Two Applications of Linear Scheduling Techniques for Complex Delay and Causation

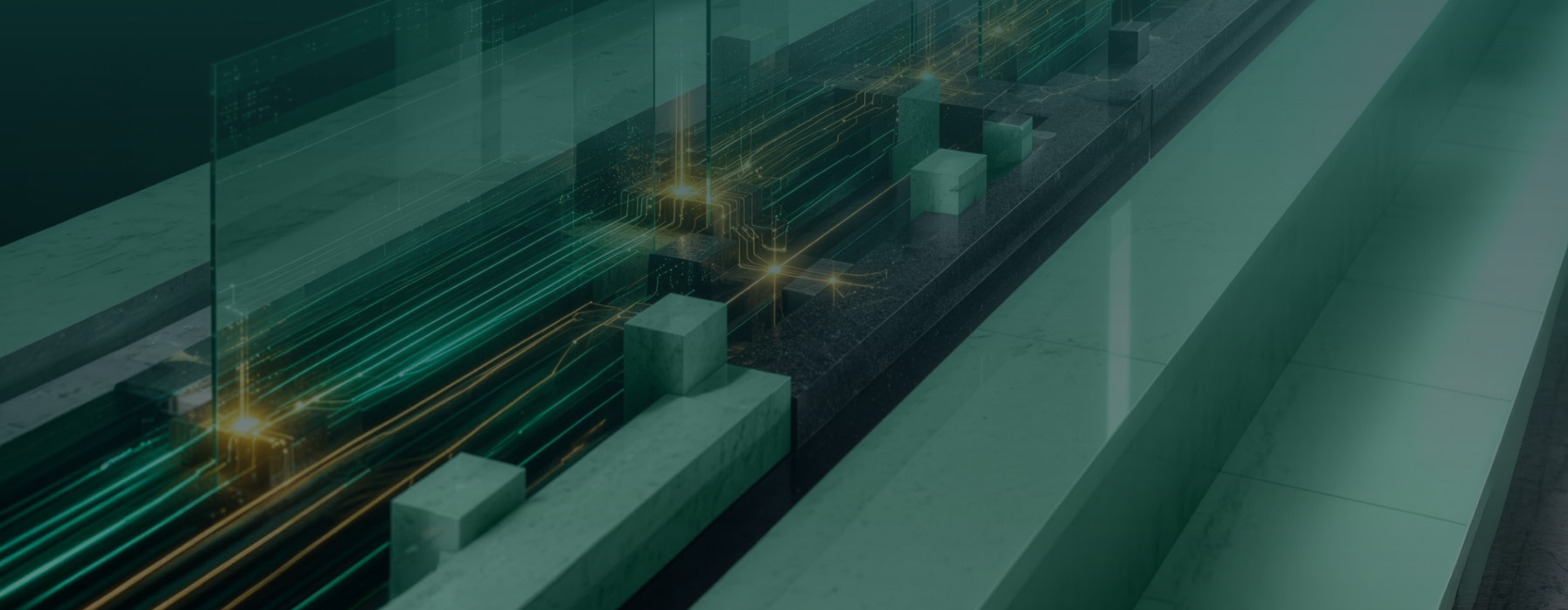
Andrew Leavitt, PE, PSP
Tim Hampson, PE, CCP, PSP
Brian Celeste, PE, CFCC
Michael Cleary, PE

Abstract

Forensic schedule analysis (FSA) in complex construction projects is often highly technical, making findings difficult for broader audiences to interpret. While FSA includes essential detail, it may not convey a clear or compelling narrative on its own. To bridge this gap, analysts can leverage intuitive visual representations that distill intricate data into accessible, persuasive insights. Effective visuals not only clarify the underlying analysis but also help decision makers grasp the significance of delays quickly and confidently.

Linear schedules offer a powerful complement to traditional CPM scheduling bar charts by clearly depicting planned work, highlighting delays, and supporting causation analysis. While widely used in horizontal construction, their ability to present progress and sequencing intuitively makes them an effective tool for conveying delay dynamics across a broad range of project types. Central to both visual representations in FSA and the use of linear schedules as a complement to bar charts is the technique of plotting progress of work as a function of time and location. Linear scheduling techniques can depict work progress and sequencing in an intuitive manner.

This paper examines two applications of linear scheduling techniques. The first application shows how linear schedules can be used to supplement CPM schedules and graphically illustrate delay and disruption within forensic schedule analyses. The second application demonstrates how linear schedules can be utilized to extend beyond supporting causation, by providing a practical means to identify, quantify, and communicate delay.



1. Introduction

Linear scheduling techniques can depict progress and sequencing of work in an intuitive manner. In forensic schedule analysis (FSA), these techniques can be applied to existing, validated data from CPM schedules and production data to clearly demonstrate key work and impacts thereto. When circumstances require, analysts' interpretation of linear schedules can be utilized to bolster their understanding of a CPM schedule for use in FSA.

When presenting an FSA, analysts must accurately and effectively present critical path delays to audiences with varying levels of construction and CPM scheduling knowledge. To do this, analysts rely on visual aids, such as bar charts (i.e., Gantt charts), to depict and demonstrate delay and disruption. In simpler analyses, a bar chart can sufficiently communicate the effect of a critical path delay. However, in the analysis of certain complex delays, bar charts may not provide the detail or depth of information to properly identify and demonstrate the causes of critical path delay.

Overreliance on bar charts to depict critical path delays or disruption risks the loss of key details in a presentation of findings. Bar charts show when an activity starts and finishes and the corresponding duration, but not the pace of the work. This leaves missing information related to the production rate over time, which is particularly impactful on long-duration activities. Bar charts also do not show the timing or geographic location of discrete impacts on an activity. Furthermore, overuse of bar charts can be fatiguing for an audience trying to assess the details that may not be available.

The greater the level of detail included in a CPM schedule, the better these key details may be shown. But not every CPM schedule contains the level of detail required to depict delay and disruption clearly and with precision. In instances such as these, analysts can prepare a linear chart to help establish the causal link between impact events and activity delay or disruption, so long as the CPM schedule is validated. As stated by Bhat and Carson, "[Linear charts] can be a good platform to analyze resources in determining the lowered productivity and establishing the true cause of the lower productivity as experienced in disrupted projects." [1]

This paper examines two applications of linear scheduling techniques for evaluating delay and determining causation in FSA. The first technique involves the use of linear charts to establish causal links between impact events and activity delay or disruption, emphasized in this paper through a vertical construction example.

