CDR.11

Forensic Schedule Analysis: Example Implementation

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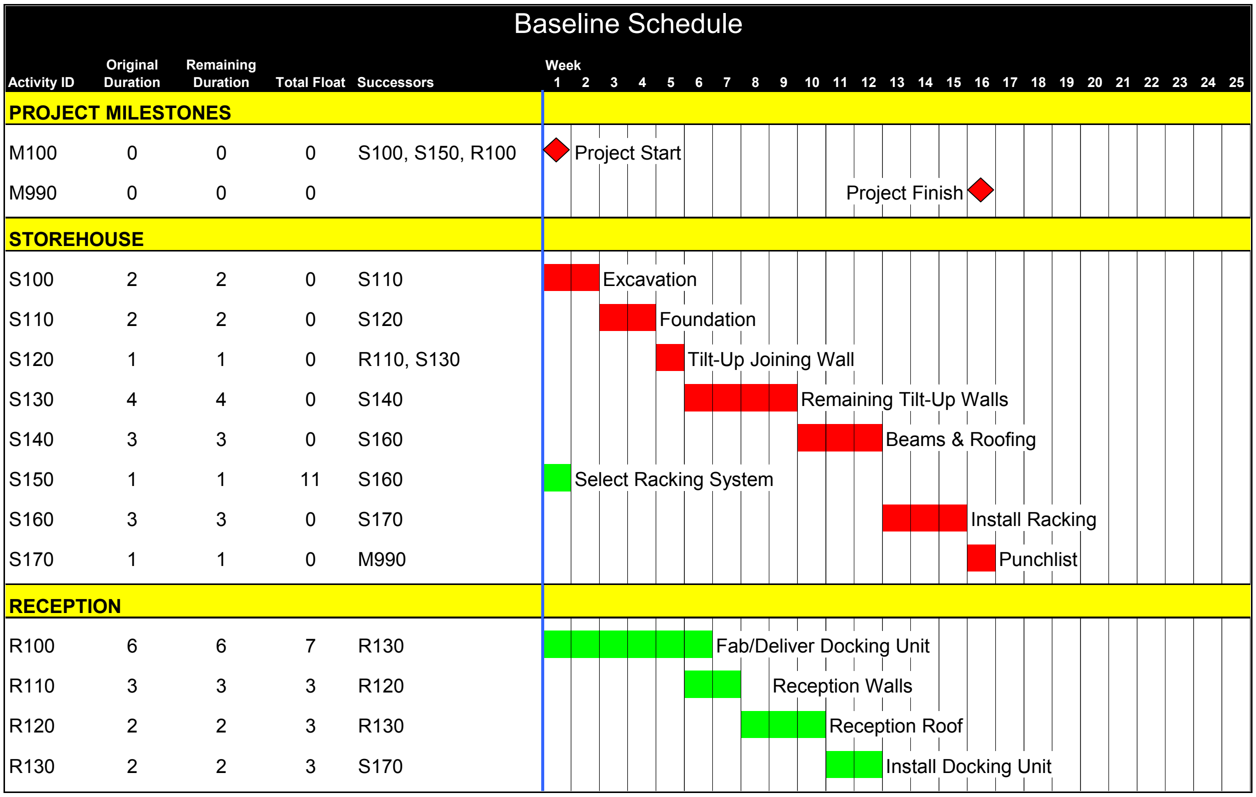
This paper presents a forensic schedule analysis (FSA) example implementation, prepared to address the application of procedures described in AACE International's **Recommended Practice on Forensic Schedule Analysis** (RP 29R-03) [1]. The techniques explored here or variations on these techniques have been commonly referred to as "windows Analysis" or "Time Impact Analysis." Those terms are not used here, in preference for the taxonomic terms presented in the RP 29R-03. This paper presents two separate analyses of the same project. The analyses are based on the Method Implementation Protocols in Sections 3.3 and 3.7 of the recommended practice. The paper has four major sections:

- model project to be analyzed;
- analysis by inserting only progress and identifying delays (mip 3.3);
- analysis by inserting progress and fragnets to model delays (mip 3.7); and
- comparison, commentary, and conclusion.

MODEL PROJECT TO BE ANALYZED

The original sample project was provided for the consideration of the participants in the RP development committee and had been used previously for the comparison of various delay analysis techniques [2]. The model project schedule and summary of project documentation described here have been elaborated somewhat in order to provide a more detailed example of the two forensic analysis techniques presented. The model project is the construction of a storage building. The building will be used to store non-hazardous, dry materials. The design consists of tilt-up concrete panels with a steel-framed, metal roof. A much smaller receiving and reception area is attached. The reception area is framed with metal studs and enclosed with an exterior-insulating and finishing system (EIFS). Personnel arrive through the reception area and goods are delivered by truck to the all-weather docking unit in that area. The available information for the project includes a baseline schedule, six schedule updates, and a summary of project events based on the contractor's and owner's files (see figure 1).



Baseline Schedule

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0	0	S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	2	0	S110
S110	2	2	0	S120
S120	1	1	0	R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	11	S160
S160	3	3	0	S170
S170	1	1	0	M990
RECEPTION				
R100	6	6	7	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	3	S170

Figure 1 – Project Baseline Schedule

In the example project schedule, the project start milestone has start-to-start relationships with its successors, and the punch list activity has a finish-to-finish relationship with the project finish milestone. All other relationships are finish-to-start, and there are no lags. Durations are in weeks, and the project is planned to take 16 weeks to complete. the baseline critical path begins with project start and proceeds through excavation, foundation, tilt-up joining wall, remaining tilt-up walls, beams and roofing, install racking, punch list, and project finish. There are no constraints in the schedule as shown in figure 2.

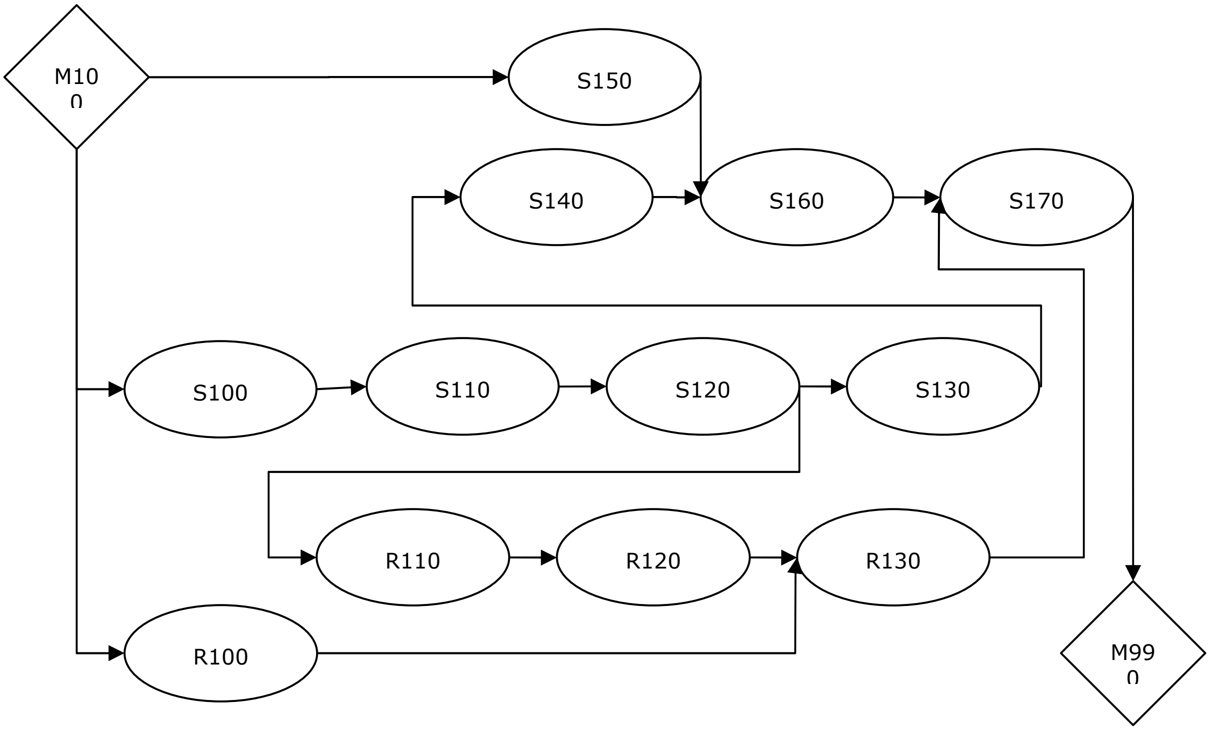
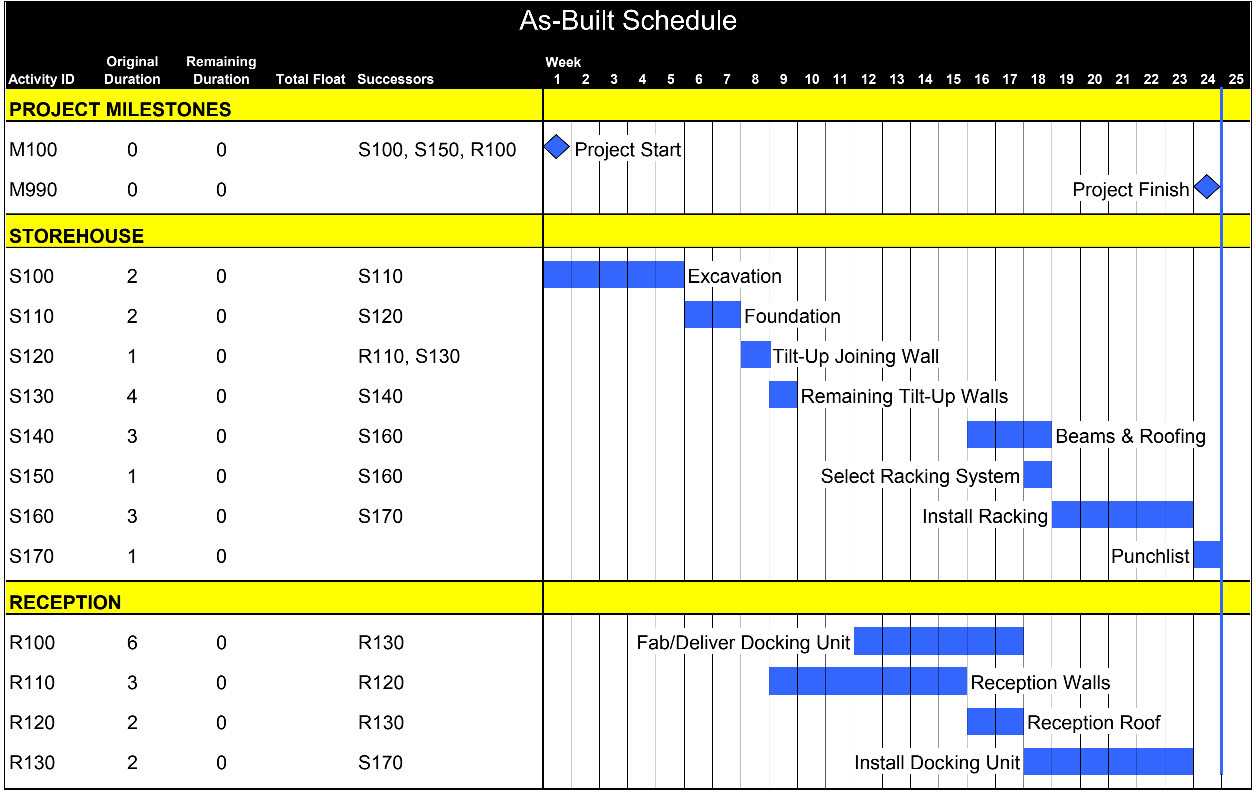


Figure 2 – Logic Diagram

Figure 3 shows the as-built schedule for the same project.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0		
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	0		S160
S150	1	0		S160
S160	3	0		S170
S170	1	0		
RECEPTION				
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	0		S170

Figure 3 – As-Built Schedule

The project actually took 24 weeks to complete. Table 1 summarizes relevant information from the project records, outlining the events that occurred during the project.

Week	Contractor's Records	Owner's Records
1	Mobilized excavator and crew; layed out building pad and began excavation at storehouse area; hit existing underground storage tank (UST) on Thursday that was shown on the project drawings as outside of the building footprint; material in building footprint smells contaminated and may require remediation or replacement; wrote RFI and moved crew to far side of building away from UST area for remainder of week	Contractor mobilized excavation crew on Monday; performed survey of building pad and placed EandS controls; began excavation late Monday; uncovered UST on Thursday (received RFI); called enviro. consultant; and they can be on site on Tuesday
2	Operator showed on Monday but refused to continue work without knowing what contamination was; got a new operator on Wednesday and continued excavation outside of contaminated area; completed all available excavation by Friday AM; received direction to over-excavate soil beginning on Monday	Enviro. consultant verified VOC in soil on Tuesday; submitted report on Friday stating that contamination is below hazardous threshold; soil can be over-excavated, aerated for one week, and replaced; consultant will be on site to monitor; contractor to begin on Monday and submit LS proposal for added work by Friday; will track TandM in the mean time just in case
3	Removed UST and began excavation of contaminated material as directed by enviro. consultant; stockpiling on site and pushing around as directed; not enough footings available to begin concrete work and site is a mess with stockpiles	Enviro. consultant monitoring remediation work; contractor submitted LS proposal for mitigation on Wednesday; meeting on Friday to negotiate proposal
4	Continuing excavation and mitigation of contaminated soil as directed by enviro. consultant; begin backfilling excavation with mitigated material as directed; executed change order for work; no time extension granted, but owner agreed to revisit the issue later in the job	Enviro. consultant continues to monitor ongoing remediation work; contractor submitted revised proposal on Tuesday; contract price adjustment in conformance with the revised proposal was returned to contractor; contractor also requested a two-week time extension, but that was not executed, because it is still early in the job and the delay may be recovered
5	On Monday, received a letter from the docking unit supplier stating that its plant is at capacity and our fabrication will start six weeks from today; told them that they would be impacting our schedule and that we cannot wait that long; completed backfill of over-excavation and restoration of all footing trenches; will proceed with footings next week	Contractor had reduced crew completing backfilling of over-excavation and footing trenches; footing rebar delivered to site on Thursday; footing bottom inspections scheduled for Monday, with placements planned on Monday and Thursday next week
6	Completed footing placements; proceeding with foundation walls; installed U/G for bathroom at reception and U/G electrical conduits for service	Footing placements completed on Monday and Thursday; contractor is forming and reinforcing foundation walls on Monday's footings; also completed underground utility work to building
7	Contacted casting yard on Monday—all tilt-up panels are ready for delivery; scheduled joining wall for next Monday; completed and backfilled all foundations	Contractor completed FRP of all foundations on Tuesday; last foundations were stripped and backfilled on Friday
8	Joining wall delivered Monday; set-up for raising; raised joining wall on Wednesday; exterior wall panels delivered on Thursday; setting up for raising next week	Tilted up joining wall on Wednesday; exterior wall panels delivered on Thursday; several panels had honeycombing; contractor followed specified repair procedures

Week	Contractor's Records	Owner's Records
9	All panels on site; raising began on Monday; connecting and providing temporary bracing per erection plan; also began framing steel stud walls at reception; panel erection subcontractor worked through Saturday to complete work and demobilized	Panel erection proceeding according to accepted erection plan; light-gage steel framing at reception also began; worked Saturday to finish all panel erection, but no steel or roofing materials have been delivered to site yet; noted concern to contractor as we were three weeks behind schedule according to the last schedule update and we could recover that time if we get roofing started next week
10	Continuing steel stud work at reception; cleaning up from panel erection and fine grading up to building	Light-gage framing at reception area continues and is 50% complete by the end of the week; minimal other work underway; no structural steel or joists on site
11	Completed framing work and exterior wall and roof sheathing at reception; installing EIFS panels and roof membrane and proceeding with interior rough-in; contacted docking unit supplier to verify start of fabrication and they said fabrication will begin next week with delivery anticipated in six weeks; this is going to be a delay	Reception area framed and sheathed; contractor is proceeding with electrical rough-in at stud walls and bathroom plumbing in reception area; note: these MEP details are not in the contractor's schedule; when asked to add them for tracking purposes, contractor indicated that they were included in the "Reception Walls" activity; still no structural steel, joists, or standing-seam materials on site
12	Completed electrical rough-in and bathroom plumbing; completed exterior panels at reception; span on installed tilt-up panels does not appear to match joist shop drawings; survey on site to verify; will field modify joists as necessary.	Surveyor on site verifying tilt-up panel installation. Contractor running conduit and plumbing in reception.
13	Steel and roof panels arrived on Monday and beam erection began, but first beam was three inches longer than bay; the steel matches the accepted shop drawings and the contract structural drawings, but the panel tie-in points do not appear to match up; survey showed that installed panels match with accepted erection drawings, but architectural drawings showing center-to-center wall dimensions and panel dimensions do not match structural drawings; erected bay is three inches shorter than shown on the structural drawings; steel and roof panels will have to be modified; submitted procedures.	Structural steel and roofing panels arrived on Monday; contractor began erection but steel did not match up with panel tie-in points; beams are three inches too long; contractor proposed field cutting steel; that can be done per spec, but full roof panels must be trimmed by manufacturer to maintain warranty; electrical and plumbing work at reception passed inspections on Wednesday.
14	Owner will not allow field modification of roof panels; panels to be returned to the supplier for modification. Proceeded with joist modifications.	Contractor did not verify all dimensions as required and contractor-fabricated tilt-up panels did not align with joists; contractor wants to field modify joists and roofing, but extensive field bending or cutting of roof panels may void warranty; directed contractor to return panels to manufacturer; joist modifications proceeded on site.
15	Completed reception framing and exterior panel erection.	Contractor working on reception panels.
16	Received half shipment of modified panels for storage; proceeding with roofing at reception.	Contractor working on reception roofing.
17	Reception roofing completed; docking unit to arrive next week; proceeding with joist and roofing installation at storage.	Contractor installed joists and began installing roofing panels at storage.

Week	Contractor's Records	Owner's Records
18	Received remaining roof panels; completed insulation and hang/tape/texture of drywall in reception area; ready for painting; docking unit arrived and installation began; have been waiting for owner to select racking system; supplier can provide multiple options, but final selection is becoming critical.	All modified roofing panels have been returned to site.
19	Began racking system installation; continuing docking unit installation.	Contractor is proceeding with racking and docking unit installation.
20	Began racking system installation; continuing docking unit installation.	Contractor is proceeding with racking and docking unit installation.
21	Began electrical installation at storage.	Racking system installation is nearing completion, but contractor is having difficulty with docking unit installation; had to reset docking unit because of misalignment.
22	Completed electrical; completing racking system and docking unit.	Contractor continues work on racking and electrical. Docking unit still incomplete. Provided contractor with punch list.
23	Completed all work; proceeding with minor punch list items.	Contractor completed racking and electrical; proceeding with punch list items.
24	Completed punch list; signed off; project complete.	Signed off on final punch list completion.

Table 1─Summary of Prpject Information

The summary of project information will be used in conjunction with the project schedules. The goal of the schedule analysis will be to identify the specific activity delays that resulted in the overall eight-week delay to project completion. Including the as-built schedule, there were six updates to the baseline schedule. The updates were completed after every four weeks of work. Thus, there will be six windows analyzed, as listed in table 2.

Window	Window Period	Schedule at Window Start	Schedule at Window Finish
1	Weeks 1 through 4	Baseline (As-Planned)	Update 1
2	Weeks 5 through 8	Update 1	Update 2
3	Weeks 9 through 12	Update 2	Update 3
4	Weeks 13 through 16	Update 3	Update 4
5	Weeks 17 through 20	Update 4	Update 5
6	Weeks 21 through 24	Update 5	Update 6 (As-Built)

Table 2─Analysis of Six Windows

The analysis will be performed in two variations—first by inserting only progress and then by inserting progress and fragnets to model the delays. Correlated to the RP/FSA Taxonomy, the analyses are classified as follows:

Analysis by Inserting only Progress and Identifying Delays

Retrospective, observational, dynamic, contemporaneous as-is (MIP 3.3)

This analysis will be performed based on the method implementation protocol (MIP) described in Section 3.3 of the RP. The analysis is classified as *retrospective* because the analysis is performed after the delay events and the impacts of those events have occurred and the outcome is known. The analysis is *observational* because no activities are added or subtracted from the schedule to model delays or changes to the plan; the progress from each update is simply compared to the plan from the previous update to identify delays. The analysis is *dynamic* because the critical path shifts according to the progress of the project; the baseline critical path is not considered to be the only critical path throughout the project duration. The analysis is *contemporaneous as-is* because there are no logic changes in the project updates that must be considered in the analysis.

