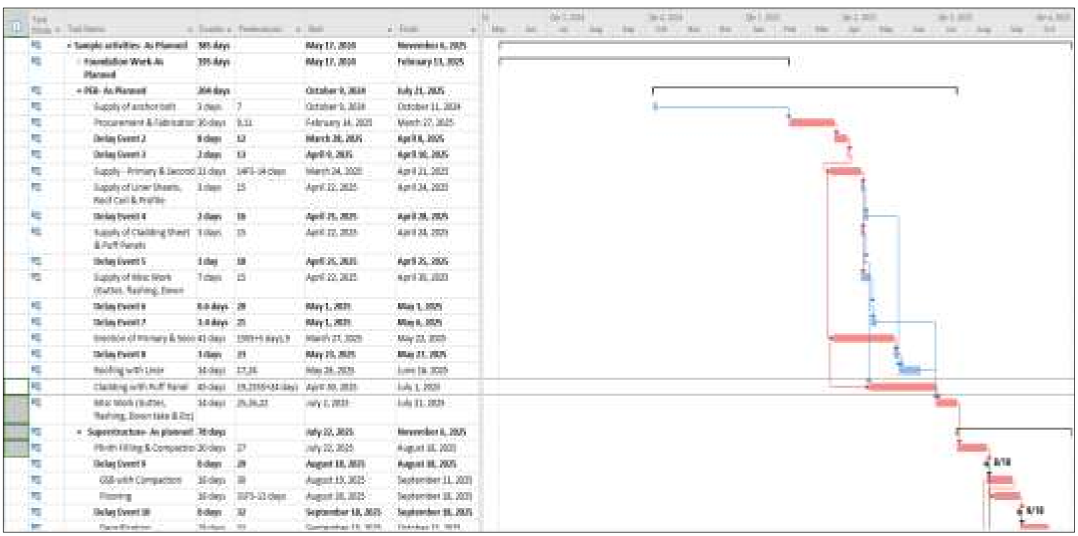


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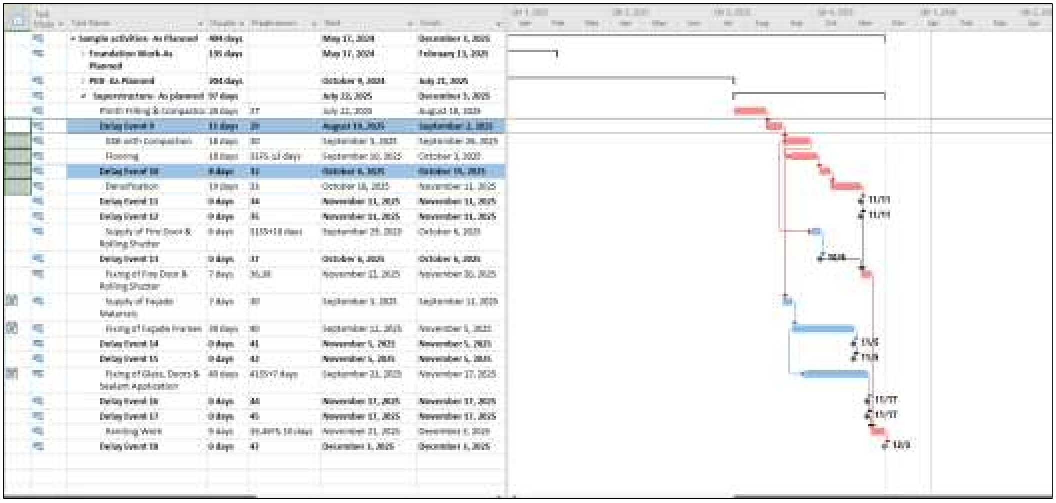
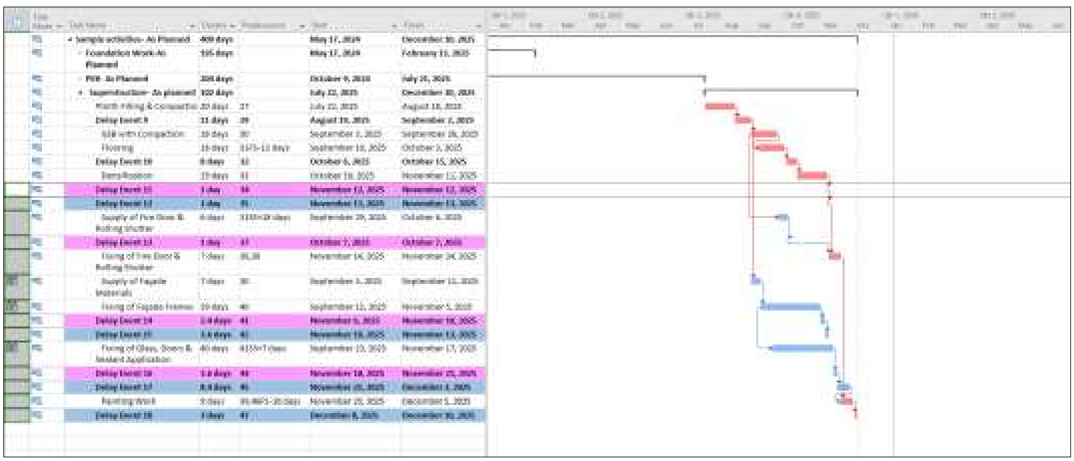
Figure 28: Window 7: 16 Aug, 25-31 Oct, 25 – Delay Events 9 and 10 Occur in this Window, and the Impact the Project Completion Days the Most; by 19 Days



Source: Created by authors

Figure 29: Window 8: 1 Nov, 25-10 Dec, 25 – Delay Events 11,12,13,14,15,16,17 & 18 lie in this Window. But Despite Many Delay Events Occurring, the Overall Impact on the Project Completion is of 5 Days Only



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