The second technique involves the use of linear schedules to identify the critical path and measure delay, highlighted in this paper through a horizontal construction example. Analysts can use linear schedules, with appropriate fact-based principles, to identify an accurate critical path. From this, a modified CPM schedule and adjoining linear schedules can measure delay and demonstrate causation.

2. Fundamentals of Linear Scheduling and Linear Charts

Linear scheduling refers to the technique of project planning and scheduling to model project activities that are repetitively performed. Both linear charts and linear schedules represent project progress as a factor of time and location. In doing so, they provide additional detail that a bar chart cannot — the production rate of the work performed. The x and y axes of the chart represent time and location (and at times, these are interchanged), and each line represents an activity or scope of work. When time is plotted along the x-axis, the steeper the slope, the greater the production rate. When time is plotted along the y-axis, the steeper the slope, the slower the production rate. Changes in slope tend to correspond with the locations or times at which project impacts occurred.

AACE Recommended Practice (RP) 129R-23: Linear Scheduling Methods provides an overview of the types of linear charts/schedules and breaks down methods of plotting progress by time and location into two major classifications: (i) Scheduling Techniques for Repetitively Linear Projects; and (ii) Scheduling Techniques for Physically Linear Projects.

Linear schedules used to contemporaneously plan the work will also often contain physical elements, such as profile maps and crossings, which depict topographic information. A block (i.e., gap or barrier area) on a linear schedule is a constraint that prevents or delays a linear activity from progressing at its planned rate or sequence and can indicate non-working calendars, such as winter windows, wildlife migration windows, or high-risk work zones, such as an avalanche window. RP 129R-23 provides additional detail about the various standard elements of linear schedules. [2] The figure below depicts an example of the use of some of these elements, including topographical/elevation information and a block, on a linear schedule.

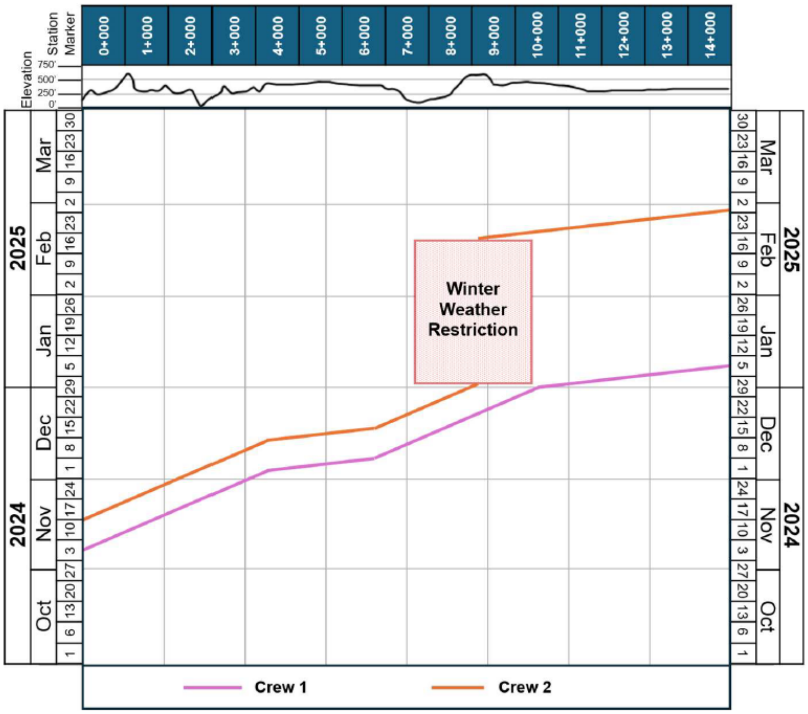


Figure 1: Simple Example of a Linear Schedule with a Winter Weather Block

In the example from the figure above, Crew 1's production, shown by the pink line, controlled the pace of Crew 2, shown by the orange line, until the end of December 2024, just before station marker 9+000. The pace of the work between stations 0+000 and 4+000 was impacted by the rapidly changing terrain indicated in the topography illustration shown at the top of the chart. However, in the beginning of January 2025, Crew 2 hit a Winter Weather Restriction area, as denoted by the light-red block, and its work was delayed until mid-February 2025. While Crew 2 was only 1.5 weeks behind Crew 1 throughout November and December 2024, the Winter Weather Restriction caused Crew 2 to complete its work seven weeks later.

A linear chart is a visual aid used in FSA to depict the progress of a particular scope of work or activity using lines to demonstrate a production rate. Linear charts utilize visual elements to demonstrate the production rate of the work performed. Without specific location data, this principle can apply to units or percentage complete. An example of how the slope represents the production rate, in this case of meters of pipeline constructed, is shown in the figure below.

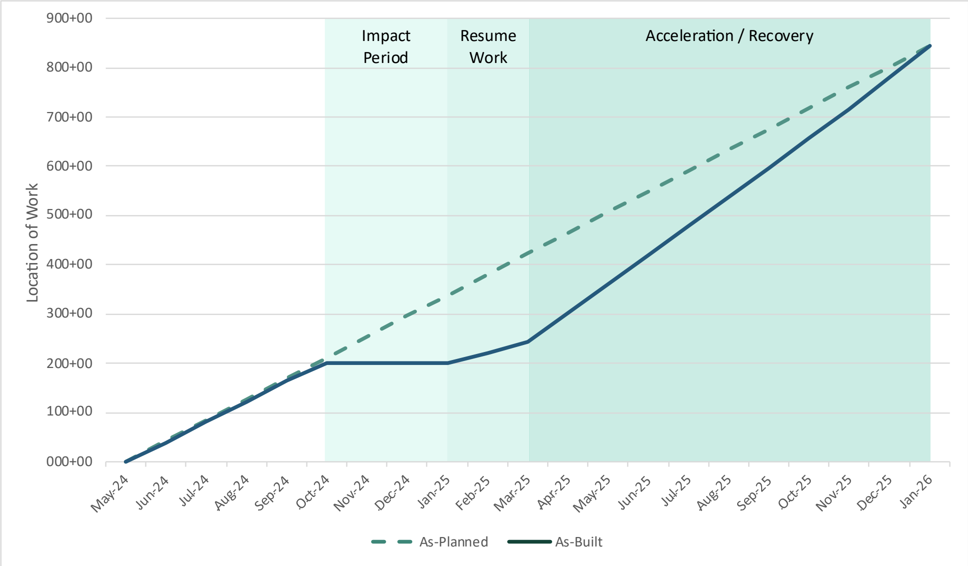


Figure 2: Simple Example of a Linear Chart: Production Rate Depicted by the Slope of the Line

In the example above, the green dashed line represents the planned production rate, and the blue line represents the as-built production rate. In the first five months, the project achieved the planned production rate. Then, between October 2024 and January 2025, progress was completely stopped at the 200+00 station marker. Between January 2025 and March 2025, work ramped slowly back up at a slower-than-planned production rate, followed by an accelerated period between March 2025 and the planned completion date in January 2026, resulting in on-time completion of the work.