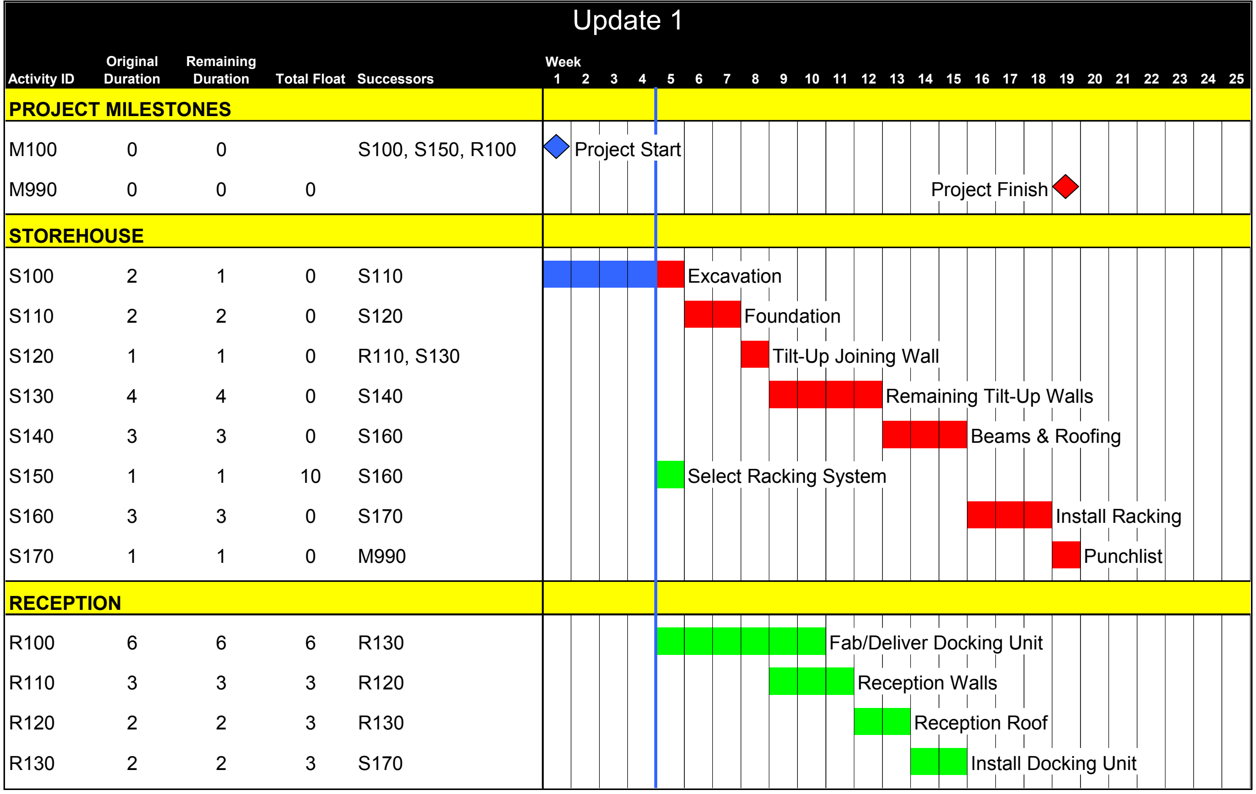
Analysis by Inserting Progress and Fragnets to Model Delays

retrospective, additive modeling, multiple-base (rp fsa 3.7)

This analysis will be performed based on the MIP described in Section 3.7 of the RP. The analysis is classified as *retrospective* because the analysis is performed after the delay events and the impacts of those events have occurred and the outcome is known. The analysis is *additive modeling* because fragnets are added to the schedules to model delays. The analysis is *multiple base* because the fragnets are added to the latest accepted project schedule at the time each delay event occurred; they are not all added to the baseline schedule as would be the case in a single-base (impacted-as-planned) analysis.

Analysis by Inserting only Progress and Identifying Delays

The first analysis will be undertaken based on Method Implementation Protocol (MIP) 3.3. That method recommends the implementation of the source validation protocols (svps) as follow: svp 2.1 (baseline validation) and svp 2.3 (update validation). For enhanced implementation, svp 2.2 (as-built validation) may also be performed. other recommendations from the rp include: (1) recognize all contract time extensions granted, (2) identify the critical path activity that will be used to track the loss or gain of time for the overall network, and (3) separately identify activities that will be used to track intra-network time losses and gains, such as on interim milestones. for the purpose of this example implementation, all of the information sources have been evaluated based on the svps and deemed to be reliable sources of project information for the analysis. There have been no contract time extensions granted. The activity that will be used to track delays to the overall network will be activity m990. There are no intermediate milestones on the project.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	1	0	S110
S110	2	2	0	S120
S120	1	1	0	R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	10	S160
S160	3	3	0	S170
S170	1	1	0	M990
RECEPTION				
R100	6	6	6	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	3	S170

Figure 4 - Window 1, Update 1

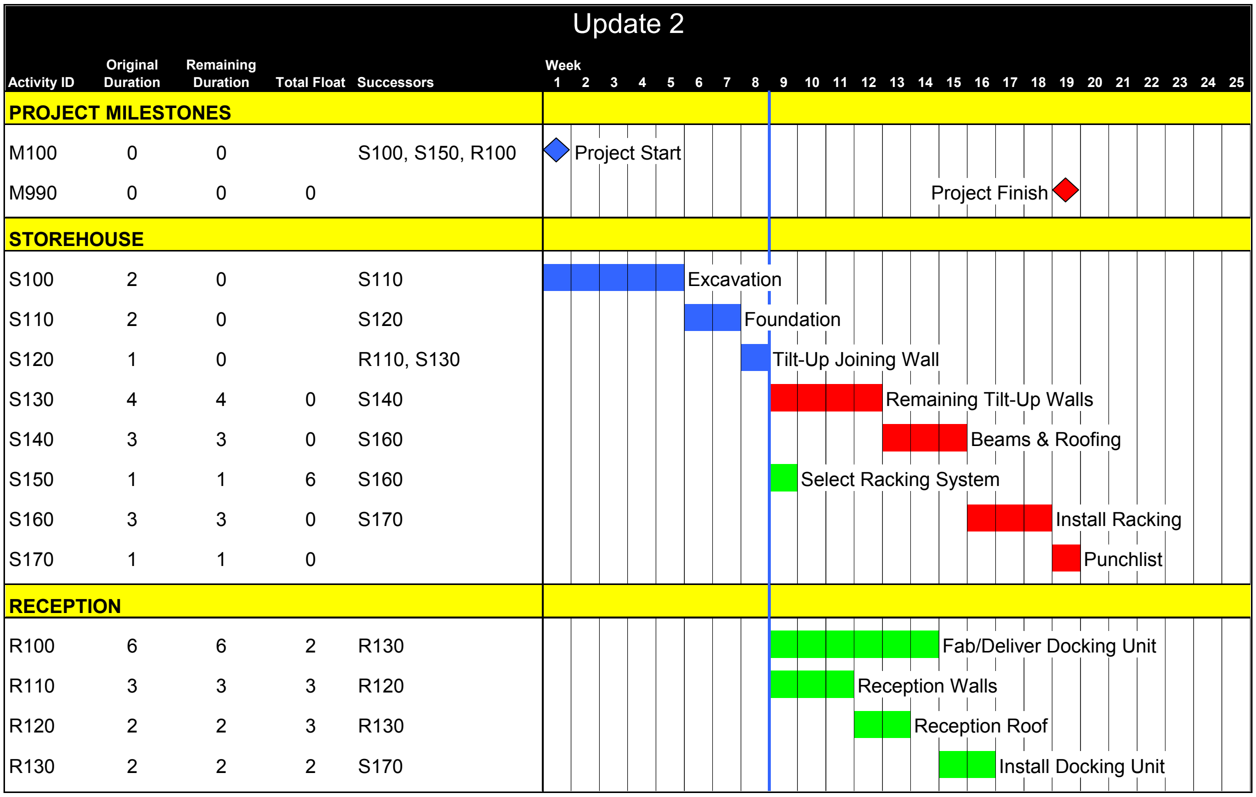
The first schedule update is shown in figure 4 As of week 5—the data date of the first update—the project finish date has been delayed three weeks. Excavation began as planned, but made slower-than-expected progress. The reason for the slower-than expected progress may be differing subsurface conditions, failure to apply sufficient resources to maintain the planned duration, or any variety of factors. However, when inserting only the progress from the next update, it is not necessary to determine the reason for the delay to the activity while performing the schedule analysis. If necessary, that determination will be made in a secondary analysis of the causes of (and perhaps responsibilities for) the specific activity delays.

Excavation was critical when it began, and remained critical as of the end of the update period. The forecast finish of excavation is now three weeks later than its forecast finish at the start of the update period. This three-week delay to a critical activity has resulted in a three-week delay to project finish. The two other logic paths in the schedule—beginning with select racking system and fab/deliver docking walls—have also experienced delays. However, those delays have not contributed to the overall delay to project finish because those paths still have float remaining. At the end of the window, the critical path begins with the remainder of Excavation.

A summary of the analysis of the first window is tabulated in table 3. Starts and finishes followed by an "a" represent actual progress, as reported in the update at the end of the window. All other dates are forecast (planned) dates, comparing the update at the start of the window to the update at the end of the window. The notes on the following table describe the type of delay (or savings) experienced by the critical activity. The following abbreviations are used: STE (slower-than-expected), BTE (better-than-expected).

Activity Description	**Start of Window**		**End of Window**		**Activity Delay or (Savings)**	**Project Delay or (Savings)**	**Forecast Project Finish Week**	**Notes**
	Planned Start	**Planned Finish**	**Revised Start**	**Revised Finish**				
Net Delay or (Savings) as of Baseline						0	16	
Project Start	1		1a		0	0	16	As-Planned
Excavation	1	2	1a	5	3	3	19	STE Progress
Net Delay or (Savings) as of Update 1						**3**	**19**	

Table 3 – Summary of Analysis of First Window



Update 2

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	6	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
R100	6	6	2	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	2	S170

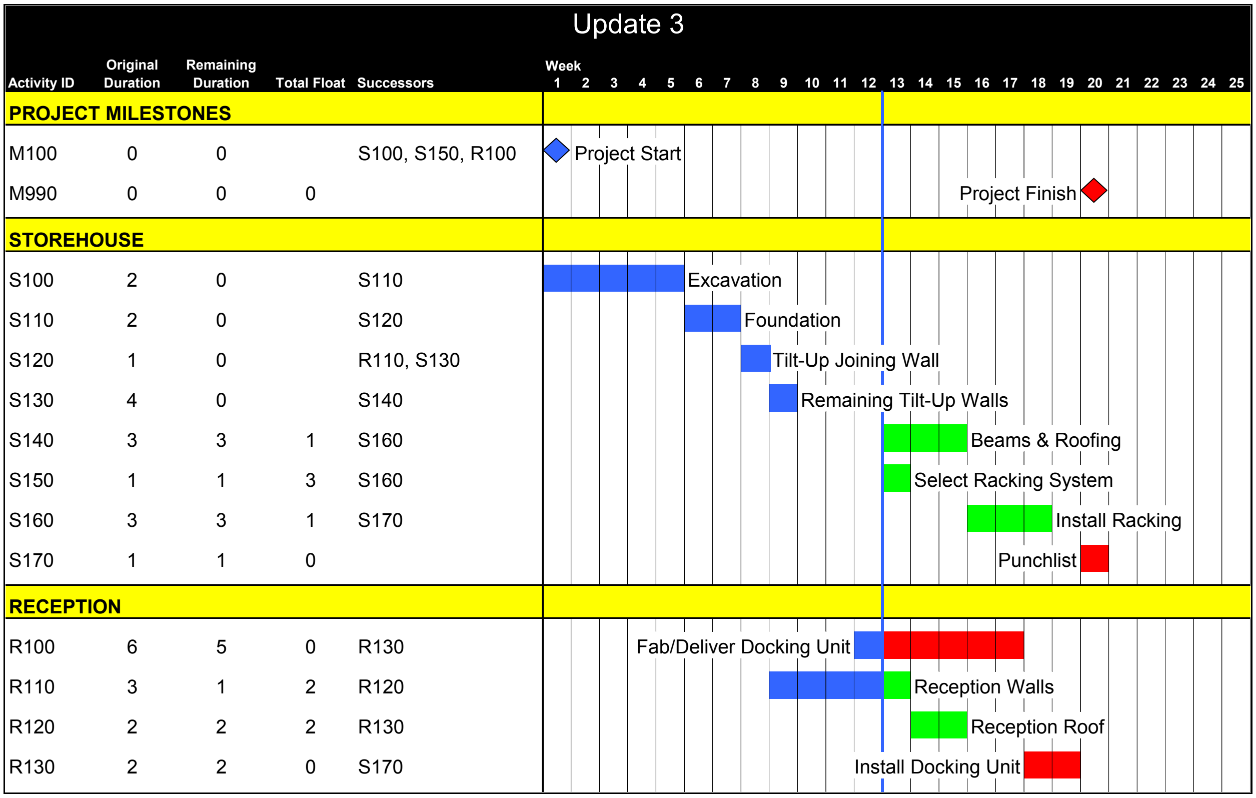
Figure 5 - Window 2, Update 2

The second update is shown in figure 5. As of the first update, the critical path began with the remainder of the excavation activity, which was forecast to be completed in week 5. Looking at the second update, it is observed that excavation was completed as forecast in the update at the beginning of the window. Moreover, the next two activities on the critical path—foundation and tilt-up joining wall—were also completed as forecast. Although the other two paths on the project still have not made any progress, there has been no additional project delay during the window, and project finish is still scheduled for week 19. at the end of the window, the critical path begins with remaining tilt-up walls.

A summary of the analysis of the second window is tabulated in table 4. Note that the excavation activity is in progress at the start of the window. The remainder of the activity is critical, as noted under the activity description, and the start date listed under the revised start column refers to the start date for that remainder. Because the activity is in progress at the start of the window, the start date for the remainder is the same as the start date for the window.

Activity Description	Start of Window		End of Window		Activity Delay or (Savings)	Project Delay or (Savings)	Forecast Project Finish Week	Notes
	Planned Start	Planned Finish	Revised Start	Revised Finish				
			Net Delay or (Savings) as of Update 1			3	19	
Excavation (Remainder)	5	5	5a	5a	0	0	19	As-Planned
Foundation	6	7	6a	7a	0	0	19	As-Planned
Tilt-Up Joining Wall	8	8	8a	8a	0	0	19	As-Planned
			Net Delay or (Savings) as of Update 2			**3**	**19**	

Table 4 – Summary of Analysis of Second Window



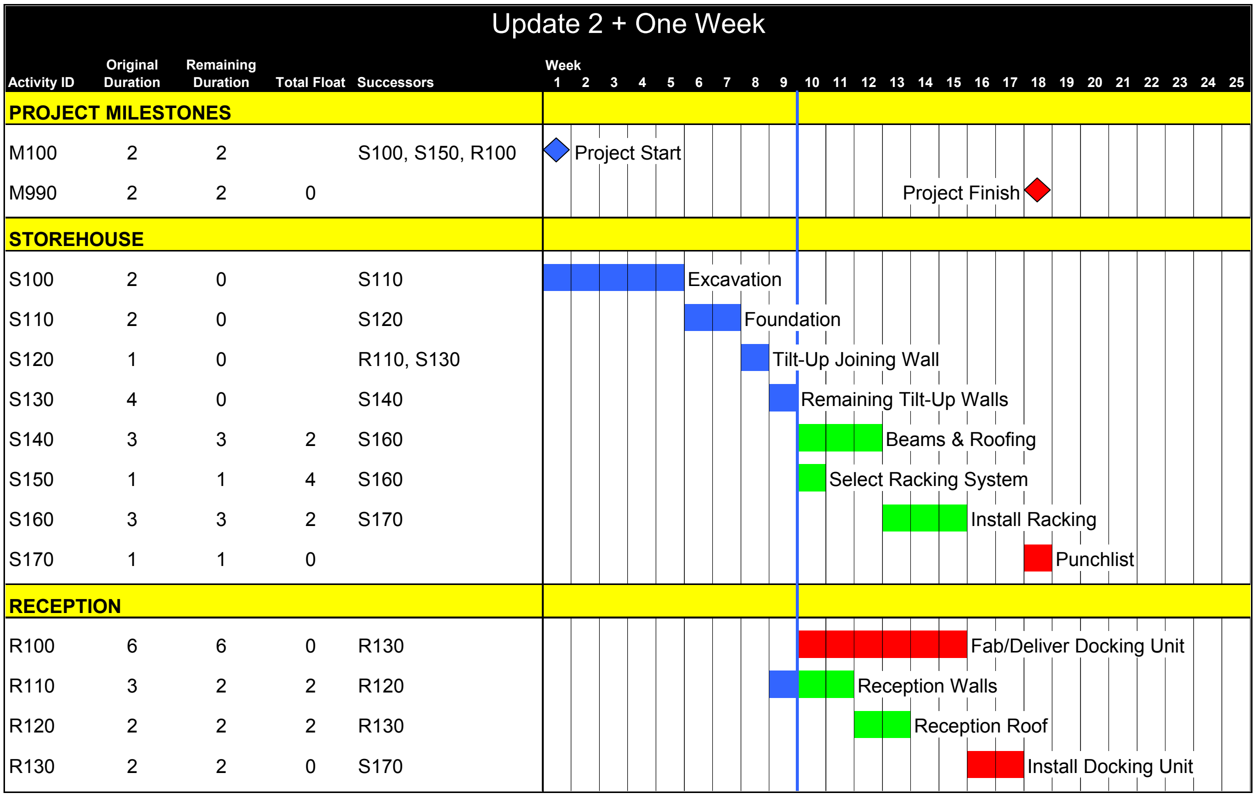
Update 3

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	3	1	S160
S150	1	1	3	S160
S160	3	3	1	S170
S170	1	1	0	
RECEPTION				
R100	6	5	0	R130
R110	3	1	2	R120
R120	2	2	2	R130
R130	2	2	0	S170

Figure 6 - Window 3, Update 3

The third update is shown in figure 6. The third update shows an overall delay of one week to project finish occurred during the window between updates 2 and 3. However, the remaining tilt-up walls activity, which was critical at the start of the window, was actually completed three weeks earlier than previously forecast. as with the previous delay to the excavation activity, the better-than-expected progress of the remaining tilt-up walls could have a variety of reasons. The contractor may have applied more resources to the activity than originally planned or the method of erection may have been changed. Again, the determination of the cause of the better-than-expected progress will be made in a subsequent analysis. For the time being, the analysis will be confined to determining to what extent the better-than-expected progress of the remaining tilt-up panels caused any savings to the forecast project finish.

in addition, it can be seen that the critical path has shifted in the third update. That shift is the result of the better-than-expected progress on the critical activity and the late start of fab/deliver docking unit. That activity is now the first activity on the new critical path that is driving project finish. Now that a shift in the critical path has been identified, it is necessary to determine when the shift occurred. This can be done by iteratively adding the progress recorded at the end of the window into the update at the beginning of the window. The schedule in figure 7 shows update 2 with one week of progress from update 3 added.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	2	2		S100, S150, R100
M990	2	2	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	3	2	S160
S150	1	1	4	S160
S160	3	3	2	S170
S170	1	1	0	
RECEPTION				
R100	6	6	0	R130
R110	3	2	2	R120
R120	2	2	2	R130
R130	2	2	0	S170

Figure 7 – Update 2 Plus One Week

Two activities made progress during the first week of the window, as reported in update 3. remaining tilt-up walls has been entirely completed and reception walls has begun. Adding that progress to update 2 and rescheduling the project as of the end of week 9 results in a one week savings to the forecast project finish. the three-week savings to the completion of the remaining tilt-up walls activity was not able to be fully realized as a savings to project finish because of the critical path shift, which occurs in week 9.

At the beginning of the window, the path of activities that begins with the fab/deliver docking unit activity had two weeks of float. In other words, the critical path, which began with the remaining tilt-up walls activity was forecast to take two weeks longer to complete. The float on the docking-unit path was completely absorbed when the tilt-up-walls path experienced the three-week savings.

It is noted that the docking unit path had only two weeks of float, and the tilt-up walls path experienced a three-week savings. Therefore, the analyst could consider that the docking unit has actually caused a one-week delay. Alternatively, if the docking unit activity had made progress in accordance with the baseline schedule or the first update, the project would have been able to achieve the full three-week savings associated with the better-than-expected progress of the tilt-up walls. However, both of these considerations are inconsistent with the actual events of the project.

Imagining that a scheduling meeting occurs every monday morning, project participants would have received update 2 at the beginning of week 9. The subcontractor responsible for fab/deliver docking unit would look at this update and determine that its work has two weeks of float. Thus, it would appear unreasonable to inform that subcontractor that its activity had caused a delay at the following scheduling meeting. It would be more reasonable to inform the subcontractor that the remaining tilt-up walls had been completed and that fab/deliver docking unit was now on the critical path to an (earlier) project completion. While it might be tempting to state that the savings to project completion would have been greater if work on fab/deliver docking unit had started, the project participants would not have known that at the start of the week. The hypothetical situation is not consistent with the contemporaneous information that was available while the work was being performed.