Actual progress can be easily compared to the plan to understand impacts during the course of a project and compare planned and actual production. Utilization of a linear chart can identify specific troublesome locations or time periods for a project. [3]

The two examples in Figures 1 and 2 above may provide a representation of the data in a more visually effective manner compared to a traditional bar chart.

3. Evaluation of Data for Forensic Application

Before an analyst creates a linear chart as part of a FSA, it is necessary to ensure the underlying data in the CPM schedule and/or linear schedule is accurate and complete.

To perform FSA accurately and present findings effectively about key work (whether the work is linear in nature or not) and impacts thereto via a linear chart, an accurate CPM schedule representing a realistic critical path and detailed production tracking information is required. If a CPM schedule does not accurately represent the project, the accuracy of FSA and the linear chart may also be diminished.

Schedule evaluation or validation is an important primary step in helping to guide an analyst's FSA methodology. [4] AACE RP 29R-03 provides source validation protocols, which analysts can use, along with other criteria and protocols (such as the Society of Construction Law's Delay and Disruption Protocol) to validate that the information in the CPM schedules reasonably and realistically represents the project and the critical path. [4, 5]

Once validated, CPM schedules serve as a primary source of information for FSA and for the development of linear charts. The activities on the critical path in the CPM schedules can be converted into linear charts. This allows for the analysis of specific production data, identification of impacts, and establishment of causal links.

For projects where a linear schedule was maintained contemporaneously, CPM schedules and linear schedules can be used in a complementary manner, and each schedule can be used to inform the other. During the project, when planning begins with a linear schedule, analysts can assess how the CPM schedule represents the information plotted in the linear schedule, cross-walking between two independent planning platforms.

However, there are important nuances to consider when evaluating a CPM schedule in concert with a linear schedule. The first nuance involves understanding the basis of project performance measurement. Linear schedules are structured around production rates, whereas CPM schedules, if not resource-loaded and managed using earned value (EVM), are structured around activity durations.

The second nuance involves understanding how activity sequences in the linear schedule are represented as logic in the CPM schedule. Linear schedules tend to have less robust logical relationships between work and crew flow than CPM schedules. Careful assumptions are needed to ensure that CPM schedules accurately depict the critical path of the project. If the nuances of translating information from a linear schedule into a CPM schedule are not considered and understood, the critical path of the project may be inaccurate. The process flow diagram on the following page illustrates the steps needed to develop a linear-chart analysis based on a CPM schedule.

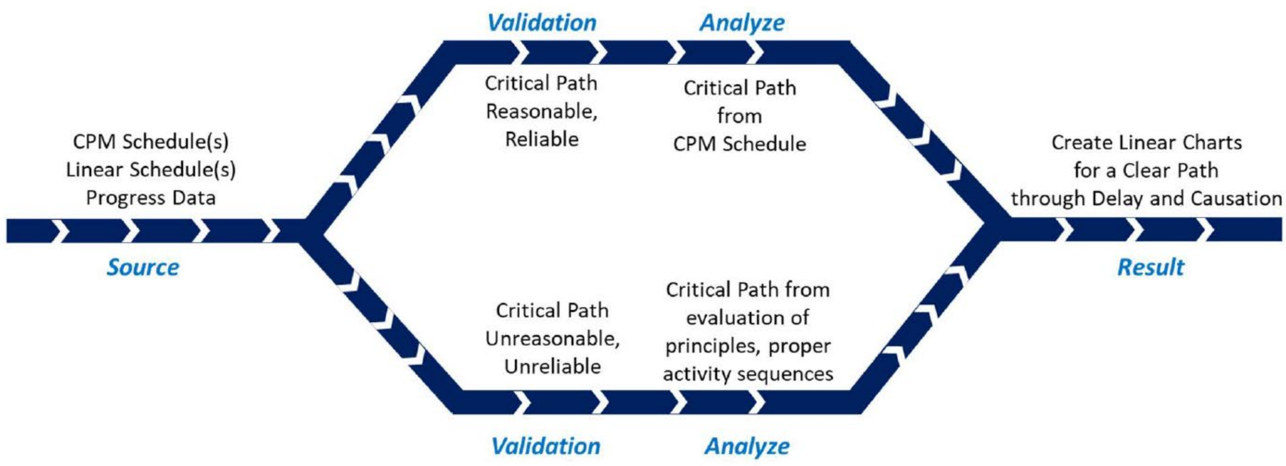


Figure 3: Process Flow Diagram for the Development of Linear Charts

As shown in the diagram above, the process starts with the collection of available source data. The source data is evaluated to determine whether it accurately represents the project and whether the critical path is reasonable and reliable. Then, once the critical path is identified, the FSA can be performed, and linear charts can be prepared to demonstrate findings related to causation of delay. The next section presents the first application of a linear schedule technique — creating linear charts for FSA.

4. Application 1: Creating Linear Charts for FSA

Based on an understanding of the CPM schedule, key sequences of work can be plotted in a linear chart. Analysts can rely on the CPM schedules for overall durations of the work, but production data, often used to help validate the CPM schedules, is also required to determine the production rate. So long as there is accurate production data (e.g., linear feet per day, units installed per week, etc.) for key work, a linear chart can be created to help depict and analyze delay and disruption.