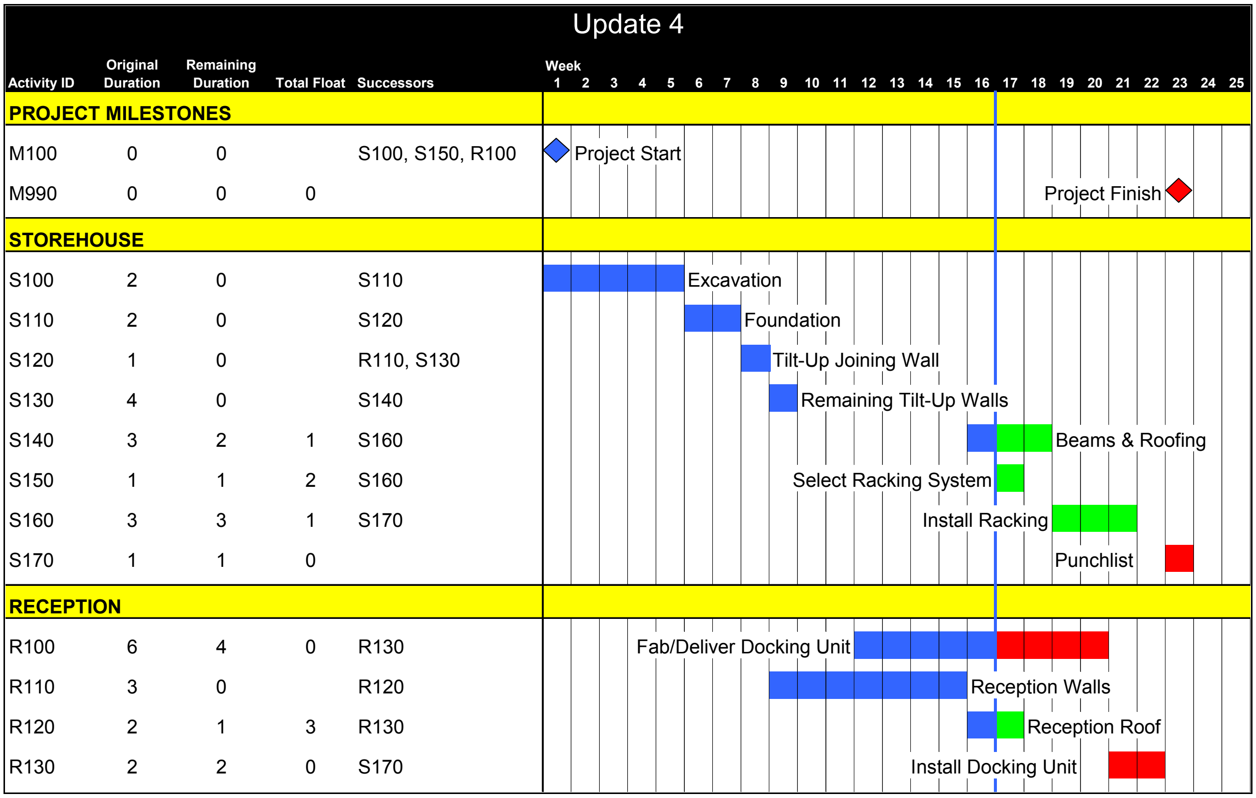
Thus, at the start of week 10, fab/deliver docking unit is critical, but it has not yet caused any project delay. Looking again to update 3, it can be seen that the fab/deliver docking unit activity did not actually begin until week 12. That late start caused a two-week delay to project finish because its timely start became critical as of week 10.

In sum, the overall one-week delay to project finish was the result of a one-week savings associated with the better-than-expected progress of the remaining tilt-up walls and a two-week delay associated with the late start of fab/deliver docking unit.

A summary of the analysis of the third window is tabulated in table 5. In this case, the savings to the critical activity's finish differed from the savings to the overall project finish date because of the critical path shift that occurred during the window.

Activity Description	Start of Window		End of Window		Activity Delay or (Savings)	Project Delay or (Savings)	Forecast Project Finish Week	Notes
	Planned Start	Planned Finish	Revised Start	Revised Finish				
Net Delay or (Savings) as of Update 2						3	19	
Remaining Tilt-Up Walls	9	12	9a	9a	(3)	(1)	18	BTE Progress
Critical Path Shift								
fab/deliver docking unit	10	15	12a	17	2	2	20	Late Start
Net Delay or (Savings) as of Update 3						**4**	**20**	

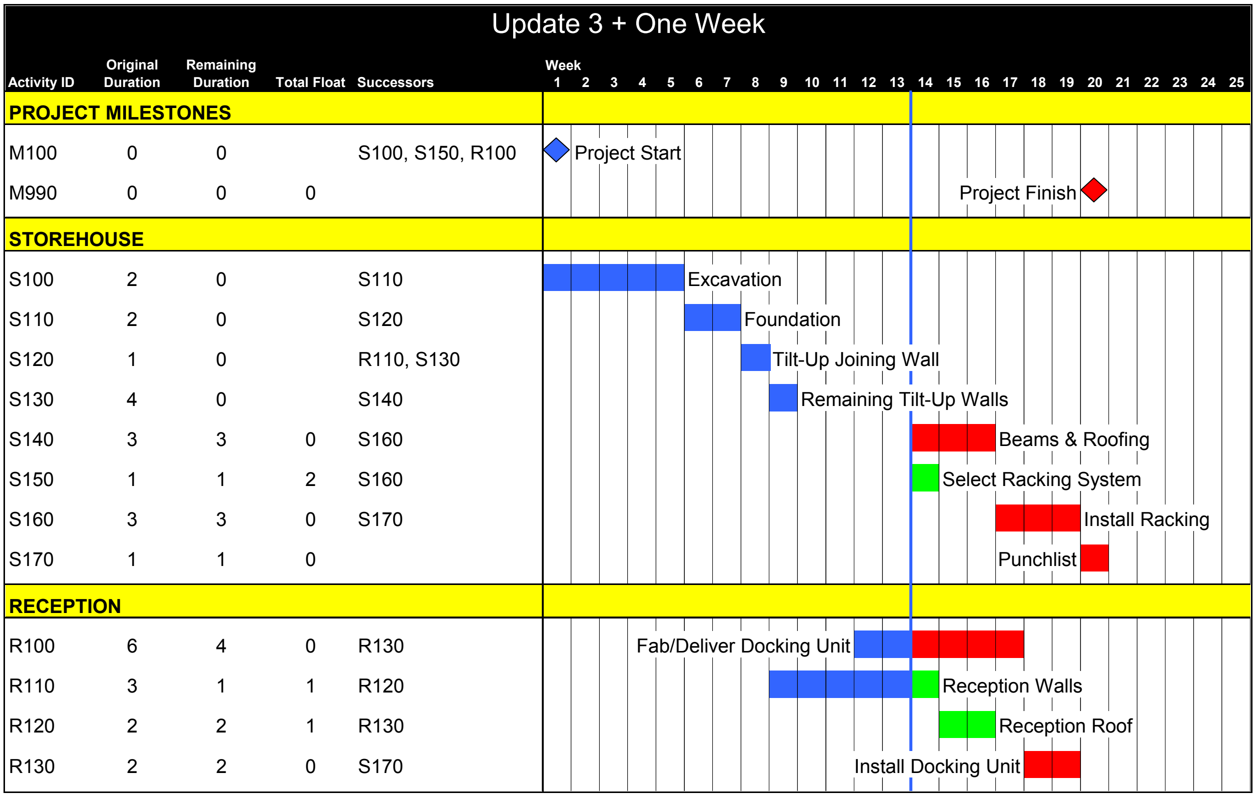
Table 5 – Summary of Analysis of Third Window



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	2	1	S160
S150	1	1	2	S160
S160	3	3	1	S170
S170	1	1	0	
RECEPTION				
R100	6	4	0	R130
R110	3	0		R120
R120	2	1	3	R130
R130	2	2	0	S170

Figure 8 - Window 4, Update 4

The fourth update is shown above. The critical activity at the start of the window, fab/deliver docking unit, had a remaining duration of five weeks at the start of the window. as of the start of week 17—the data date of update 4 and the end of the window 4—fab/deliver docking unit has a remaining duration of four weeks. Its one week of progress is credited in week 13, the first week of the window. During that same week, beams and roofing, which had one week of float, was scheduled to begin. However, that activity failed to start and became concurrently critical with the fab/deliver docking unit path. Figure 9 shows update 3 with one week of progress from update 4 added.



Update 3 + One Week

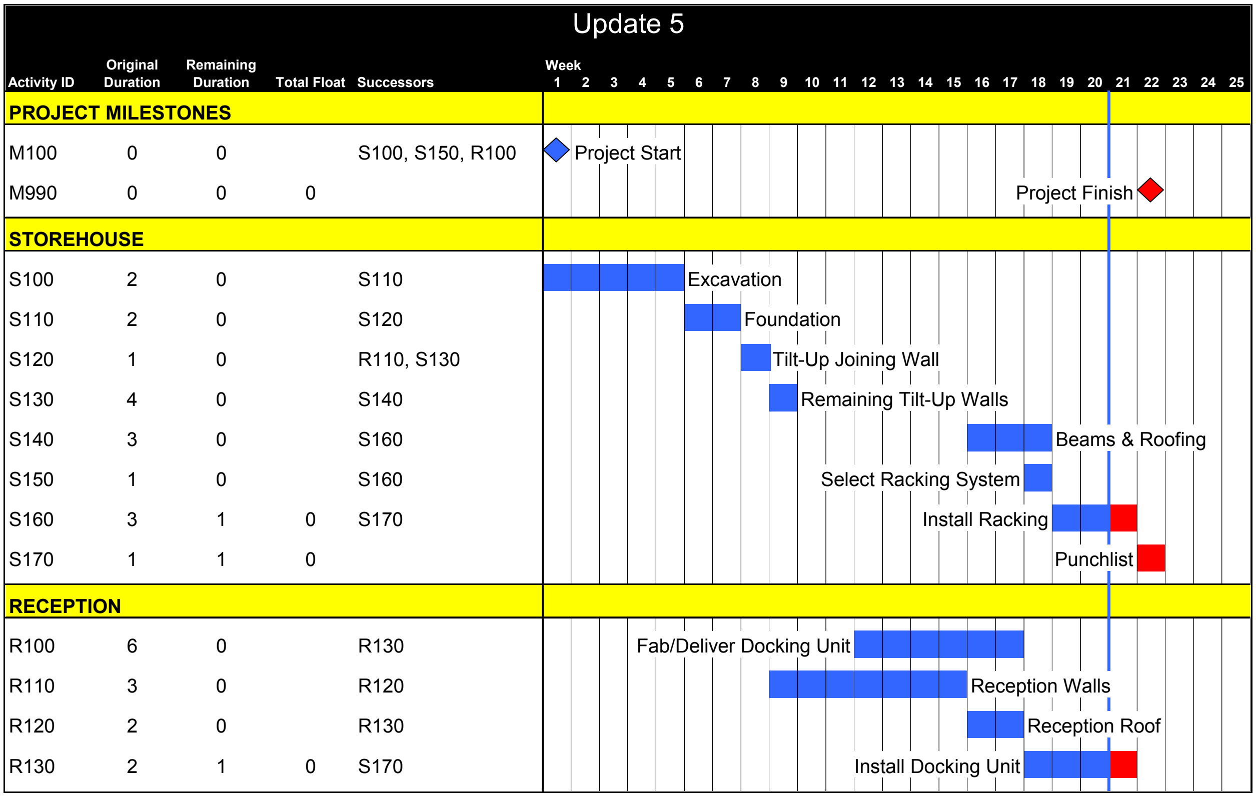
Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	3	0	S160
S150	1	1	2	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
R100	6	4	0	R130
R110	3	1	1	R120
R120	2	2	1	R130
R130	2	2	0	S170

Figure 9 – Update 3 Plus One Week

At the end of week 13, there are two concurrent critical paths—one beginning with fab/deliver docking unit and one beginning with beams and roofing. Fab/deliver docking unit does not make any additional progress during the final three weeks of the window. Because it is critical, the lack of progress results in a three-week delay to project finish. However, beams and roofing does not start until week 16. Because it became critical in week 14, beams and roofing concurrently delays project finish during weeks 14 and 15. Once it makes a week of progress in week 16, beams and roofing gains a week of float and ceases to be critical. A summary of the analysis of the fourth window is shown in table 6.

Activity Description	**Start of Window**		**End of Window**		**Activity Delay or (Savings)**	**Project Delay or (Savings)**	**Forecast Project Finish Week**	**Notes**
	Planned Start	**Planned Finish**	**Revised Start**	**Revised Finish**				
Net Delay or (Savings) as of Update 3						4	20	
fab/deliver docking unit (Remainder)	13	17	13a	20	3	2 (c), 1	23	STE Progress
Critical Path Shift (beams and roofing becomes concurrently critical with fab/deliver docking unit in Week 14)								
beams and roofing	14	16	16a	18	2	2 (c)	23	
Net Delay or (Savings) as of Update 4						**7**	**23**	

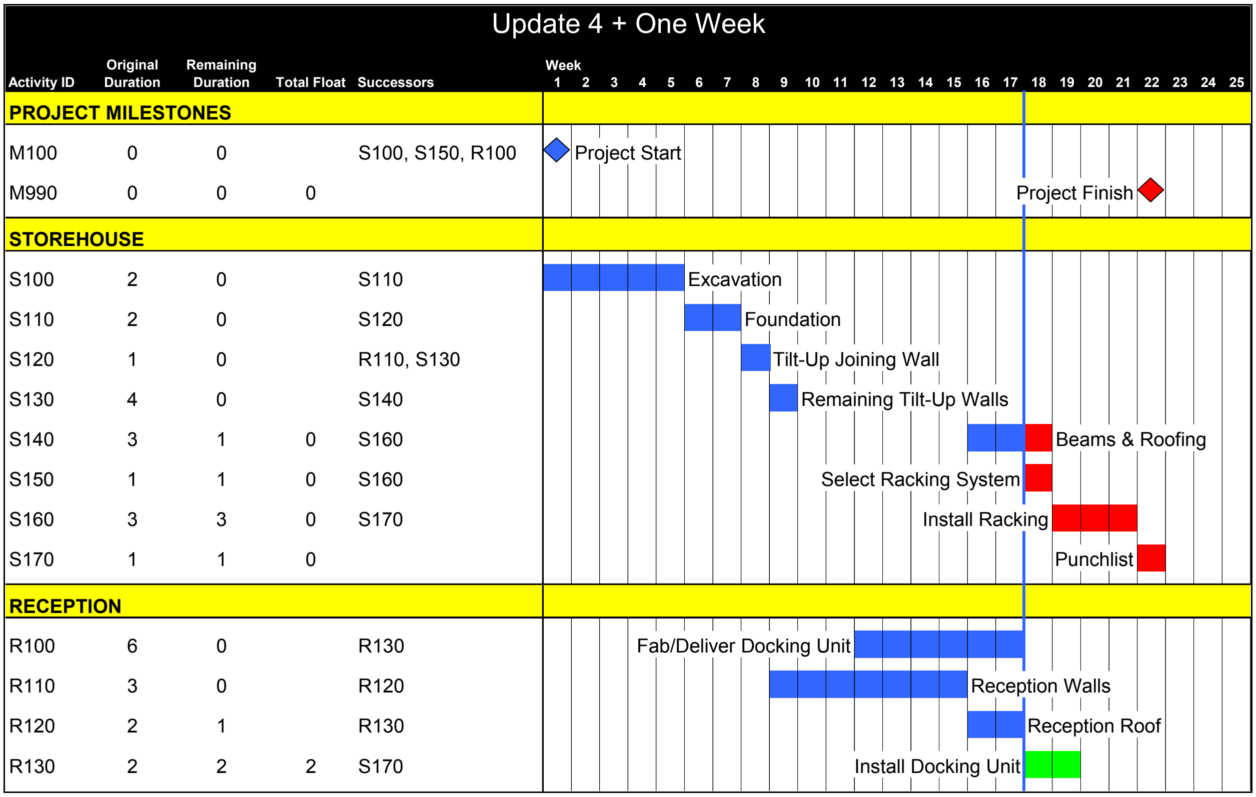
Table 6 – Summary of Analysis of Fourth Window



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	0		S160
S150	1	0		S160
S160	3	1	0	S170
S170	1	1	0	
RECEPTION				
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	1	0	S170

Figure 5 - Window 5, Update 5

The fifth update, which contains the progress made during window 5, is shown above. During the first week of the window—week 17—fab/deliver docking unit was completed. That activity was critical at the start of the window, and was not expected to be completed until week 20. The better-than-expected progress of the critical activity results in a critical path shift. Figure 11 shows update 4 with one week of progress added from update 5.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	1	0	S160
S150	1	1	0	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
R100	6	0		R130
R110	3	0		R120
R120	2	1		R130
R130	2	2	2	S170

Figure 11 – Update 4 Plus One Week

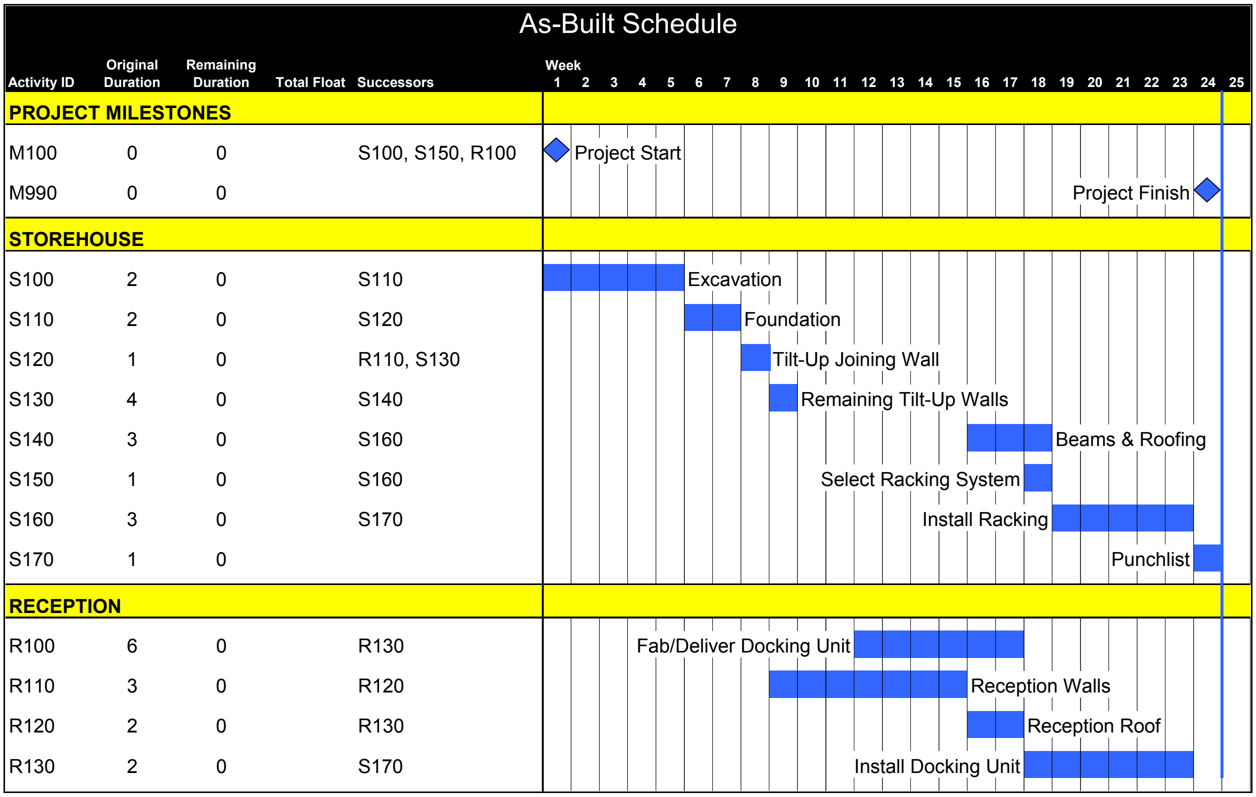
As shown in the figure 11, the better-than-expected progress of fab/deliver docking unit results in a one-week project savings. Project finish was forecast to occur in week 23 at the start of the window, and it is now forecast to occur in week 22. Beams and roofing made one week of progress in week 17, but with the completion of fab/deliver docking unit, it is now critical again. in addition, select racking system, which failed to start in week 17, has finally become critical.

As shown in figure 10, update 5, both beams and roofing and select racking system proceed as expected after week 17. Thus, there are no additional project delays caused by those activities. When they are completed in week 18, their successor, install racking, becomes critical. Meanwhile, install docking unit, which has two weeks of float as of week 18, makes only one week of progress during the remaining three weeks of the window. thus, install docking unit becomes critical at the end of the window.

A summary of the analysis of the fifth window is shown in table 7. As described previously, the critical path shifted to two activities because of the better-than-expected progress of the fab/deliver docking unit. However, both of those activities made as-planned progress, as did the subsequent critical activity. Finally, note that at the end of the period, the remainder of the install docking unit activity also has become critical (although this additional path is not noted in the table), and there will be two concurrent critical paths at the start of the next window.

Activity Description	**Start of Window**		**End of Window**		**Activity Delay or (Savings)**	**Project Delay or (Savings)**	**Forecast Project Finish Week**	**Notes**
	Planned Start	**Planned Finish**	**Revised Start**	**Revised Finish**				
Net Delay or (Savings) as of Update 4						7	23	
fab/deliver docking unit (Remainder)	17	20	17a	17a	(3)	(1)	22	BTE Progress
Critical Path Shift								
beams and roofing (Remainder)	18	18	18a	18a	0	0	22	As-Planned, Concurrent
Select Racking System	18	18	18a	18a	0			
Install Racking	19	21	19a	21	0	0	22	As-Planned
Net Delay or (Savings) as of Update 5						**6**	**22**	

Table 7 – Summary of Analysis of Fifth Window



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0		
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	0		S160
S150	1	0		S160
S160	3	0		S170
S170	1	0		
RECEPTION				
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	0		S170

Figure 12 – Window 6, As-Built Schedule

The sixth update—the final as-built schedule—is shown above. At the start of window 6, project finish was forecast to occur in week 22. However, project finish actually occurred in week 24. Thus, there are two weeks of project delay in window 6 for which activity delays must be identified. As of update 5, the remainders of the install racking and install docking unit activities were both critical. Both of the activities were forecast to finish in week 21. However, both made slower-than-expected progress and finished in week 23. Thus, they concurrently caused the two-week delay to project finish. Their successor, punch list, was completed as expected after that two-week delay. A summary of the analysis of the sixth and final window is tabulated in table 8.

Activity Description	**Start of Window**		**End of Window**		**Activity Delay or (Savings)**	**Project Delay or (Savings)**	**Forecast Project Finish Week**	**Notes**
	Planned Start	**Planned Finish**	**Revised Start**	**Revised Finish**				
Net Delay or (Savings) as of Update 5						6	22	
Install Racking (Remainder)	21		21a	23a	2	2 (c)	24	STE Progress, Concurrent
Install Docking Unit (Remainder)	21	21	21a	23a	2	2 (c)	24	
Punchlist	24	24	24a	24a	0	0	24	As-Planned
Project Finish		24		24a	0	0	24	As-Planned
Net Delay or (Savings) as of Update 6						**8**	**24**	

Table 8 – Summary of Analysis of Sixth Window

Summary of Analysis Without Fragnet Insertions

Table 9 outlines a summary of the individual activity delays that contributed to overall project delay, as determined by the preceding six windows analyses. In calculating activity totals, concurrent delays were allocated equally among the activities that contributed to the project delay.

Activity	**Window**						**Total**
	1	**2**	**3**	**4**	**5**	**6**	
Project Start	0	0	0	0	0	0	**0**
Excavation	3	0	0	0	0	0	**3**
Foundation	0	0	0	0	0	0	**0**
Tilt-Up Joining Wall	0	0	0	0	0	0	**0**
Remaining Tilt-Up Walls	0	0	(1)	0	0	0	**(1)**
beams and roofing	0	0	0	2 (c)	0	0	**1**
Select Racking System	0	0	0	0	0	0	**0**
Install Racking	0	0	0	0	0	2 (c)	**1**
Fab/Del Docking Unit	0	0	2	2 (c), 1	(1)	0	**3**
Reception Walls	0	0	0	0	0	0	**0**
Reception Roof	0	0	0	0	0	0	**0**
Install Docking Unit	0	0	0	0	0	2 (c)	**1**
Punchlist	0	0	0	0	0	0	**0**
Project Finish	0	0	0	0	0	0	**0**
Total	**3**	**0**	**1**	**3**	**(1)**	**2**	**8**

Table 9 – Summary of Individual Activity Delays

The concurrent delays shown in the table can be simplified by distributing the final apportioned delay to each activity through the table. The simplified table is shown table 10.

Activity	**Window**						**Total**
	1	**2**	**3**	**4**	**5**	**6**	
Project Start	0	0	0	0	0	0	**0**
Excavation	3	0	0	0	0	0	**3**
Foundation	0	0	0	0	0	0	**0**
Tilt-Up Joining Wall	0	0	0	0	0	0	**0**

Activity	Window						Total
	1	2	3	4	5	6	
Remaining Tilt-Up Walls	0	0	(1)	0	0	0	**(1)**
beams and roofing	0	0	0	1	0	0	**1**
Select Racking System	0	0	0	0	0	0	**0**
Install Racking	0	0	0	0	0	1	**1**
Fab/Del Docking Unit	0	0	2	2	(1)	0	**3**
Reception Walls	0	0	0	0	0	0	**0**
Reception Roof	0	0	0	0	0	0	**0**
Install Docking Unit	0	0	0	0	0	1	**1**
Punchlist	0	0	0	0	0	0	**0**
Project Finish	0	0	0	0	0	0	**0**
Total	**3**	**0**	**1**	**3**	**(1)**	**2**	**8**

Table 10─Simplified Table

In the Baseline schedule, project finish was forecast for week 16. Project finish actually occurred in week 24. as shown through the preceding analysis, the eight-week delay to project finish was the result of:

- a three-week delay caused by excavation;
- a one-week savings associated with remaining tilt-up walls;
- a one-week delay caused by beams and roofing;
- a one-week delay caused by install racking;
- a three-week delay caused by fab/deliver docking unit; and
- a one-week delay caused by install docking unit.

Now that the activity delays that contributed to the overall project delay have been quantified, the delay analysis would be followed by a responsibility analysis to determine which party was responsible for each delay. The responsibility analysis would include a review of contract requirements and the specific events that led to the delay. It is possible that more than one party might be identified as the responsible party for a particular activity delay. It is also possible that some of the delays might be associated with weather or other events for which both parties are contractually relieved of responsibility.

ANALYSIS BY INSERTING PROGRESS AND FRAGNETS TO MODEL DELAYS

The second analysis will be undertaken based on MIP 3.7. That method recommends the implementation of SVP 2.1 (baseline validation), SVP 2.3 (update validation), and SVP 2.4 (delay identification and quantification). For enhanced implementation, SVP 2.2 (as-built validation) may also be performed. The other recommendations from the RP include the following:

- recognize all contract time extensions granted;
- verify that there is at least one critical path, using the longest path criterion that starts at NTP or some earlier start milestone and ends at a finish milestone that is the latest occurring schedule activity in the network, after the insertion of delay activities;
- tabulate and justify each change made to the base model to create the impacted schedule;
- use both the longest path and the least float criteria to identify the controlling chain of activities;
- establish a new analysis period with each significant change in the critical path chain of activities; and
- prepare a tabulation that summarizes the variances quantified for each analysis period and reconcile the total to the result that would be obtained through a competent implementation of MIP 3.1.

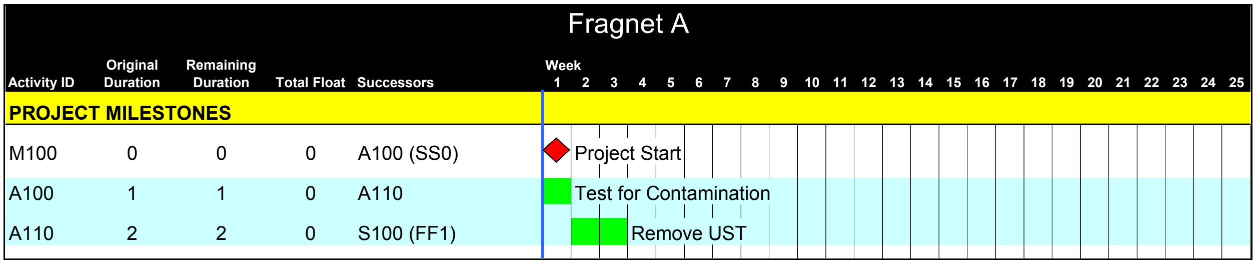
For the purpose of this example implementation, all of the information sources have been evaluated based on the SVPs and deemed to be reliable sources of project information for the analysis. There have been no contract time extensions granted. The schedule will be progressed to the point of each delay, and the critical path will be reviewed with the insertion of each fragnet. The total float and longest path of the schedule will be evaluated with each fragnet insertion, and a final tabulation of delays will be prepared, and checked against the overall eight-week project delay.

Window 1

In order to model delays with the insertion of fragnets, details of the project must be reviewed in order to have a basis for the creation of the fragnets and the insertion of the fragnets into the schedule using appropriate logic ties.

Based on a review of the project summary information, the excavation activity in the storehouse area was impacted because of the discovery of an existing underground storage tank (UST) that was shown on the project drawings as outside of the building footprint.

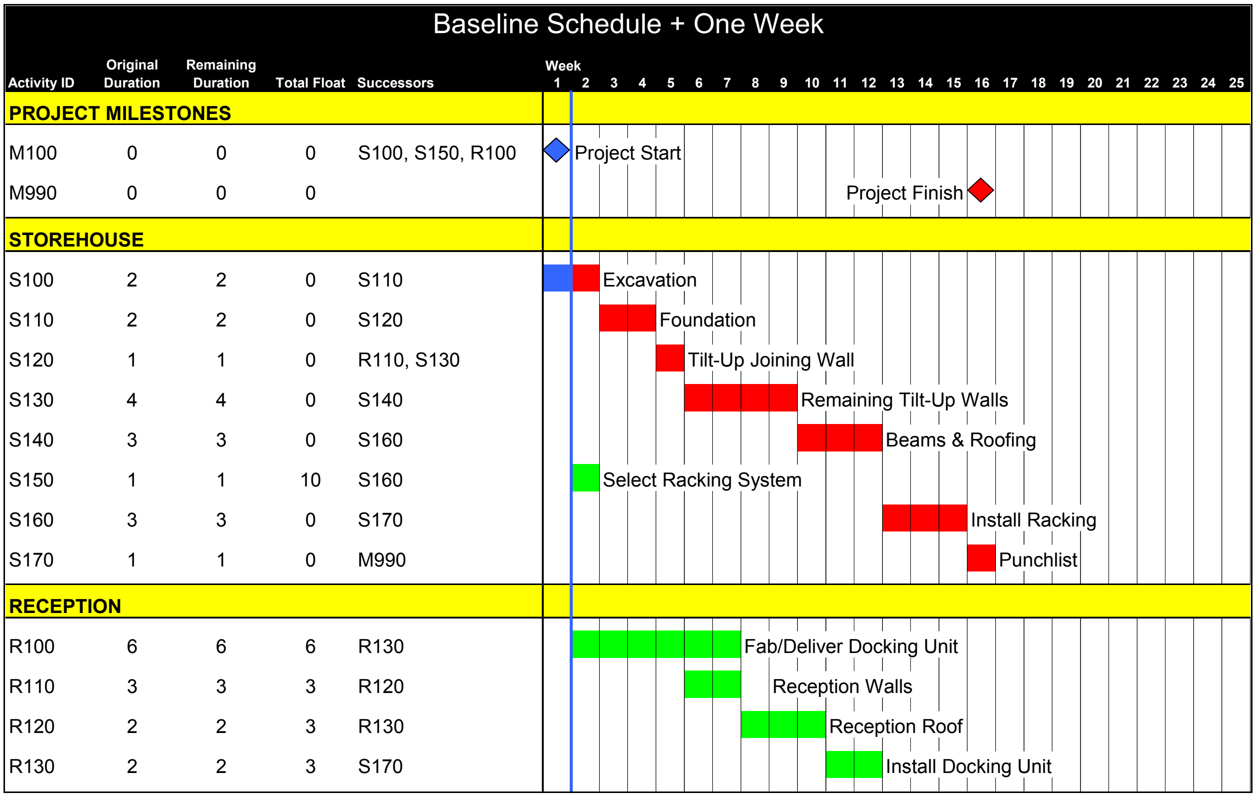
The excavation activity began as planned in week 1. However, at the end of the week, the storage tank was discovered. Excavation proceeded, but was suspended in the area of the storage tank. One week was spent testing the surrounding soil for contamination and developing appropriate remediation efforts. Then, two weeks were spent removing the UST and contaminated soil before completing excavation activities. Fragnet A was developed to model the work associated with the UST. The following figure shows the activities in fragnet A. Activities from the project schedule are listed only to show the logic between the fragnet and the existing activities. All relationships are finish-to-start with zero lag, unless detailed in parentheses.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0	0	A100 (SS0)
A100	1	1	0	A110
A110	2	2	0	S100 (FF1)

Figure 13 – Fragnet A

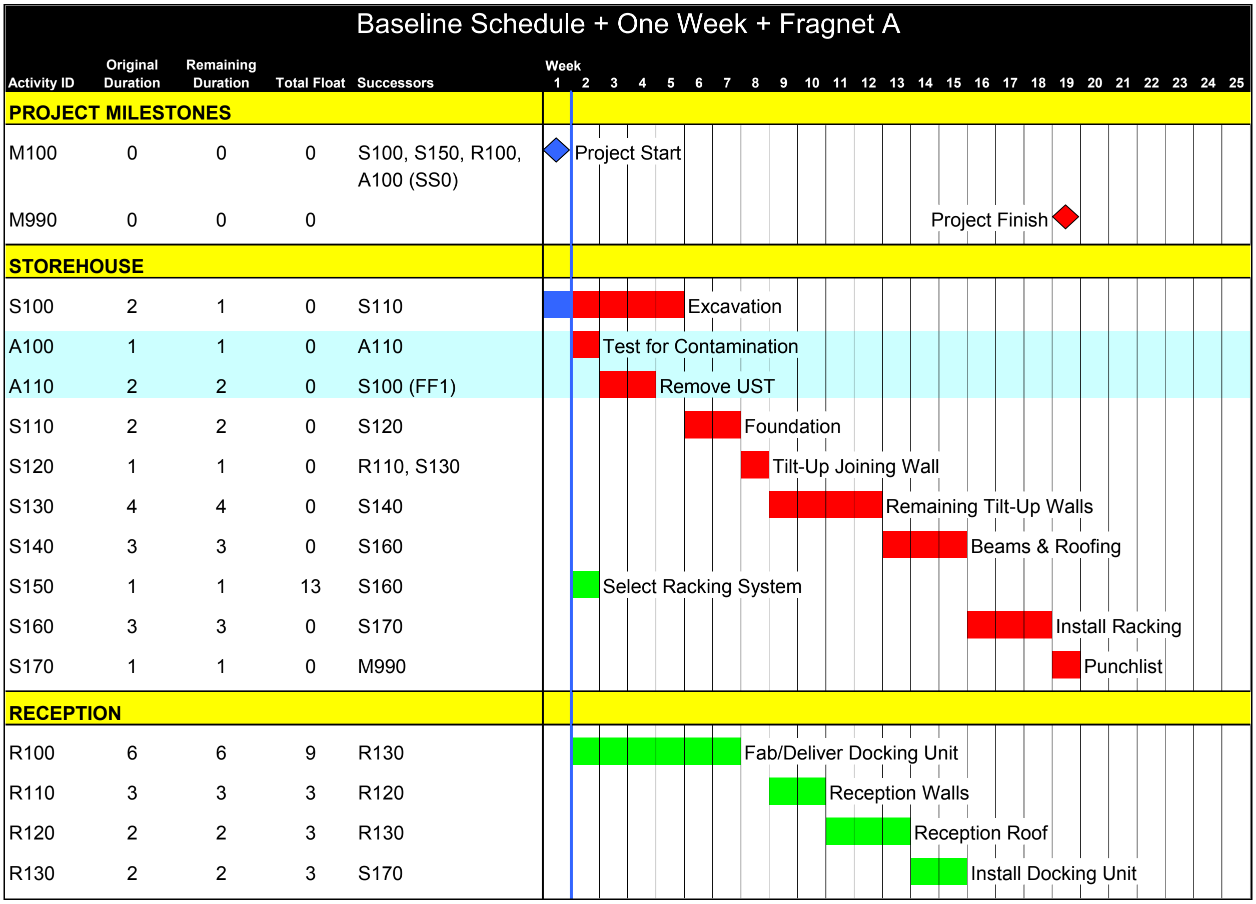
Because the delay occurred at the end of week 1, the schedule is first updated with progress that occurred during the first week.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0	0	S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	2	0	S110
S110	2	2	0	S120
S120	1	1	0	R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	10	S160
S160	3	3	0	S170
S170	1	1	0	M990
RECEPTION				
R100	6	6	6	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	3	S170

Figure 14 – Baseline Schedule Plus One Week

As shown in the figure above, no overall project delay has occurred in week 1, and the project is still scheduled to be completed in 16 weeks. However, the select racking system and fab/deliver docking unit activities have each lost one week of float because they did not make any progress. Next, fragnet a is inserted, as shown in figure 15.



Baseline Schedule + One Week + Fragnet A

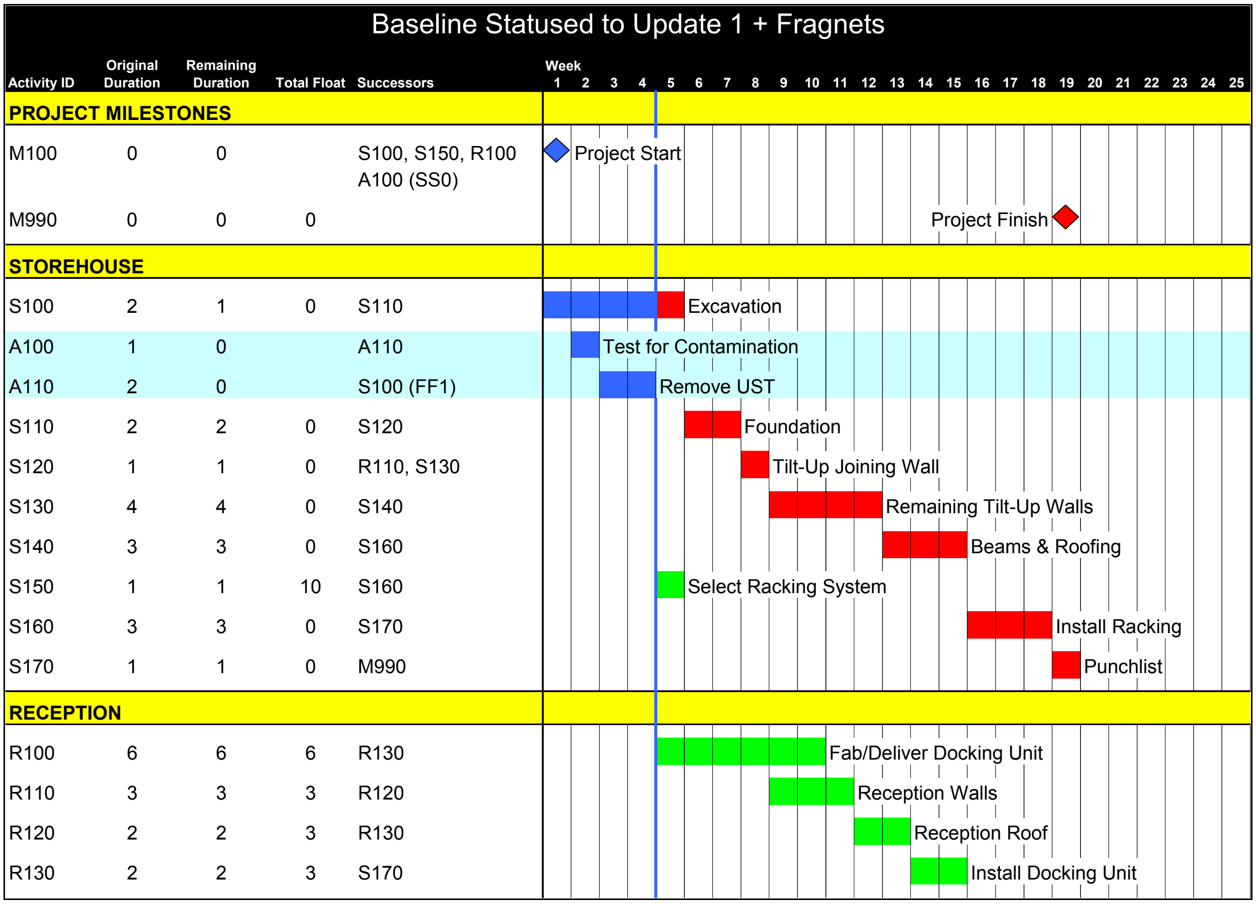
Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0	0	S100, S150, R100, A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	1	0	S110
A100	1	1	0	A110
A110	2	2	0	S100 (FF1)
S110	2	2	0	S120
S120	1	1	0	R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	13	S160
S160	3	3	0	S170
S170	1	1	0	M990
RECEPTION				
R100	6	6	9	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	3	S170

Figure 15 – Baseline Schedule Plus One Week Plus Fragnet A

After insertion of the fragnet, the overall project has been delayed three weeks and is now scheduled to finish in week 19. Some analysts might tie the first activity of fragnet a with a start-to-start relationship with a one week lag from the start of excavation. However, completing one week of excavation was not a necessary predecessor to discovering the ust; the timing of the discovery may have been simply chance. Thus, the start of the fragnet was tied directly to project start for the purposes of the analysis.

As a result of the insertion of fragnet a, the select racking system and fab/deliver docking unit activities have gained three weeks of float, and those two activities now have two weeks more float than they had in the baseline schedule. Note that the start of those activities two activities has been delayed by one week, but those delays were not modeled in the analysis because there was no project documentation identified that indicated that the activities were delayed and the delays were not critical. In effect, the analyst has assumed that these activities are simply using some of their available float.

Based on a review of the progress in the schedule and other available project documentation, no further delays occurred during window 1. The remainder of the progress was added to the schedule in order to model the status of the project at the end of the window. In updating the schedule, the activities in the fragnet are also statused.



Baseline Statused to Update 1 + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	1	0	S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	2	0	S120
S120	1	1	0	R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	10	S160
S160	3	3	0	S170
S170	1	1	0	M990
RECEPTION				
R100	6	6	6	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	3	S170

Figure 16 – Baseline Statused to Update 1 Plus Fragnets

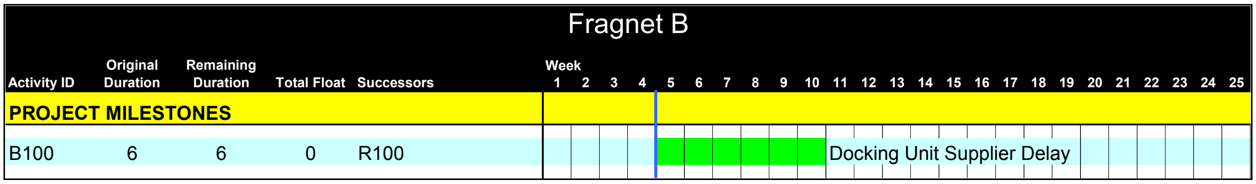
Note that the status of each activity in the schedule at the end of the window is identical to the status of the activity at the beginning of the next window. That would not be the case if the activities in the fragnet were driving any of the activities in Update 1. A summary of the analysis of the first window is tabulated in table 11. Details of individual activity delays that are preceded by the "-" symbol are subtotaled adjacent to the activity named above the details.

Activity Description	Start of Window		Activity Delay or (Savings)	End of Window		Project Delay or (Savings)	Forecast Project Finish Week	Notes
	Planned Start	Planned Finish		Revised Start	Revised Finish			
Net Delay or (Savings) as of Baseline						0	16	
Project Start	1		1a		0	0	16	As-Planned
Excavation	1	2	3	1a	5	3	19	UST/Soil Remediation causes a three-week delay to excavation
- Test for Contam.			1			1		
- Remove UST			2			2		
Net Delay or (Savings) as of Update 1						**3**	**19**	

Table 11 – Summary of Analysis of First Window

Window 2

As of the start of window 2, the UST and contaminated soil have been removed and excavation is scheduled to be completed in week 5. However, based on review of project documentation, the contractor's supplier indicated that it would not begin fabricating the docking unit until week 11 because its factory was operating at capacity on other projects. The supplier wrote a letter to the contractor detailing the delay at the start of week 5; however, the contractor did not make the owner aware of the situation. Fragnet B (see figure 17) was created to model the delay to the docking unit.