Not all work can be clearly represented using linear charts and in such cases, it may be preferable to present impacts using a traditional bar chart. [1] However, in the case of linear or repetitively linear work, a linear chart can clearly demonstrate delay and disruption to an activity or a set of activities. For instance, in vertical construction (e.g., a high-rise building), the progress that a framing crew makes going up a building can be transcribed from a CPM bar chart to a linear chart, and the production rate of that framing crew can be compared to follow-on trades like MEP and drywall. In linear horizontal projects, like pipelines and roadways, this process is even simpler and it is not uncommon for those projects to utilize linear schedules for project controls.

Depending on the available data and type of project, analysts can create a linear chart that plots the production rate of a critical trade or activity. The following types of work can be represented in a linear chart: [6]

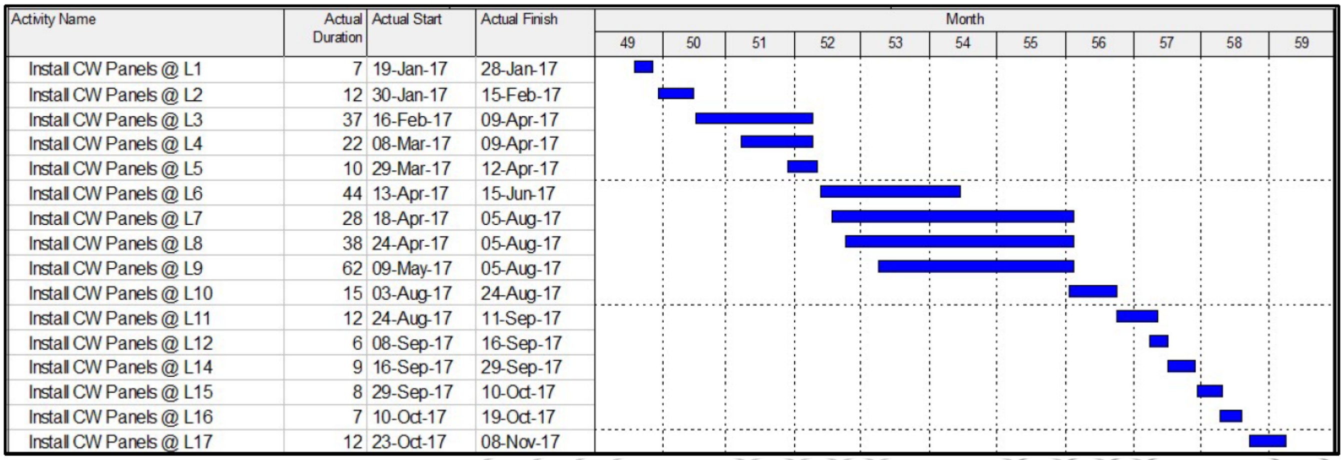
- If a project or activity is physically linear, an analyst may be able to create a linear chart based on time and location data.
- If a project or activity contains repetitive work packages (repetitively linear), an analyst may be able to create a linear chart that shows the progress of each successive work package.
- If a project is linear in nature, but location data is unavailable, an analyst may be able to create a linear chart based on time and quantity data.

A linear chart of production data can identify periods of time and/or geographic locations where impacts occurred and to what extent those impacts delayed the work. An example of this is explored below via a case study.

5. Curtainwall Linear Chart Case Study

To illustrate one of these use cases, the following presents a simplified case study of an FSA related to a curtainwall contractor's performance on a 17-story building. The CPM schedule was first validated to confirm that it accurately reflected the project's scope, appropriate sequencing, and planned work durations in accordance with AACE RP 29R-03. Once validated, an FSA was performed and the critical path was examined and found to run through curtainwall installation — a conclusion supported by project records and personnel interviews.

A linear chart was developed only after an FSA was performed on validated schedules. However, the as-built data recorded in the CPM schedules alone was insufficient because it included only summary durations for curtainwall installation by floor, which did not provide enough detail to determine production rates, identify on which floors the curtainwall was critical, or identify specific issues. As shown in the accompanying figure, installation challenges occurred, but the CPM view remained one-dimensional — only indicating extended durations and concurrent floor activity without revealing the underlying causes.



Activity Name	Actual Duration	Actual Start	Actual Finish
Install CW Panels @ L1	7	19-Jan-17	28-Jan-17
Install CW Panels @ L2	12	30-Jan-17	15-Feb-17
Install CW Panels @ L3	37	16-Feb-17	09-Apr-17
Install CW Panels @ L4	22	08-Mar-17	09-Apr-17
Install CW Panels @ L5	10	29-Mar-17	12-Apr-17
Install CW Panels @ L6	44	13-Apr-17	15-Jun-17
Install CW Panels @ L7	28	18-Apr-17	05-Aug-17
Install CW Panels @ L8	38	24-Apr-17	05-Aug-17
Install CW Panels @ L9	62	09-May-17	05-Aug-17
Install CW Panels @ L10	15	03-Aug-17	24-Aug-17
Install CW Panels @ L11	12	24-Aug-17	11-Sep-17
Install CW Panels @ L12	6	08-Sep-17	16-Sep-17
Install CW Panels @ L14	9	16-Sep-17	29-Sep-17
Install CW Panels @ L15	8	29-Sep-17	10-Oct-17
Install CW Panels @ L16	7	10-Oct-17	19-Oct-17
Install CW Panels @ L17	12	23-Oct-17	08-Nov-17

Figure 4: Bar Chart from Primavera P6 Showing Actual Level-by-Level Installation of Curtainwall Panels

A linear chart was developed to compare the planned and actual production rates. The contemporaneous CPM schedule data was used as a basis to form the as-planned installation curve, in green in the figure below. The reported earned progress, utilizing installation trackers, delivery records, and project correspondence is shown in blue.