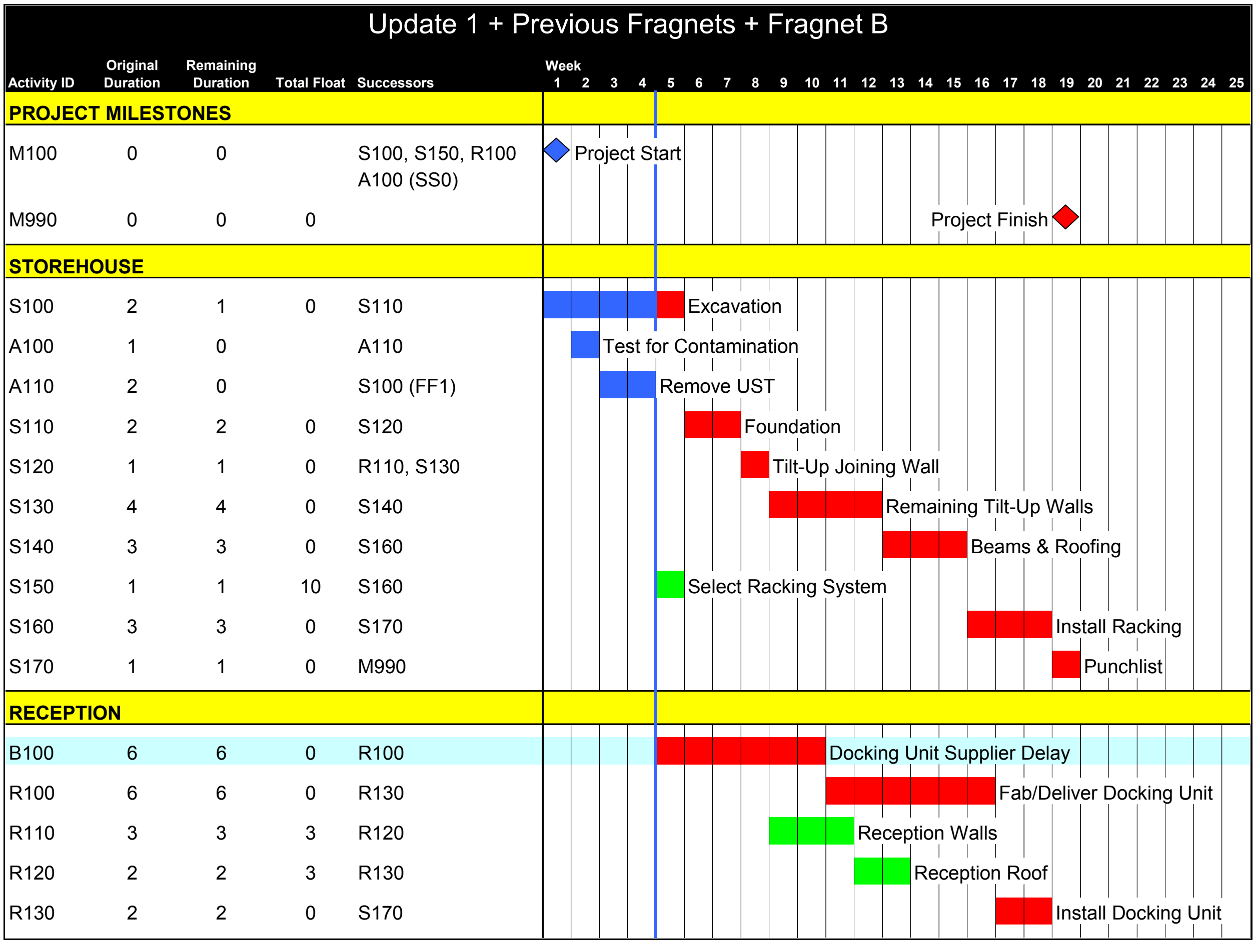


Fragnet B

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
B100	6	6	0	R100

Figure 17

Because the delay to fab/deliver docking unit occurred at the start of week 5—the data date of update 1—it is inserted directly into the update without any need to status the update first.

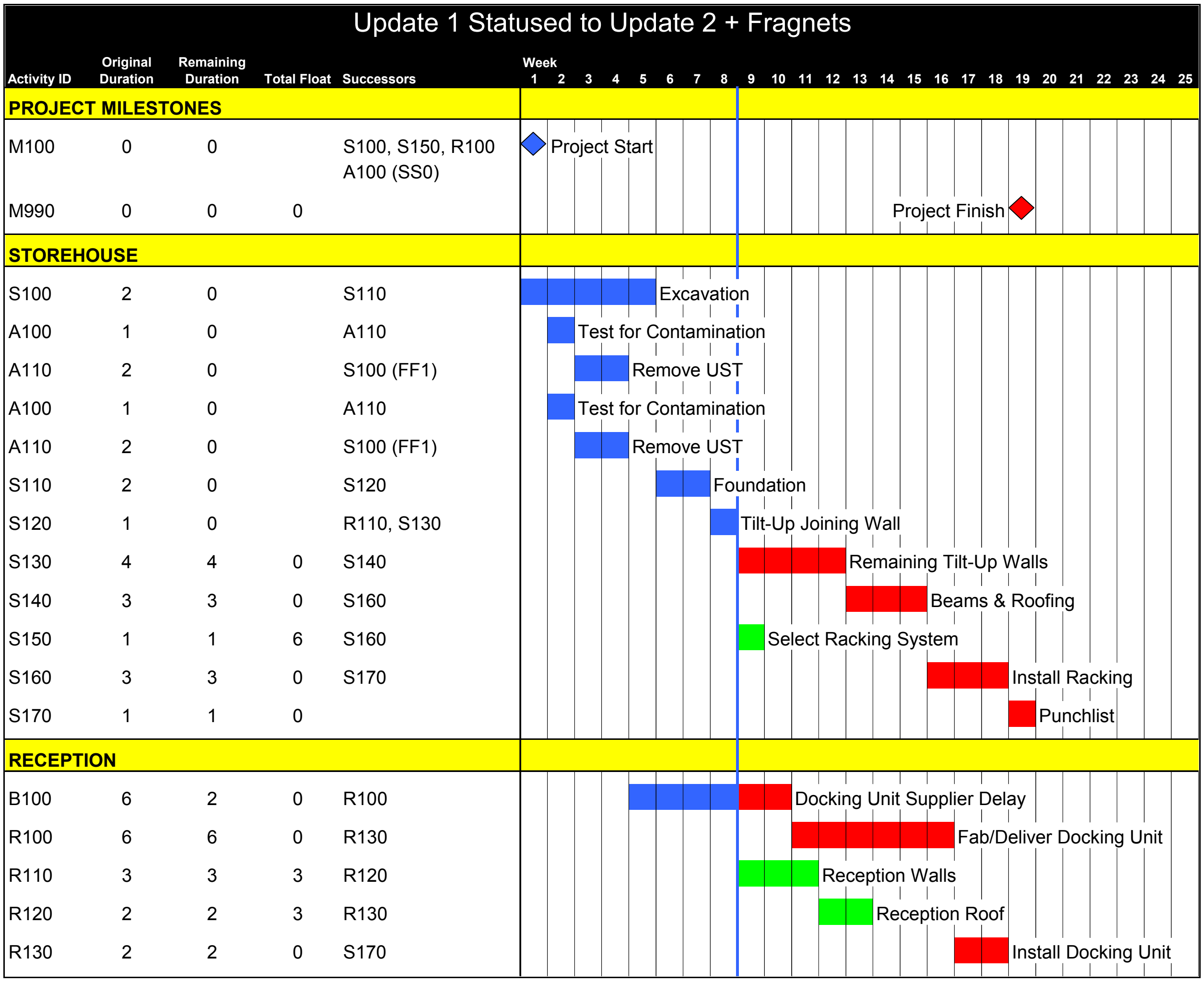


Update 1 + Previous Fragnets + Fragnet B

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	1	0	S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	2	0	S120
S120	1	1	0	R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	10	S160
S160	3	3	0	S170
S170	1	1	0	M990
RECEPTION				
B100	6	6	0	R100
R100	6	6	0	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	0	S170

Figure 18 – Fragnet B

With the knowledge that the contractor had at the start of week 5 incorporated into the schedule, the supply of the docking unit has become concurrently critical with the progress of the path that begins with excavation. the docking unit supplier delay was added into the schedule with no predecessors because it is an external supplier delay and not driven by other activities in the schedule. Alternatively, it could be tied as a successor to project start simply to maintain the completeness of the network. Once all progress from update 2 is added into update 1, the overall status of the project is as depicted in figure 19.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	6	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
B100	6	2	0	R100
R100	6	6	0	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	0	S170

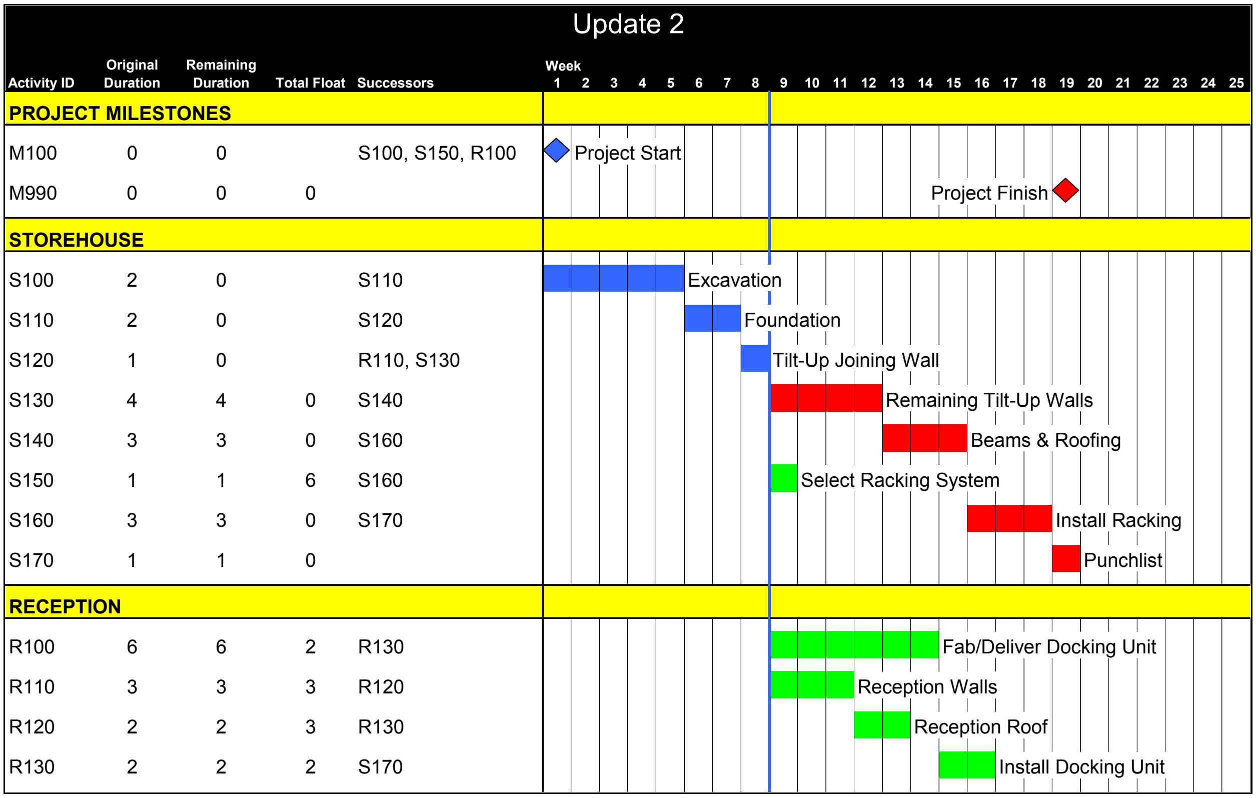
Figure 19 – Update 1 Statused to Update 2 Plus Fragnets

Although fab/deliver docking unit became critical in window 2, there was no additional project delay. A summary of the analysis of the second window is tabulated in table 12.

Activity Description	Start of Window		Activity Delay or (Savings)	End of Window		Project Delay or (Savings)	Forecast Project Finish Week	Notes
	Planned Start	Planned Finish		Revised Start	Revised Finish			
Net Delay or (Savings) as of Update 1						3	19	
Excavation (Remainder)	5	5	0	5a	5a	0	19	As-Planned
Foundation	6	7	0	6a	7a	0	19	As-Planned
Tilt-Up Joining Wall	8	8	0	8a	8a	0	19	As-Planned
Critical Path Shift (fab/deliver docking unit path becomes concurrently critical because of delay)								
Fab/Del Docking Unit	5	10	6	11	16	0	19	Supplier delay causes docking unit to become critical
- Supplier Delay			6			0		
Net Delay or (Savings) as of Update 1						**3**	**19**	

Table 12 – Net Delay of (Savings) as of Update 1

Note that incorporating the knowledge of the docking unit fabrication delay into update 1 has caused the analysis to forecast a date later than was actually forecast in update 2, depicted in figure 20 without fragnet insertions.



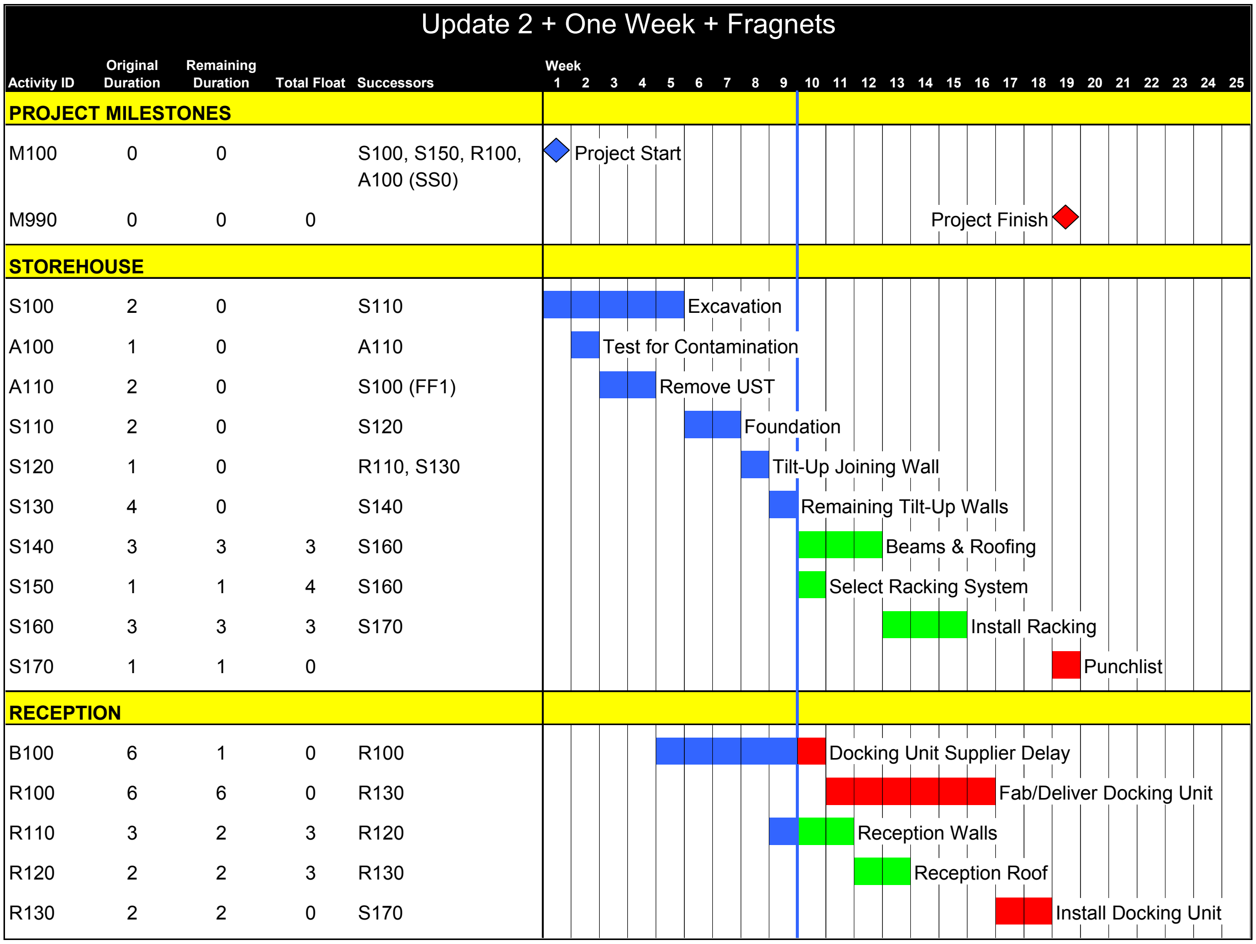
Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
S110	2	0		S120
S120	1	0		R110, S130
S130	4	4	0	S140
S140	3	3	0	S160
S150	1	1	6	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
R100	6	6	2	R130
R110	3	3	3	R120
R120	2	2	3	R130
R130	2	2	2	S170

Figure 20 – Update 2

In the project record schedule, fab/deliver docking unit was scheduled to begin immediately at the start of week 9 and was not critical. However, once all progress and fragnets have been added into update 1 in the analysis, fab/deliver docking unit is scheduled to begin in week 11 and is critical. Thus, the analysis is consistent with the letter that the contractor received from the supplier, but it is not consistent with the contemporaneous project schedule. That type of discrepancy is not uncommon in a schedule analysis that uses fragnet insertions. It is up to the analyst to select the best source of information when the project schedule and other contemporaneous project documentation provide conflicting information.

Window 3

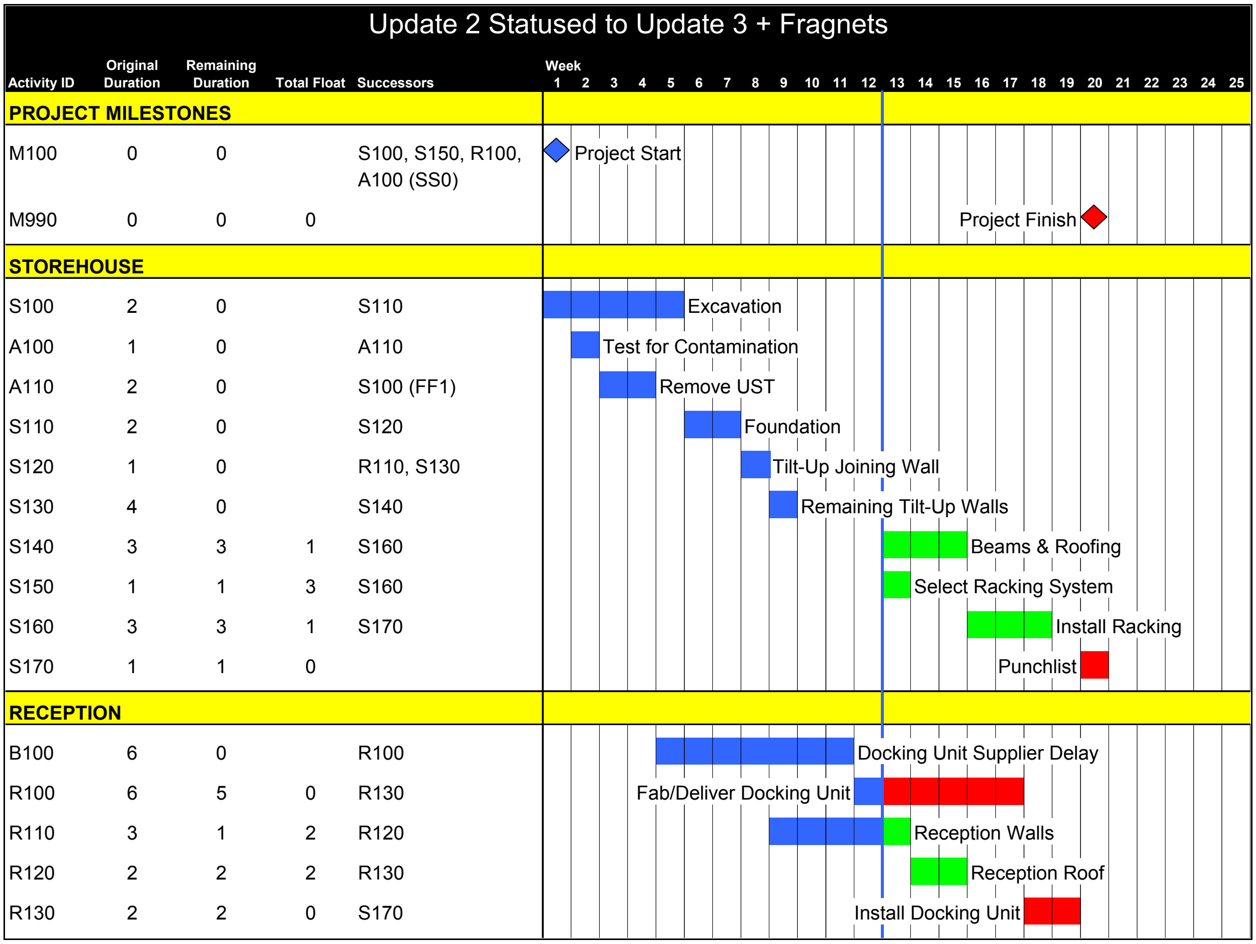
In the analysis without fragnet insertions, adding the first week of progress in window 3 produced a one week savings to the project completion date. With fragnet insertions, the knowledge that fab/deliver docking unit will not begin until week 11 has already been incorporated into the project schedule at the start of window 3. The first week of progress from the schedule update at the end of the window (update 3) is incorporated into the update at the beginning of the window (update 2 + fragnets) in figure below 21.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100, A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	3	3	S160
S150	1	1	4	S160
S160	3	3	3	S170
S170	1	1	0	
RECEPTION				
B100	6	1	0	R100
R100	6	6	0	R130
R110	3	2	3	R120
R120	2	2	3	R130
R130	2	2	0	S170

Figure 21 – Update 2 plus One Week Plus Fragnets

Although there was a two-week savings to the path that began with remaining tilt-up walls, there was no overall savings to the project completion date because the docking unit supplier delay continued to drive project completion to week 19. With the savings on the previous path, the docking unit supplier delay becomes the sole activity that is immediately critical in week 10. Review of the project documentation did not identify any on-site delays during window 3, so it appeared that the fab/deliver docking unit path continued to drive project completion for the remainder of the window. The remaining progress during the window was added to the update, as shown in figure 22.