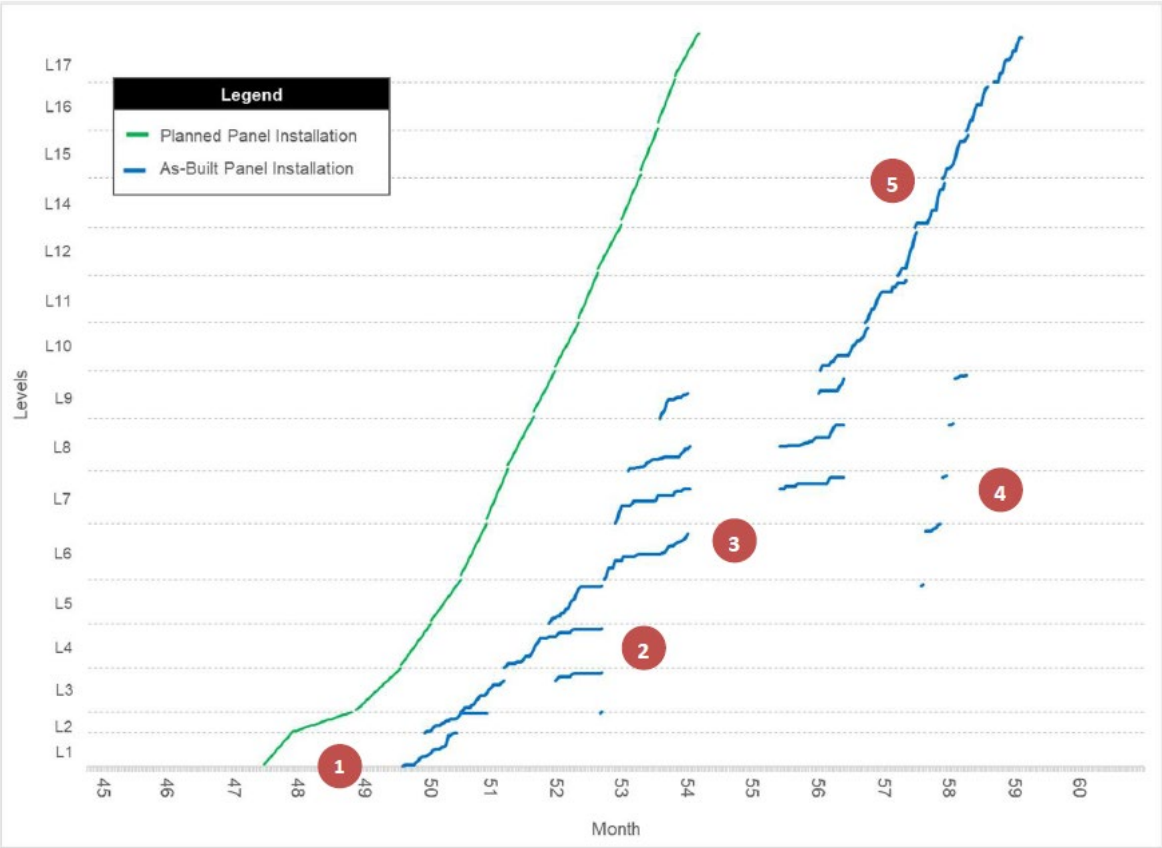


Figure 5: Linear Chart Depicting Planned vs. Actual Level-by-Level Installation of Curtainwall Panels

By comparing actual installation with the plan in a linear view, the analysts identified key impacts and the periods in which progress was impeded. The actual installation ran into issues that impeded progress. In this case, the contractor was impacted by a start delay caused by predecessor work (shown at Point 1, in red). Additionally, the linear chart demonstrates that the Level 1 production rate was slower than planned as evidenced by the shallower as-built line when compared to the planned line.

Next, the curtainwall contractor experienced production impacts (shown at Point 2). The contractor performed work concurrently on Levels 3–5 in an attempt to accelerate. However, its work on these floors started and stopped — something which the bar chart could not show. Because of the starts and stops, the critical path actually jumped from Level 3 to 4 and then from Level 4 to 5 before either Levels 3 or 4 were complete. This critical path detail could not be depicted on the bar chart either.

Eventually, the contractor moved its crews to Levels 6-9, but a stop work order (shown at point 3) paused work on all four parallel work areas. The contractor-provided CPM schedule did not show this stopped work, but rather simply increased the duration of these activities to account for the delay. While this is a common practice in the field, it obfuscates the critical path. The linear chart clearly shows the stopped work and demonstrates that, while level 8 restarted at the same time as Level 7, level 8 had more work to complete, and was therefore more critical. Level 9 restarted later than Levels 7 and 8, which was also a detail not shown in the bar chart. Furthermore, the contractor marked that the work on level 6 was complete at the start of the stop work order, despite some outstanding work remaining.

When the contractor resumed its work, it continued to work out of sequence on Levels 7-9, but it had to perform unplanned comeback work (shown at point 4) after it had marked Levels 6-9 complete in the CPM schedule. Although not on the critical path, the comeback work was also absent from the bar chart. in the bar chart. This come-back work may have also contributed to later production issues by dilution/reassignment of manpower.

In month 57, the contractor restarted its planned sequence of work, but it never reached its planned production rate (shown at point 5). Contributing factors to this production rate included fabrication and delivery delays, reassignment of manpower to come-back work, and manpower shortages.

When compared with Figure 4, the ability of the linear chart in Figure 5 to show discrete details of installation makes the story of installation challenges faced by the curtainwall contractor much easier to tell. Discrete issues like production rate, the stopped work, and out-of-sequence work were unable to be sufficiently shown by the Gantt chart.

The case study presented above works when the CPM schedule is reliable in the measurement of delay (i.e., the CPM schedule shows a realistic and reasonable critical path). The use of a linear chart to support a delay analysis works when the delay can be measured using the CPM schedules contemporaneously generated during a project and then the linear charts discussed above are useful in demonstrating how installation performed against the plan. The linear charts are not used to identify the critical path and they are not the primary tool used to measure delay. The linear charts are supportive of the analysis performed using the CPM schedules.

This case study depicted various impacts to critical path work, which were easily explainable using a linear chart. Indicators that a project may benefit from a linear chart include:

- Impacts to the critical path, which are indirectly linked to the critical path, such as the come-back work that was not depicted in the schedule or fabrication and delivery delays that impacted production rate.
- Multiple work areas are active along the critical path and are being performed in parallel by the same trade.
- Extended durations of activities along the critical path, particularly of activities for which a production rate can be readily determined.

- Instances where critical path work causes following trades to pace their work, but the delayed critical path work had available workfronts — meaning that the critically delaying trade controlled the pace of production for following trades.

In these instances, determining and demonstrating the production rate and/or discrete impacts on a linear chart improves an analyst's storytelling ability and enables an analyst to clearly link cause to effect.

6. Application 2: Using Linear Schedules to Identify the Critical Path and Measure Delay

Contractors are increasingly required to develop and maintain a linear schedule alongside the CPM schedule. When the CPM schedule is prepared first, it can serve as the foundation for the linear schedule. Once plotted, the linear schedule clarifies the work by time and location, highlighting intersecting lines that reveal potential conflicts between crews or operations.