Update 2 Statused to Update 3 + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100, A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
S140	3	3	1	S160
S150	1	1	3	S160
S160	3	3	1	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	5	0	R130
R110	3	1	2	R120
R120	2	2	2	R130
R130	2	2	0	S170

Figure 22 – Update 2 Statused to Update 3 Plus Fragnets

Fab/deliver docking unit did not begin as planned in week 11. Although the available information indicated that the start of fabrication would be delayed until week 11, it was actually delayed until week 12, causing a one-week delay to the project during window 3.

The path beginning with beams and roofing also experienced a delay because of the failure of beams and roofing to start as planned during the window. The predecessors to the activity are all completed, and there were no indications in the project documentation as to why the activity did not begin. The activity delay did not cause a project delay. In light of the absence of a project delay from the beams and roofing path and the lack of information regarding any delay, the delay was not modeled in the analysis. It appears that the beams and roofing activity is simply taking advantage of some of its available float. (Note that the consumed float would not have been available if not for the delay to the docking unit fabrication.) A summary of the analysis of the third window is tabulated below.

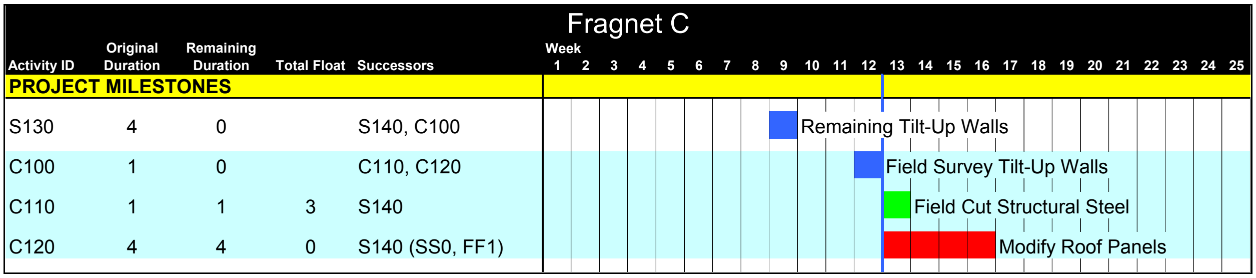
Activity Description	Start of Window		Activity Delay or (Savings)	End of Window		Project Delay or (Savings)	Forecast Project Finish Week	Notes
	Planned Start	Planned Finish		Revised Start	Revised Finish			
Net Delay or (Savings) as of Update 2						3	19	
Fab/Del Docking Unit	11	16	1	12	17	1	20	Supplier delays start of unit one week more than forecast
- Supplier Delay			1			1		
Net Delay or (Savings) as of Update 3						**4**	**20**	

Table 13 – Summary of Analysis of Third Window

Window 4

As of week 13—the data date of update 3—project completion has been delayed by a total of four weeks. Based on project documentation, structural steel arrives on site at the start of week 13. The steel has been fabricated in accordance with the contract drawings and the accepted shop drawings. However, when the erected tilt-up panels were surveyed, it was determined that there was an error in the contract drawings that caused numerous roof members and metal roof panels to be fabricated too long.

The specifications contain a pre-approved procedure for cutting the steel members in the field. However, the specifications do not allow metal roof panels to be field cut or bent, and the owner will not waive that requirement because it would void the roof warranty. Thus, the panels will be returned to the supplier for modification. The field cutting of structural steel is expected to take one week, but the panel modifications are expected to take four weeks. The panels will be shipped in two partial deliveries in order to minimize the delay. The first half will be returned to the project site at the end of the second week, and the second half will be returned at the end of the fourth week. Fragnet C was developed to model these delays and is depicted below.

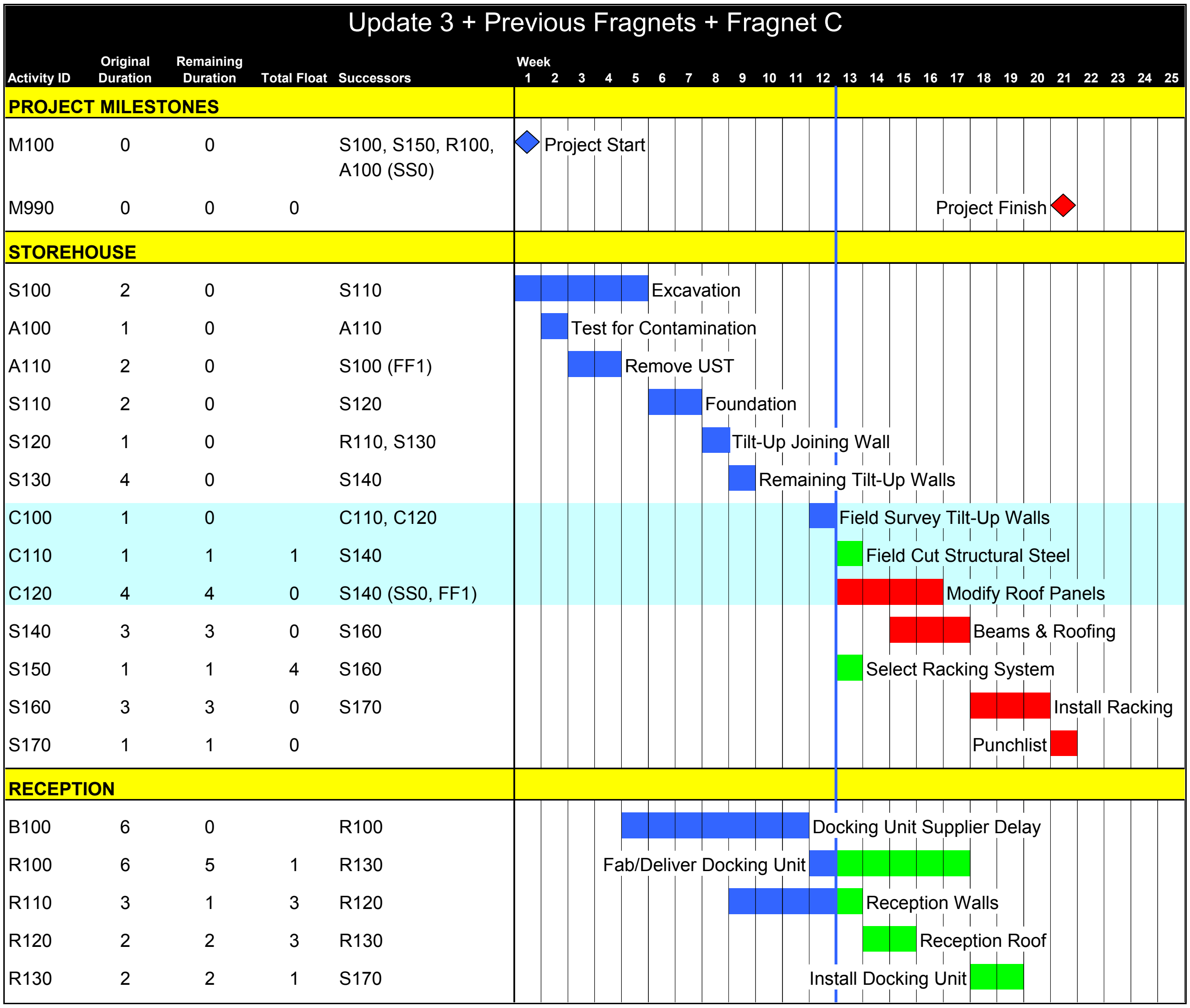


Fragnet C

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
S130	4	0		S140, C100
C100	1	0		C110, C120
C110	1	1	3	S140
C120	4	4	0	S140 (SS0, FF1)

Figure 23 – Fragnet C

The first activity in the fragnet—field survey tilt-up walls—was tied with a finish-to-start relationship from the remaining tilt-up walls activity. The tilt-up wall erection was completed at the start of the update, and the field survey activity is added as a completed activity. Therefore, neither activity has any effect on the remaining activities in the fragnet. The field survey activity is added for information only, in effect. An argument could be made that this activity should have been inserted into the analysis of the previous window. However, based on the project documentation, the contractor did not become aware of the design errors until the start of week 13, after the field survey had been completed. The field survey was not modeled in the original schedule, and if it had been completed immediately after the completion of tilt-up panel erection, some of the delay would likely have been avoided. However, the path of activities associated with beams and roofing had float at the time the survey work was allowed to slide. The contractor and owner did not know that the work would be critical until week 13, when update 3 was the most recent approved schedule. Therefore, the fragnet was incorporated into update 3. Figure 24 shows the addition of fragnet C into update 3.



Update 3 + Previous Fragnets + Fragnet C

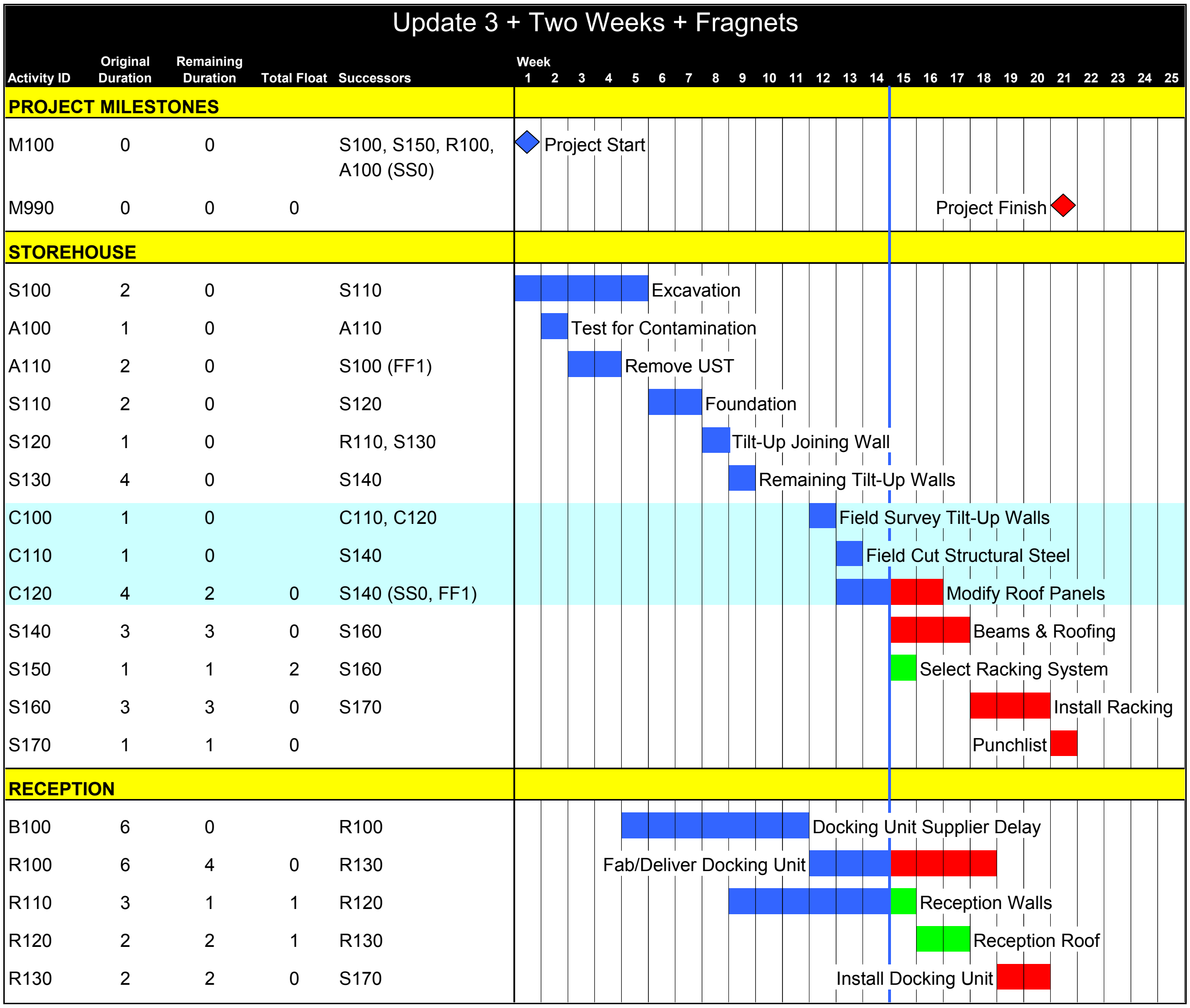
Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100, A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	1	1	S140
C120	4	4	0	S140 (SS0, FF1)
S140	3	3	0	S160
S150	1	1	4	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	5	1	R130
R110	3	1	3	R120
R120	2	2	3	R130
R130	2	2	1	S170

Figure 24 – Update 3 Plus Previous Fragnets Plus Fragnet C

The field cut structural steel activity is tied with a finish-to-start relationship to the beams and roofing activity because erection of the structural steel will begin as soon as the field cutting is completed. However, the modify roof panels activity is tied to the beams and roofing activity with a start-to-start relationship with a two-week lag and a finish-to-finish relationship with one week of lag. Those relationships are intended to model the two-stage return of the modified roof panels.

Alternatively, roof panel erection could be split into several activities, but that would involve modifying the activities in the original schedule in order to model the delay. In the fragnet presented, new activities and relationships have been added to the project schedule, but none of the original activities or relationships have been modified or removed. It is preferred to alter the existing activities as little as possible during the analysis, but it may not always be possible to accurately model delays if some of the original activities are suspended for long periods or there is out-of-sequence progress for which to account in the schedule analysis. Finally, note that the beams and roofing activity is scheduled as “contiguous,” although that scheduling option has no effect on the overall duration of the path or the amount of project delay caused by the path in this case.

After the addition of fragnet C to the update, the critical path has shifted to the path that begins with modify roof panels, and the project completion date is delayed by one week. The previously critical path, which begins with the remainder of the fab/deliver docking unit activity, now has one week of float. Then, the first two weeks of progress are added into update 3, as shown in figure 25.

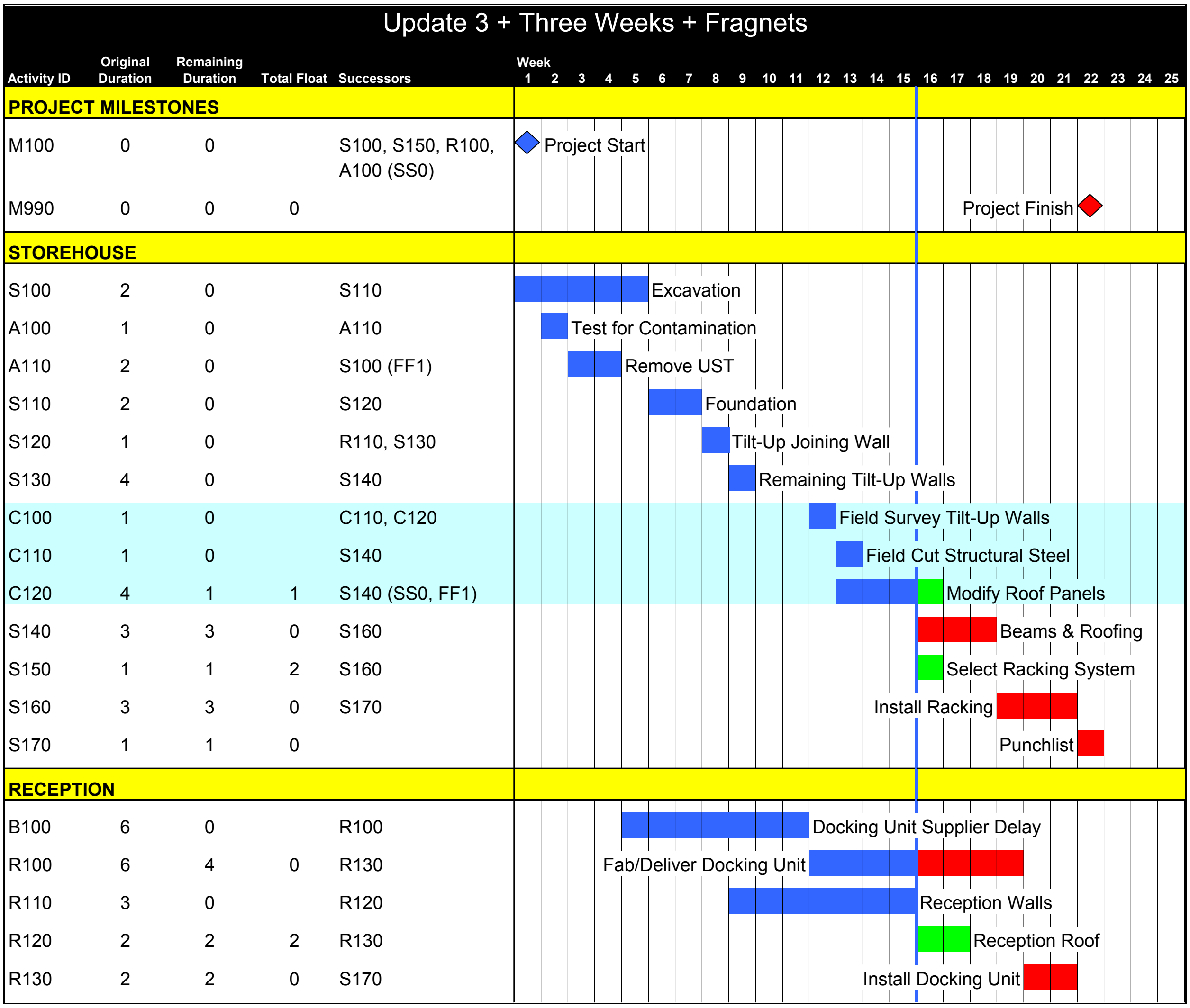

Update 3 + Two Weeks + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100, A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	2	0	S140 (SS0, FF1)
S140	3	3	0	S160
S150	1	1	2	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	4	0	R130
R110	3	1	1	R120
R120	2	2	1	R130
R130	2	2	0	S170

Figure 25 – Update 3 plus Two weeks Plus Fragnets

After the addition of two weeks of progress, the fab/deliver docking unit path has become critical again because of its slower-than-expected progress. The fabrication activity only made one week of progress during the window between updates 3 and 4. That week of progress was credited to the activity in week 13, the first week of the window. After the addition of fragnet C, the fabrication activity had one week of float, which was absorbed in week 14. The fabrication activity became concurrently critical with the modification of roof panels in week 15.

When one more week of progress is added to the schedule, one week of project delay occurs. The fab/deliver docking unit path remains concurrently critical with the beams and roofing path, as shown in figure 26.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100, A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	1	1	S140 (SS0, FF1)
S140	3	3	0	S160
S150	1	1	2	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	4	0	R130
R110	3	0		R120
R120	2	2	2	R130
R130	2	2	0	S170

Figure 26 – Update 3 Plus Three Weeks + Fragnets

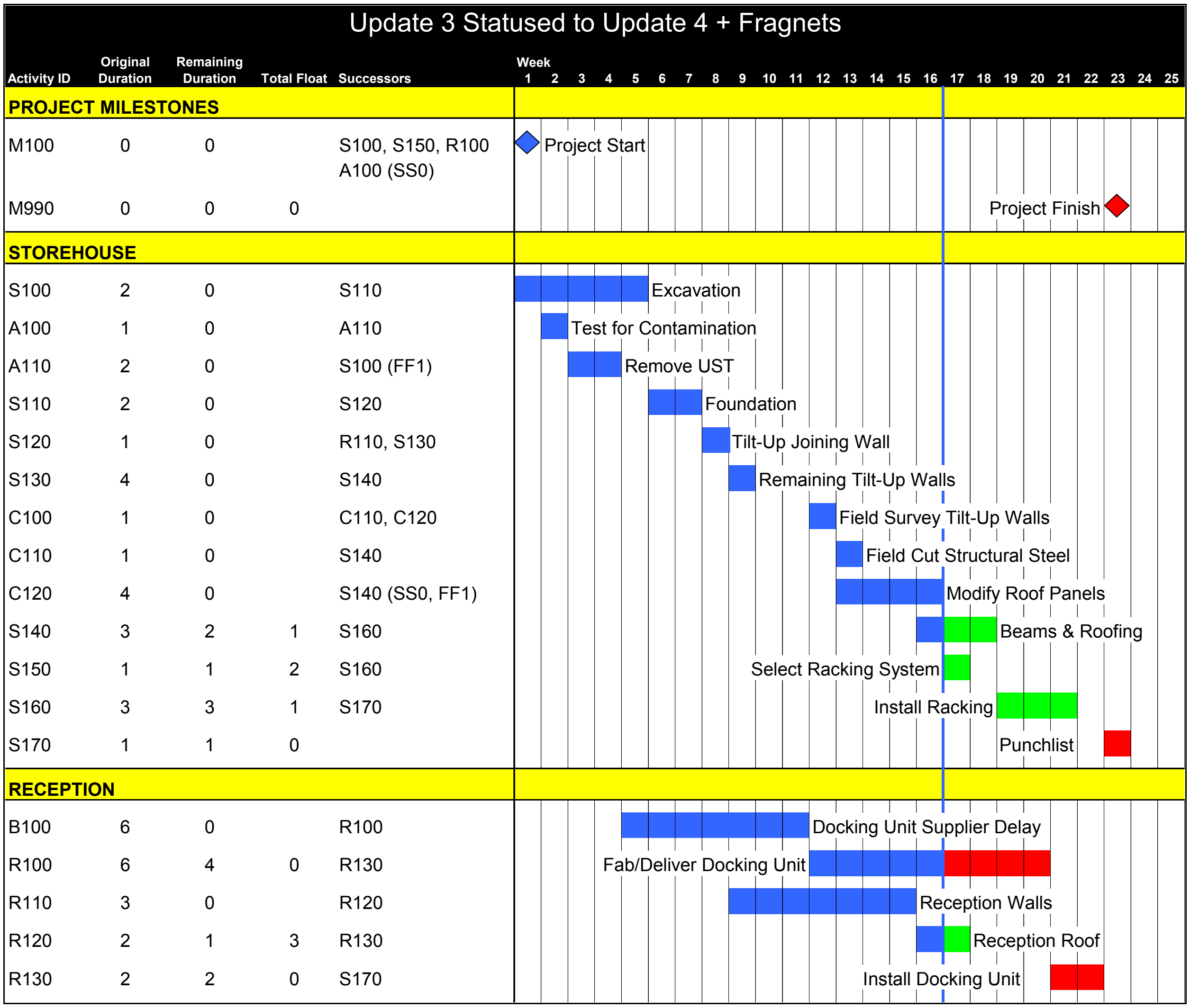
The fab/deliver docking unit made only one week of progress during window 4—between updates 3 and 4. That week of progress was credited to the activity in week 13, the first week of the window. (Note that the docking unit supplier delay activity that was added to the schedule in the analysis of window 2. That activity was completed in week 11—in window 3 and one week later than forecast when it was added to the analysis. fab/deliver docking unit began the week after that, the last week in window 3. fab/deliver docking unit then made one additional week of progress during window 4, as shown by the remaining duration of the activity in the schedule at the end of the window—viz., update 4.)