But what happens when the linear schedule is developed ahead of the CPM schedule? It is important to understand how the linear schedule was developed. AACE Recommended Practice RP 129R-23 establishes a 10-step process to develop a linear schedule, as depicted in the figure below.

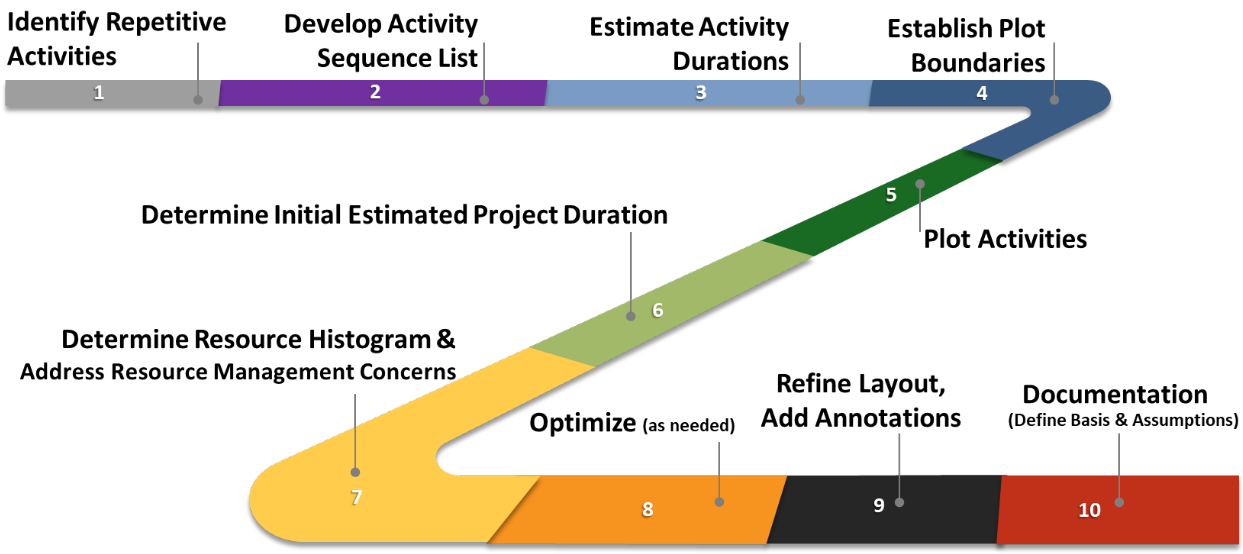


Figure 6: RP 129R-23 Linear Schedule Development Steps

As a linear schedule is developed, it is essential to follow each of the steps above. When considering the use of a linear schedule for FSA, particular attention should be given to evaluating how thoroughly these steps were carried out:

- Step 2, Develop Activity Sequence List: In this step, "relationships between activities and all possible logical activity sequences" [2] are defined. Activity sequence lists need to be prepared to identify activity dependencies and all possible activity sequences for each location. Only after undertaking this step can the planned sequence of work be established. On multiyear megaprojects, this effort can be highly labor intensive. If it is bypassed, the resulting activity relationships in the linear schedule remain unvalidated, leaving a CPM scheduler to rely on incomplete activity sequences and make assumptions about the interdependencies between activities.
- Step 3, Estimate Activity Durations: Project conditions and contractor means and methods that influence expected productivity rates are integrated into defining activities with a corresponding planned duration. In linear schedules, it is common to annotate a schedule with an average production rate per workday, forming the basis of the estimated duration, and the slope of the line in the linear schedule.
- Step 6, Determine Initial Project Duration: Once all activities are plotted, a planned completion date can be identified. However, in practice, contractors more commonly develop schedules to align with predetermined contractual milestone dates.
- Step 8, Optimize: Where necessary to meet target milestone dates, the linear schedule may be optimized by reordering operations or adjusting planned durations. When this occurs, it is essential to understand the decisions made and the rationale behind them. Any optimization must still reflect a realistic and achievable plan.
- Step 10, Documentation: To document the underlying assumptions, dependencies, and the basis for developing the linear schedule, a supporting narrative can serve as a valuable tool to explain the plan and "identify critical areas of work that put the project completion at risk."

If steps are skipped, the linear schedule may have limited reliability as a source for developing a CPM schedule. The resulting CPM schedule is susceptible to inferred logic that may not accurately reflect critical sequences of work. Consequently, any CPM schedule critical path derived from such a linear schedule requires rigorous scrutiny, as unvalidated assumptions can mask the true drivers of project completion and undermine the reliability of the analysis.

When CPM schedules do not contain a reasonable, reliable critical path, analysts can use the linear schedules to help determine an accurate critical path. Once the critical path is identified, planned and actual progress on critical work can be extracted from linear schedules, CPM schedules, and other progress tracking information to create linear charts. This allows the process of demonstrating and analyzing delay and disruption to proceed.

7. Making Sense of the Critical Path of a Linear Schedule

Tilos, a linear-scheduling platform, can generate detailed, logic-driven schedules. In practice, however, many of its advanced logic capabilities are rarely used. Early in a project, stakeholders may favor linear schedules primarily for their ability to present a clear overview of major operations. As a result, these schedules frequently emphasize only the basic questions of what work occurs, where it occurs, and when. Sequencing considerations are typically limited to i) ensuring that a crew is not scheduled in two places simultaneously and that ii) multiple crews do not plan to occupy the same location at the same time. Once these minimal criteria are met, many linear schedules are treated as complete, without undergoing further validation. Unfortunately, this creates a classic cart-before-the-horse scenario in which demonstrating that there is 'a plan' takes priority over developing a good plan."

As noted above, "Developing an Activity Sequence List" is a foundational step in producing a logical linear schedule. When skipped, the practitioner responsible for developing the CPM schedule must match the planned dates reflected in the linear schedule while also introducing logical relationships that may yet be defined. In such cases, thorough documentation of assumptions, inferred dependencies, and the reasoning for the CPM schedule logic becomes essential. These assumptions should then be cross-checked against the draft linear schedule to determine whether revisions are required once the proper activity sequences are established. When this oversight is identified early, during CPM schedule development, these issues can still be corrected before the schedule is finalized.

But what happens when assumptions go unvalidated? When a linear schedule is used as the project baseline — with the expectation that a CPM schedule will be developed later — the resulting critical path, even if identified and explained, requires rigorous scrutiny. Without validation of the underlying assumptions and logic, the apparent critical path may not reflect the true drivers of project completion and should therefore be carefully evaluated.

The next section provides details on how this scenario was addressed on a recently completed pipeline.

8. Pipeline Linear Schedule Case Study

This case study involves the analysis of contemporaneously prepared linear schedules and CPM schedules as part of an FSA on a completed pipeline project. As a foundational step for the analysis, a core group of factually supported logical relationships was established based on several self-evident principles, including the following:

- For mechanical completion to be achieved, all testing and all mechanical operations must be completed.
- For testing to commence, mechanical operations at the location must be completed.
- Seasonal non-work windows shall be observed and avoided. Work planned in a non-work window is at significantly greater risk.

With these facts established, the analyst possesses the foundational framework required to evaluate the linear schedule. The first task is to assess the degree to which the contemporaneous linear and CPM schedules conform to the principles outlined above. This initial review revealed several notable anomalies, summarized in the table below.

Principle	Observation
For Mechanical Completion to be achieved, all testing and all mechanical operations must be completed.	Linear and CPM schedules were **consistent** with the principle
For Testing to commence, mechanical operations at the location must be completed.	Linear and CPM schedules were **inconsistent** with the principle
Seasonal non-work windows shall be observed and avoided. Work planned in a non-work window is at significantly greater risk.	Linear and CPM schedules were **inconsistent** with the principle

Figure 7: Case Study Principles and Observations

As these inconsistencies called into question the reasonableness of the schedules, the linear and CPM schedules were further scrutinized. The classic cart-before-the-horse scenario emerged: an unvalidated linear schedule was manually constructed and then promoted as the basis for deriving planned start and finish dates in the CPM schedule. A snapshot of the linear schedule is displayed below.

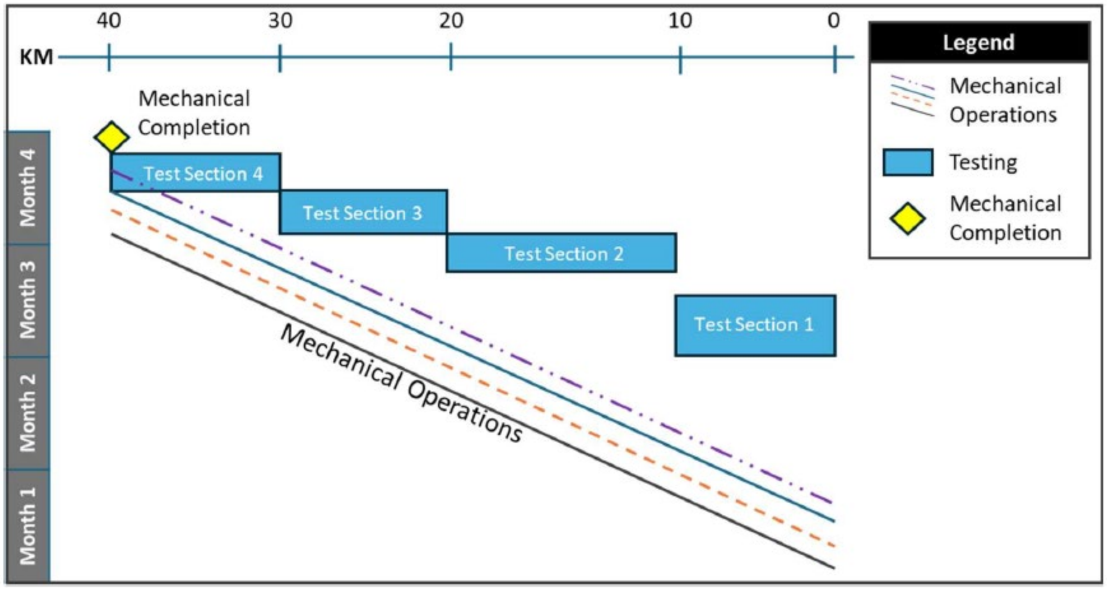


Figure 8: Linear Schedule Snapshot — Pipeline Case Study

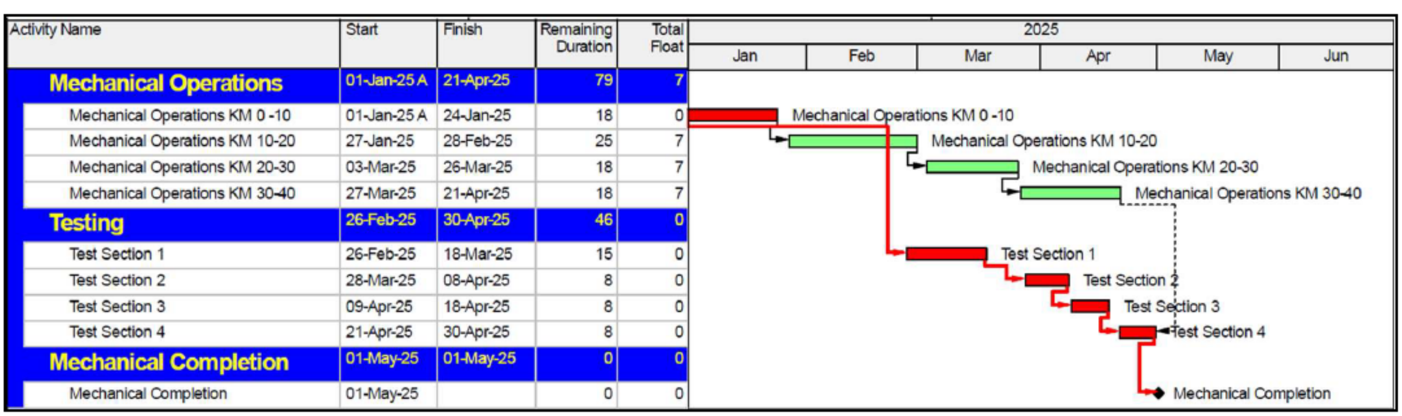
The linear schedule shown above allocates four months to complete the mechanical operations work required to achieve mechanical completion. Testing activities are depicted as blue blocks, representing four test sections planned along the pipeline.