In week 15, the slower-than-expected progress of the docking unit fabrication causes a one-week delay to project finish. However, the path of activities that begins with modify roof panels and beams and roofing concurrently causes that same one-week delay. Although the modify roof panels activity makes as-planned progress, the beams and roofing activity fails to start in week 15. Both activities were immediately critical in week 15 because of the overlap created by the finish-to-finish relationship between the activities. Thus, both must make progress in order for the project finish date to be maintained.

Based on a review of project documentation, the field cutting of structural steel has been completed and the steel is ready for erection. The first shipment of roof panels have been returned to the project site, and the second shipment is expected during week 16. Project documents indicate that the contractor has scheduled a crane to erect structural steel beginning in week 16. The crane will be needed to erect steel and install the docking unit. The contractor indicated that this scheduling was necessary in order to minimize crane costs because the docking unit is not expected to arrive until week 19. The contractor had originally planned and budgeted for three weeks of crane time based on its baseline schedule. The contractor is now attempting to minimize the amount of crane time on site, and delaying the start of beams and roofing until week 16 will reduce the amount of crane time by one week.

A one-activity fragnet could be added to the schedule to model the one-week delay to the start of beams and roofing because of the contractor's election. However, the delay is not related to any project event, and the delay is modeled by the late start of beams and roofing. Thus, the late start has not been modeled by the addition of a fragnet. It is noted that if the one-week delay were modeled by the addition of a fragnet at the start of week 15, the beams and roofing path would become one week longer than the fab/deliver docking unit path, giving the fab/deliver docking unit path one week of float. Thus, the analysis might find that the beams and roofing path remained the sole path that contributed to delays during window 4.

Adding one more week of progress to update 3 brings the analysis to the end of the window, as shown in figure 27.



Update 3 Statused to Update 4 + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	0		S140 (SS0, FF1)
S140	3	2	1	S160
S150	1	1	2	S160
S160	3	3	1	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	4	0	R130
R110	3	0		R120
R120	2	1	3	R130
R130	2	2	0	S170

Figure 27 – Update 3 Statused to Update 4 Plus Fragnets

The beams and roofing activity starts in week 16 and makes one week of progress. Meanwhile, the fab/deliver docking unit activity makes no additional progress and causes one week of project delay. A summary of the analysis of the fourth window is tabulated table 14.

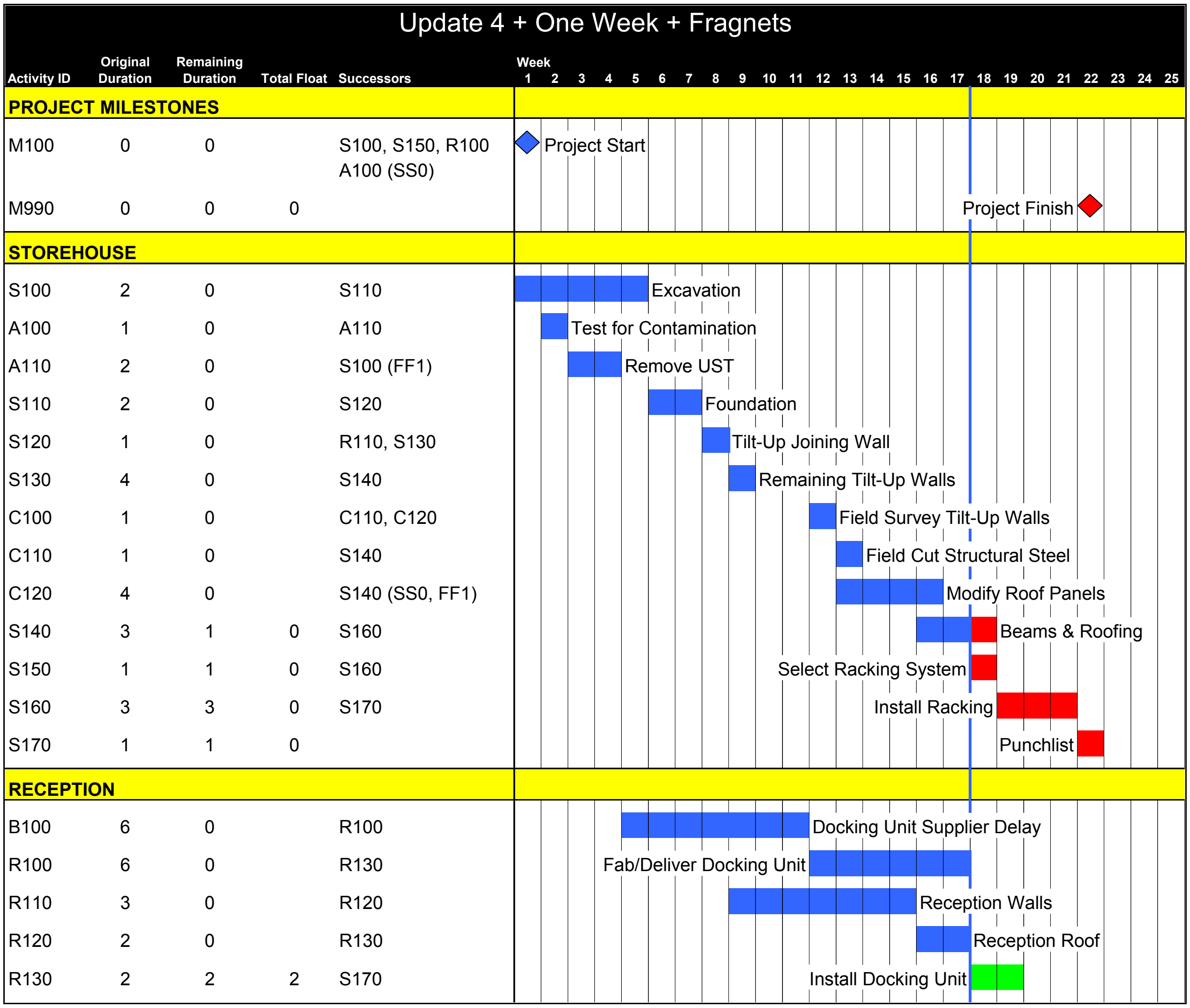
Activity Description	**Start of Window**		**Activity Delay or (Savings)**	**End of Window**		**Project Delay or (Savings)**	**Forecast Project Finish Week**	**Notes**
	Planned Start	**Planned Finish**		**Revised Start**	**Revised Finish**			
Net Delay or (Savings) as of Update 3						4	20	
beams and roofing	13	15	3	16a	18	2	22	Modification to roof panels causes a two-week delay; crane scheduling causes a one-week delay concurrent with docking unit; field cutting does not contribute to the delay
- Modify Roof Panels			2			1		
- Crane Delay			1			1 (c)		
Fab/Del Docking Unit (Rem.)	13	17	3	13a	20	1 (c), 1	23	STE Progress; one-week delay concurrent with beams and roofing in Week 15; one week additional delay in Week 16 makes Fab/Del Docking Unit solely critical
Net Delay or (Savings) as of Update 4						**7**	**23**	

Table 14─Tabulated Analysis of the Fourth Window

Note that the separate delays caused by the fragnet activity Modify Roof Panels and the late start of beams and roofing caused by the crane delay are isolated in the summary of delays. The Modify Roof Panels activity caused a two-week delay to beams and roofing when it was added to the project schedule, but beams and roofing had one week of float at the start of the window. Therefore, the two-week activity delay produced a one-week project delay. The crane delay caused an additional 1 week of delay to beams and roofing; however, the associated one week of project delay was concurrently caused by the slower-than-expected progress of Fab/Del Docking Unit.

Window 5

At the start of window 5, the forecast project finish date is week 23. All previously inserted fragnets are added to update 4 at the start of window 5, and the schedule for the remaining activities is identical to that depicted in update 4 without the previously inserted fragnets. The schedule is, in fact, identical to the schedule developed by adding all progress from update 4 into update 3. Then, the first week of progress in window 5 is added, as shown in figure 28.



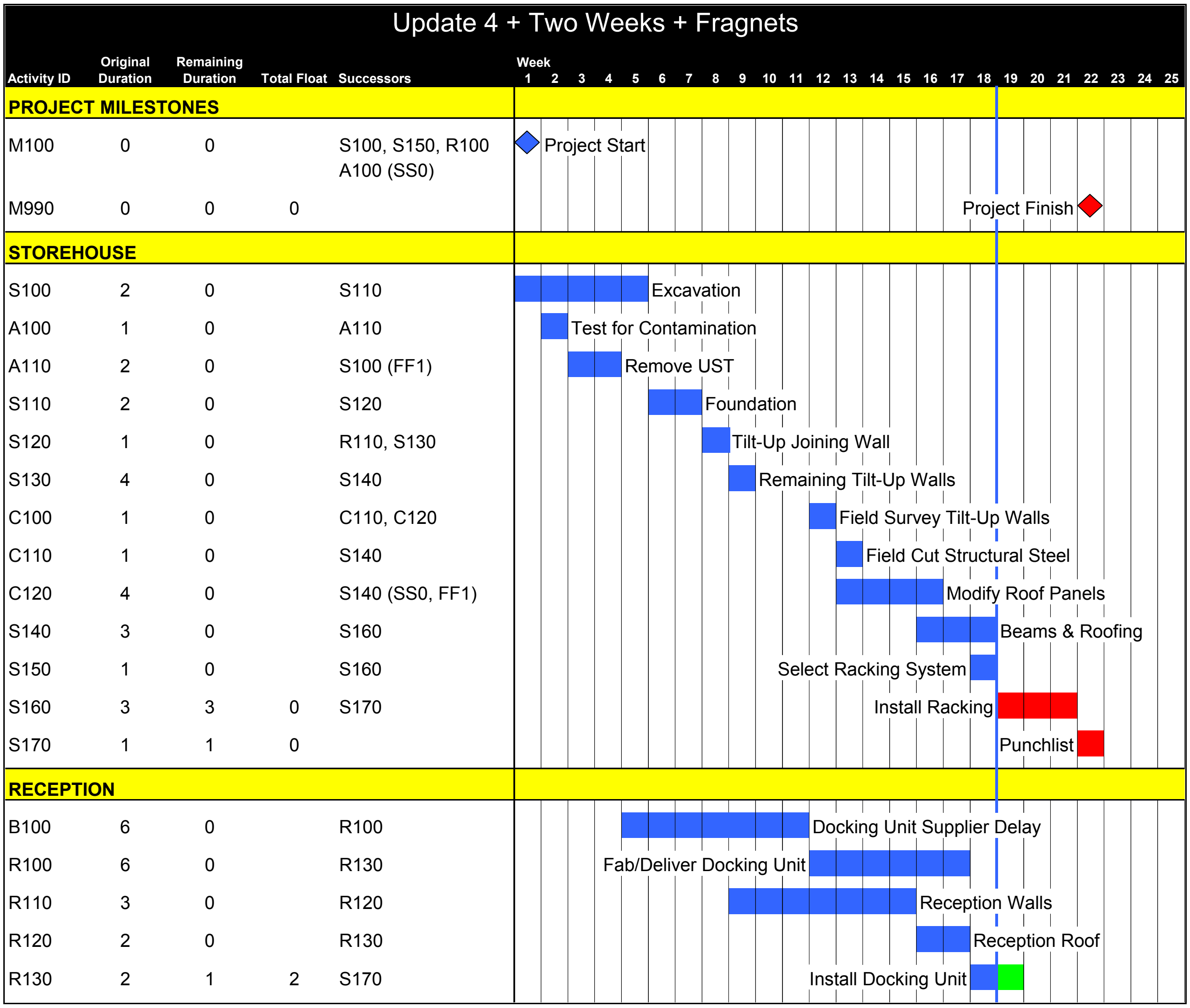
Update 4 + One Week + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	0		S140 (SS0, FF1)
S140	3	1	0	S160
S150	1	1	0	S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	2	2	S170

Figure 28 – Update 4 Plus One Week Plus Fragnets

In week 17, fab/deliver docking unit is completed. At the start of the window, the activity was anticipated to take four weeks to complete. According to an e-mail from the supplier, it had provided that forecast to the contractor at the time that update 4 was prepared. However, a principal with the contractor subsequently contacted the supplier, and the supplier expedited the remaining fabrication. The better-than-expected progress caused a one week savings to the forecast project finish date. It also causes a critical path shift back to beams and roofing, which made one week of progress during week 17, as expected. in addition, the select racking system activity—planned for week 1 in the baseline and still not completed—finally has become critical. thus, there are two new concurrently critical paths—one starting with the remainder of the beams and roofing activity and one starting with select racking system. The paths merge at the install racking activity.

When one more week of progress is added to the schedule, beams and roofing and select racking system are completed. Both activities proceeded as planned in the previous week. Figure 29 shows update 4 with two weeks of progress from update 5 and all fragnets previously inserted.

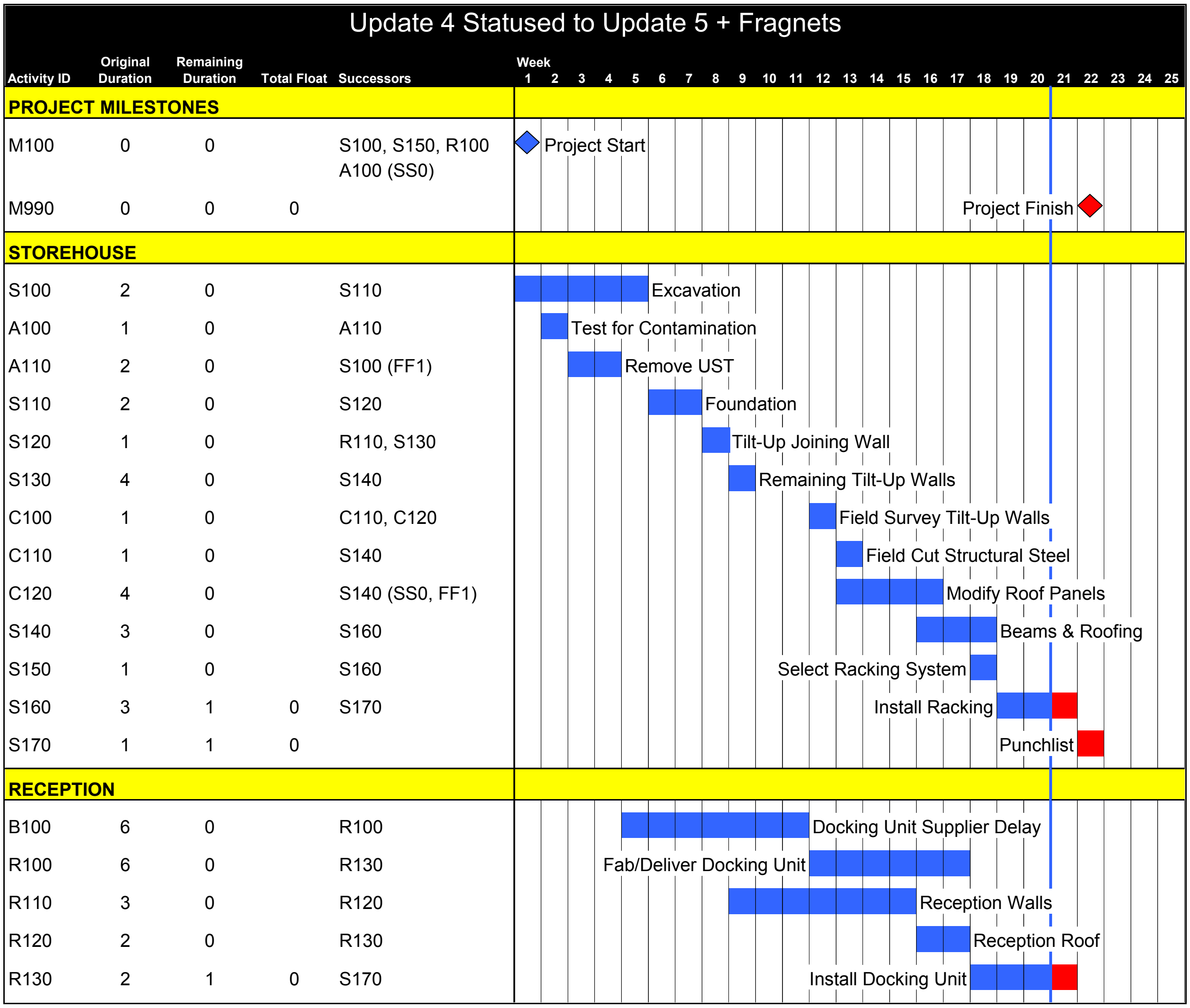


Update 4 + Two Weeks + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	0		S140 (SS0, FF1)
S140	3	0		S160
S150	1	0		S160
S160	3	3	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	1	2	S170

Figure 29 – Update 4 Plus Two Weeks Plus Fragnets

Window 5 still has two weeks remaining. According to update 5, during those two weeks, Install Racking makes two weeks of progress, and it has one week remaining at the end of the window. However, Install Docking Unit makes no additional progress, and it also has one week remaining at the end of the window. Both activities are predecessors to punch list, and Install Docking Unit exhausted its float in week 20. Thus, both activities are now critical, as shown in figure 30.



Update 4 Statused to Update 5 + Fragnets

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	0		S140 (SS0, FF1)
S140	3	0		S160
S150	1	0		S160
S160	3	1	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	1	0	S170

Figure 30 – Update 4 Statused to Update 5 Plus Fragnets

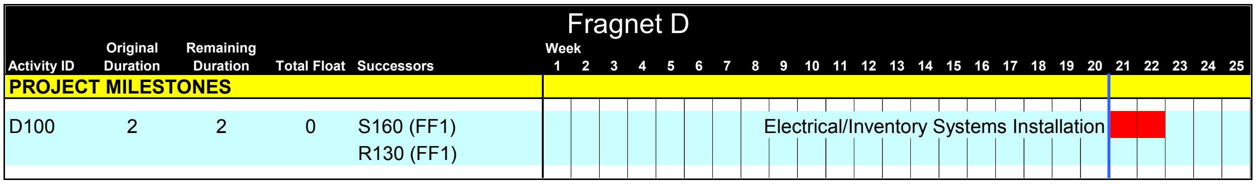
A summary of the analysis of the fifth window is tabulated in table 15.

Activity Description	**Start of Window**		**Activity Delay or (Savings)**	**End of Window**		**Project Delay or (Savings)**	**Forecast Project Finish Week**	**Notes**
	Planned Start	**Planned Finish**		**Revised Start**	**Revised Finish**			
Net Delay or (Savings) as of Update 4						7	23	
Fab/Del Docking Unit (Rem.)	17	20	(3)	17a	17a	(1)	22	BTE Progress—supplier expedites remaining fabrication
Critical Path Shift (beams and roofing and Select Racking System become concurrently critical)								
beams and roofing (Rem.)	18	18	0	18a	18a	0	22	As Planned Progress; critical paths converge at Install Racking
Select Racking System	18	18	0	18a	18a	0	22	
Install Racking	19	21	0	19a	21	0	22	As Planned Progress, but Install Docking Unit becomes concurrently critical because of STE progress
Net Delay or (Savings) as of Update 5						**6**	**22**	

Table 15 – Summary of Analysis of Fifth Window

Window 6

As of the start of week 21—the data date of update 5 and the first week of window 6—there are two weeks of work remaining, including punch list. However, there is one more impact to the project finish date. The owner informs the contractor that it had expected general contract work to be complete by now. The owner had scheduled an electrical contractor to install a computerized receiving and inventory system during weeks 21 and 22. The electrical contractor will occupy the majority of the docking area and storehouse during that time. Thus, an activity is added to the schedule with finish-to-finish ties to the remainder of the install docking unit and install racking activities. Because those activities both have one week remaining, the relationships are finish-to-finish with one-week lags.

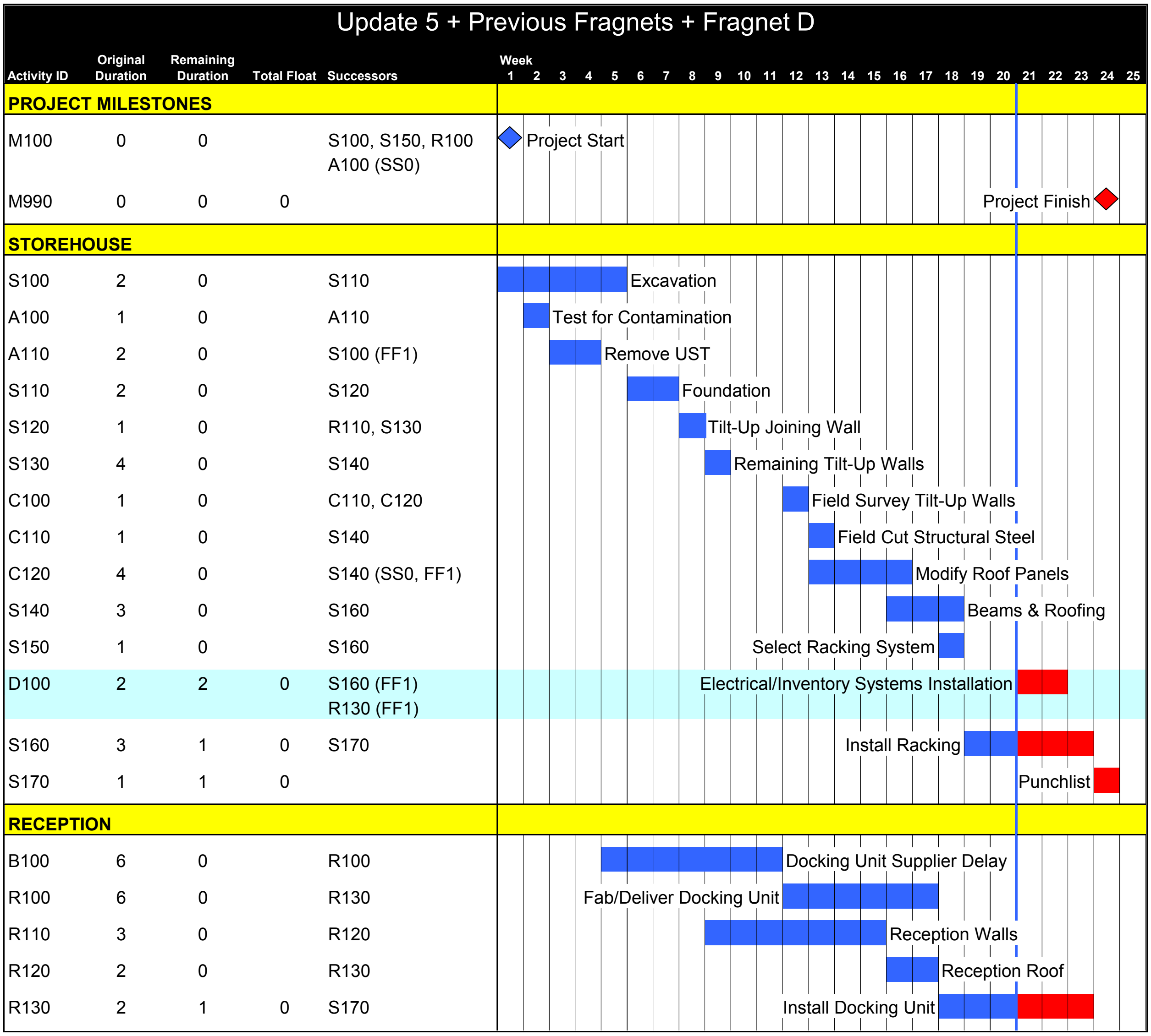


Fragnet D

Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
D100	2	2	0	S160 (FF1) R130 (FF1)

Figure 31 – Fragnet D

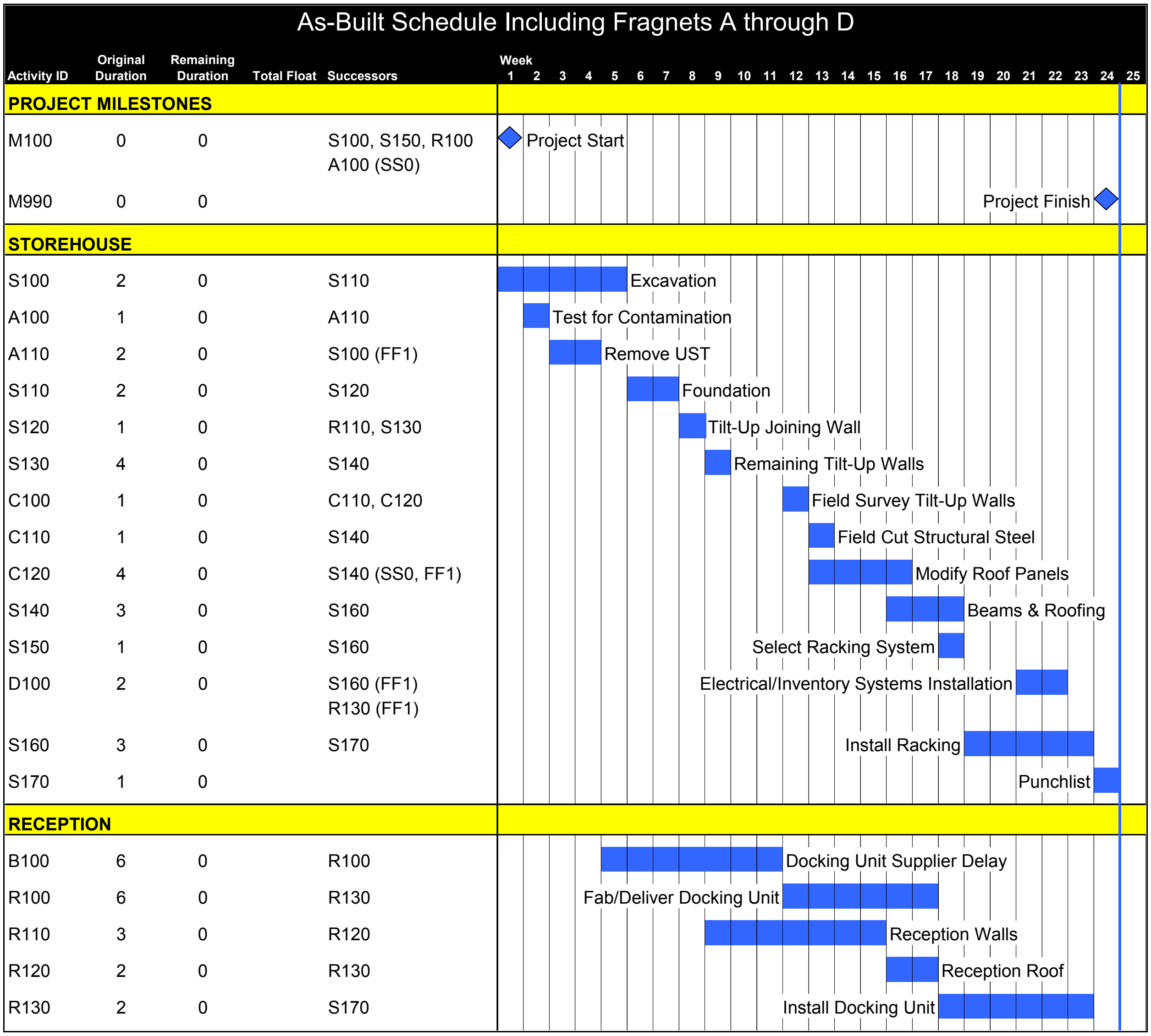
Inserting all previous fragnets and Fragnet D into update 5 produces the schedule shown in figure 31 and figure 32.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0	0	
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	0		S140 (SS0, FF1)
S140	3	0		S160
S150	1	0		S160
D100	2	2	0	S160 (FF1) R130 (FF1)
S160	3	1	0	S170
S170	1	1	0	
RECEPTION				
B100	6	0		R100
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	1	0	S170

Figure 32 – Update 5 Plus Previous Fragnets Plus Fragnet D

The added electrical/inventory systems installation activity delays both critical activities by two weeks and causes a two-week delay to project finish. However, after that impact, all activities are completed as expected. The final project update—the as-built schedule, including all inserted fragnets—is shown in figure 33 and table 16.



Activity ID	Original Duration	Remaining Duration	Total Float	Successors
PROJECT MILESTONES				
M100	0	0		S100, S150, R100 A100 (SS0)
M990	0	0		
STOREHOUSE				
S100	2	0		S110
A100	1	0		A110
A110	2	0		S100 (FF1)
S110	2	0		S120
S120	1	0		R110, S130
S130	4	0		S140
C100	1	0		C110, C120
C110	1	0		S140
C120	4	0		S140 (SS0, FF1)
S140	3	0		S160
S150	1	0		S160
D100	2	0		S160 (FF1) R130 (FF1)
S160	3	0		S170
S170	1	0		
RECEPTION				
B100	6	0		R100
R100	6	0		R130
R110	3	0		R120
R120	2	0		R130
R130	2	0		S170

Figure 33 – As-Built Schedule Including Fragnets A – D

A summary of the analysis of the sixth window is shown in table 16.

Activity Description	Start of Window		Activity Delay or (Savings)	End of Window		Project Delay or (Savings)	Forecast Project Finish Week	Notes
	Planned Start	Planned Finish		Revised Start	Revised Finish			
Net Delay or (Savings) as of Update 5						6	22	
Install Racking (Rem.)	21	21	2	23a	23a	2 (c)	24	Work suspended for two weeks during separate electrical contract
- Elec. Inventory System Installation Delay			2			2 (c)		
Install Docking Unit (Rem.)	21	21	2	23a	23a	2 (c)	24	Work suspended for two weeks during separate electrical contract
- Elec. Inventory System Installation Delay			2			2 (c)		
Punchlist	24	24	0	24a	24a	0	24	As Planned Progress
Net Delay or (Savings) as of Update 6						**8**	**24**	

Table 16 – Summary of Analysis of Sixth Window

Table 17 outlines a summary of the individual activity delays that contributed to overall project delay, as determined by the preceding six windows analyses. The fragnet activities that contributed to delays to original schedule activities are listed below the activities that they delayed, and the delays are subtotaled above the fragnet activities, to the right of the original activities. Concurrent delays are apportioned in equal parts to each contributing activity in the totals.

Activity	Window						Total
	1	2	3	4	5	6	
Project Start	0	0	0	0	0	0	**0**
Excavation	3	0	0	0	0	0	**3**
- Test for Contam.	1						
- Remove UST	2						
Foundation	0	0	0	0	0	0	**0**
Tilt-Up Joining Wall	0	0	0	0	0	0	**0**
Remaining Tilt-Up Walls	0	0	0	0	0	0	**0**
beams and roofing	0	0	0	1.5	0	0	**1.5**
- Modify Roof Panels				1			
- Crane Delay				1 (c)			
Select Racking System	0	0	0	0	0	0	**0**
Install Racking	0	0	0	0	0	2 (c)	**1**
- Elec. Inventory System Installation Delay						2 (c)	
Fab/Del Docking Unit	0	0	1	1 (c), 1	(1)	0	**1.5**
- Supplier Delay			1				
Reception Walls	0	0	0	0	0	0	**0**
Reception Roof	0	0	0	0	0	0	**0**
Install Docking Unit	0	0	0	0	0	2 (c)	**1**
- Elec. Inventory System Installation Delay						2 (c)	
Punchlist	0	0	0	0	0	0	**0**
Project Finish	0	0	0	0	0	0	**0**
Total	**3**	**0**	**1**	**3**	**(1)**	**2**	**8**

Table 17 – Summary of Individual Activity Delays

The concurrent delays shown in table 17 can be simplified by distributing the final apportioned delay to each activity through the table. In addition, the fragnet delays can be summarized into the activity delays. The simplified table is shown as table 18.

Activity	**Window**						**Total**
	1	**2**	**3**	**4**	**5**	**6**	
Project Start	0	0	0	0	0	0	**0**
Excavation	3	0	0	0	0	0	**3**
Foundation	0	0	0	0	0	0	**0**
Tilt-Up Joining Wall	0	0	0	0	0	0	**0**
Remaining Tilt-Up Walls	0	0	0	0	0	0	**0**
beams and roofing	0	0	0	1.5	0	0	**1.5**
Select Racking System	0	0	0	0	0	0	**0**
Install Racking	0	0	0	0	0	1	**1**
Fab/Del Docking Unit	0	0	1	1.5	(1)	0	**1.5**
Reception Walls	0	0	0	0	0	0	**0**
Reception Roof	0	0	0	0	0	0	**0**
Install Docking Unit	0	0	0	0	0	1	**1**
Punchlist	0	0	0	0	0	0	**0**
Project Finish	0	0	0	0	0	0	**0**
Total	**3**	**0**	**1**	**3**	**(1)**	**2**	**8**

Table 18 – Simplified Table

In the Baseline Schedule, project finish was forecast for week 16. Project finish actually occurred in week 24. As shown through the preceding analysis, the eight-week delay to project finish was the result of:

- a three-week delay caused by excavation;
- a one-and-a-half-week delay caused by beams and roofing;
- a one-week delay caused by install racking;
- a one-and-a-half-week delay caused by fab/deliver docking unit; and
- a one-week delay caused by install docking unit.

A portion of the responsibility analysis was performed in order to create the fragnets. Now that the activity delays that contributed to the overall project delay have been fully quantified, the relevant portions of the responsibility analysis can be completed and the party responsible for each delay can be identified. The completion of the responsibility analysis would include a review of contract requirements and any further information regarding the specific events that led to the delay that was not analyzed when the fragnets were created. This additional analysis may be necessary because the significance of each activity delay (how much each contributed to the project delay) was not known when the fragnets were created. For example, additional review of the events that led to the delay to excavation may be deemed necessary. It is possible that more than one party might be identified as the responsible party for a particular activity delay. It is also possible that some of the delays might be associated with weather or other events for which both parties are contractually relieved of responsibility.

COMPARISON AND COMMENTARY

Both derivations of the windows analysis method identified the same quantity of delay in each of the windows. However, the delays were attributed to the underlying activities in slightly different portions. Table 19 compares how the project delays were attributed in each of the two methodologies.

Activity	Analysis Without Fragnet Insertions	Analysis With Fragnet Insertions
Project Start	0	0
Excavation	3	3
Foundation	0	0
Tilt-Up Joining Wall	0	0
Remaining Tilt-Up Walls	(1)	0
beams and roofing	1	1.5
Select Racking System	0	0
Install Racking	1	1
Fab/Del Docking Unit	3	1.5
Reception Walls	0	0
Reception Roof	0	0
Install Docking Unit	1	1
Punchlist	0	0
Project Finish	0	0
Total	**8**	**8**

Table 19 – How Project Delays Were Attributed

Both forms of the analysis identified three weeks of project delay associated with excavation, one week of delay associated with install racking, and one week of delay associated with install docking unit. Both analyses found no delays associated with project start, foundation, tilt-up joining wall, select racking system, reception walls, reception roof, punch list, and project finish. The following sections describe the discrepancies between the two analyses.

Remaining Tilt-Up Walls

The first analysis attributed a one-week savings associated with better-than-expected progress on that activity, but the second analysis found no savings. The first analysis found that the savings occurred during window 3. At the start of window 3, remaining tilt-up walls was critical according to the current schedule update. The activity was completed three weeks earlier than planned in that update. The reason that no project savings was associated with remaining tilt-up walls in the second analysis is that fab/deliver docking unit was concurrently critical with remaining tilt-up walls in that analysis because of the docking unit supplier delay that had been added in window 2. Which analysis provides a more accurate representation of actual project events? Did the better-than-expected progress of remaining tilt-up walls cause a project savings, which was later absorbed by the late start of fab/deliver docking unit? Was fab/deliver docking unit actually delayed in week 5, absorbing all of its available float and preventing any savings associated with remaining tilt-up walls from ever occurring?

There is information available to support both analyses. update 2 showed that fab/deliver docking unit had two weeks of float available as of week 9. Thus, the first analysis is supported. Based on the schedule, one week of savings could be achieved by accelerating the remaining tilt-up walls. However, in week 5 the docking unit supplier had indicated to the contractor that it would not begin fabricating the docking unit until week 11. If that information had been incorporated into the project schedule, then no savings would have been identified in the first analysis. However, the information was not incorporated into the schedule during the project. The contractor's field personnel may have believed that they could achieve a project savings by accelerating work in week 9.

If the responsibilities for the docking unit supplier delay and the savings associated with the better-than-expected progress of remaining tilt-up panels both lie with the contractor, whether any savings were associated with the accelerated work during week 9 may be a moot point. After all, a one-week project delay occurred during week 9. If that delay was associated with a one-week savings because of remaining tilt-up walls and a delay to fab/deliver docking unit or simply a delay to fab/deliver docking unit, the contractor is still responsible for the overall one-week delay that occurred during the window. Alternatively, if the owner (or another party for which the contractor has no responsibility) is responsible for the delay to fab/deliver docking unit, the question may be important in the final assessment of liquidated damages or determination of actual damages. For example, if the contractor was required to procure the docking unit from a supplier selected by the owner, the owner may be held responsible for the delays associated with the supplier. In that case, it would be important to determine whether the contractor is entitled to any savings associated with the better-than-expected progress of its other work.

Beams and Roofing

The beams and roofing activity was found to have caused one week of project delay in the first analysis, and one-and-a-half weeks in the second analysis. In both analyses, the delays were identified during window 4. The difference is associated with when the delay to beams and roofing was incorporated into the analysis. In the first analysis, the remainder of beams and roofing became concurrently critical with fab/deliver docking unit in week 14, because of its failure to start. In the second analysis, beams and roofing became critical in week 13, when the fragnet associated with the modifications to structural steel and roof panels was incorporated into the schedule. Again, which is the better model of the delay?

One could argue that the information regarding the beams and roofing delay became available in week 13. Thus, it should be incorporated into the analysis at that time. However, doing so takes fab/deliver docking unit off of the critical path. fab/deliver docking unit was critical at the start of window 4 and was making slower-than-expected progress. In the second analysis, it is removed from the critical path in week 13, by the insertion of the roofing fragnet. However, it returns to the critical path in week 15 because of its continued slower-than-expected progress, and it remains on the critical path in update 4 at the end of the window. Thus, it appears to be unrealistic to find that the activity was not critical in weeks 13 and 14 when the project schedules show that it was critical at both the beginning and end of the window, and the analysis shows that it was critical in the middle of the window.

Fab/Deliver Docking Unit

The final discrepancy in the two analyses is associated with the fab/deliver docking unit activity. This activity caused delays in windows 3 and 4 and a savings in window 5 in both analyses. The difference in the two analyses was the quantity of delay found in windows 3 and 4. The first analysis found two weeks of delay in each window. The second found one week in window 3 and one-and-a-half weeks in window 4.

In the first analysis, fab/deliver docking unit became critical in week 10. It did not actually begin until week 12, creating a two-week project delay. In the second analysis, fab/deliver docking unit became concurrently critical with excavation in week 5, when the supplier's delay was identified. However, fab/deliver docking unit did not cause a delay until it failed to start in week 11. The difference between the two analyses of window 3 is associated with the same cause as the one-week savings that was attributed to the better-than-expected progress of remaining tilt-up panels in the first analysis during that window. There was a net delay of one week during window 3. If there was a one-week savings associated with remaining tilt-up panels, then fab/deliver docking unit caused two weeks of delay—resulting in a net one-week delay. If there was no savings associated with remaining tilt-up panels, then fab/deliver docking unit only caused one week of delay.

The analyses of the fab/deliver docking unit activity in window 4 differ because of the portion of the delay associated with the beams and roofing activity. In the first analysis, beams and roofing became critical in week 14 and caused a concurrent delay, along with fab/deliver docking unit, for two weeks. In the second analysis, beams and roofing became solely critical in week 13, and caused one week of project delay before fab/deliver docking unit became critical again in week 15.

Overall, the differences in the two analyses highlight the importance of the timing of activity delays and how those delays are modeled in the analysis. When there are multiple impacts to a project and many activities are performed later than their original late dates, the partitioning of project delay into the underlying activity delays can be more easily influenced by the analysis technique chosen. In the example presented, the excavation delay, while one of the longest delays identified, was one of the easiest to model. The fab/deliver docking unit delays were more difficult to quantify because they occurred across several windows and concurrently with numerous other project delays.

The analysis performed was much simpler than most real-world forensic schedule analyses. For example, the schedules presented did not include any out-of-sequence progress. While some activities started late or proceeded faster or slower than expected, none of the original logic relationships from the baseline schedule were ever violated. In practice, some out-of-sequence progress is typical. In addition, no logic changes were made from update to update. Again, it is typical for the plan for project completion to be modified over the course of the project. Decisions must be made regarding how to treat those modifications, especially when the modifications result in critical path shifts, preventing activity delays from contributing to the overall project delay.

The schedules are often the best available model for the project execution plan. However, they are not perfect. When the progress or logic shown in the schedule differs from other project documentation, those discrepancies should be taken into account in the analysis. Delays may be modeled with fragnets, but a model that is created by modifying the actual project schedules is more subject to bias than one that is based on the unaltered schedules. Every activity that does not proceed exactly as originally planned could be modeled with a fragnet insertion, but the amount of information that would be necessary to create a realistic model of every activity delay is not likely to be available. Thus, the delays that are modeled characterize only a portion of the actual activity delays on the project. While the major delays may be incorporated, neglecting numerous minor delays may result in an incorrect model of what was critical when more major delays occurred.

In sum, the best analyses are those that take advantage of the best sources of project information available and incorporate that information into an objective analysis of the project schedule. When project delays are extensive and result from numerous underlying activity delays, the windows analysis method is seen as one of the best methods for producing an objective analysis. However, the two principal versions of the windows analysis method currently in practice can produce different results when applied to the same project schedules. In the end, the results of any analysis must be tied to actual project events to ensure that the model is a fair reflection of reality.

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