The test sections were scheduled to begin in a sequence generally aligned with the pace of the mechanical operations. Although testing could commence earlier, doing so would cause the testing crew to advance more quickly than the mechanical work, resulting in planned periods of idle time. To avoid unnecessary standby costs and because the testing sequence remained flexible — though still dependent on completion of mechanical operations — the contractor scheduled testing as late as possible.

Another fundamental observation was the contractor's plan to complete mechanical operations towards the end of month four, during the testing operations at the same location. This is an early warning sign that the mechanical operations are required to be finished as soon as possible, so that the balance of testing can be carried out and Mechanical Completion can be achieved.

However, since the linear schedule did not establish activity sequences, the CPM schedule did not properly incorporate these principles into its planned logic. The CPM schedule linked the first test section to mechanical operations using a start-to-start relationship with a lag from the start of mechanical work at KM 0. While this is a reasonable forward-pass relationship — reflecting that testing begins several workdays after mechanical operations commence — it is not the only sequence governing the relationship between the two scopes. In practice, mechanical operations directly influence how testing must be executed.

However, the CPM schedule omits a key logic relationship: at least one additional activity sequence tying the finish of mechanical operations to the corresponding portion of testing that must occur afterward. The absence of this mandatory tie results in a critical path to mechanical completion that is inconsistent with fundamental pipeline construction principles. A depiction of the CPM logic before incorporating the missing relationship is shown in the figure below.



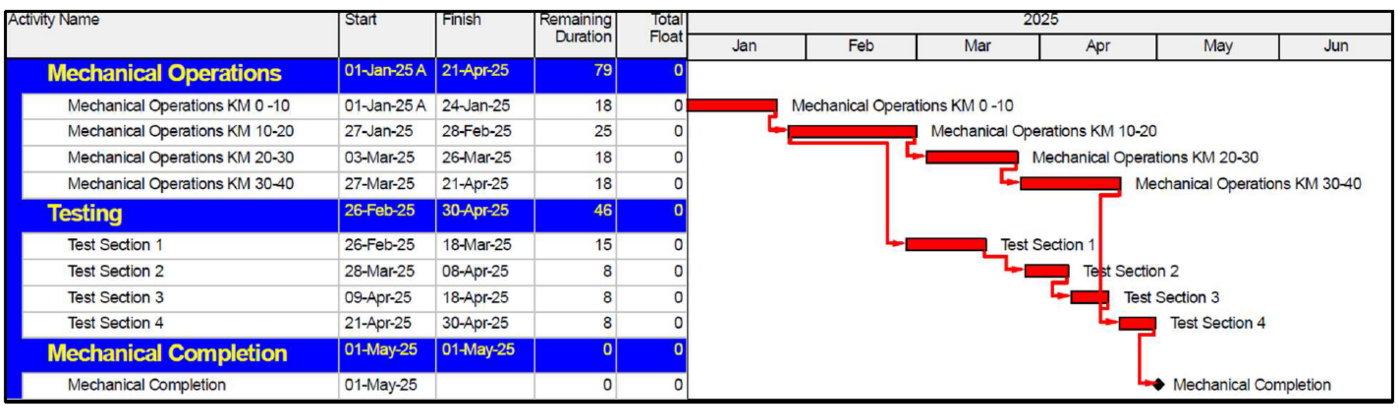
Activity Name	Start	Finish	Remaining Duration	Total Float
Mechanical Operations	01-Jan-25 A	21-Apr-25	79	7
Mechanical Operations KM 0 -10	01-Jan-25 A	24-Jan-25	18	0
Mechanical Operations KM 10-20	27-Jan-25	28-Feb-25	25	7
Mechanical Operations KM 20-30	03-Mar-25	26-Mar-25	18	7
Mechanical Operations KM 30-40	27-Mar-25	21-Apr-25	18	7
Testing	26-Feb-25	30-Apr-25	46	0
Test Section 1	26-Feb-25	18-Mar-25	15	0
Test Section 2	28-Mar-25	08-Apr-25	8	0
Test Section 3	09-Apr-25	18-Apr-25	8	0
Test Section 4	21-Apr-25	30-Apr-25	8	0
Mechanical Completion	01-May-25	01-May-25	0	0
Mechanical Completion	01-May-25		0	0

Figure 9: Critical Path Based on Assumed and Unvalidated Activity Sequences

As shown in the figure above, the critical path to mechanical completion was driven by mechanical operations at KM 0–10, which were linked to the start of Test Section 1 through a start-to-start relationship with a 40-workday lag. Under this logic, testing would begin a fixed number of days after mechanical operations commenced, regardless of the actual progress achieved in the field. Because of this extended lag, the critical path to mechanical completion incorrectly flowed through the testing sequence. This schedule creates an unachievable scenario where the mechanical operations are allowed to finish as late as April 30, 2025, the same date as the finish of testing. This violates the principle established above where mechanical operations at the location must be completed in order for testing to commence.

In addition, the planned effort indicates that mechanical operations should control the sequence. Mechanical operations require 79 crew-days, compared with 46 crew-days for testing. Emphasizing the testing as the controlling sequence despite the substantially greater amount of mechanical operations work results in an illogical critical path.

When the flawed logic is addressed, the critical path to mechanical completion is driven by a different sequence, governed by the mechanical operations work, as depicted in the figure below. To limit modifications to the schedule, the testing sequence remains unchanged. In practice, testing could begin earlier and testing in Sections 1–3 need not be modeled as critical provided the crew remains productive and minimizes unplanned idle time.



Activity Name	Start	Finish	Remaining Duration	Total Float
Mechanical Operations	01-Jan-25 A	21-Apr-25	79	0
Mechanical Operations KM 0 -10	01-Jan-25 A	24-Jan-25	18	0
Mechanical Operations KM 10-20	27-Jan-25	28-Feb-25	25	0
Mechanical Operations KM 20-30	03-Mar-25	26-Mar-25	18	0
Mechanical Operations KM 30-40	27-Mar-25	21-Apr-25	18	0
Testing	26-Feb-25	30-Apr-25	46	0
Test Section 1	26-Feb-25	18-Mar-25	15	0
Test Section 2	28-Mar-25	08-Apr-25	8	0
Test Section 3	09-Apr-25	18-Apr-25	8	0
Test Section 4	21-Apr-25	30-Apr-25	8	0
Mechanical Completion	01-May-25	01-May-25	0	0
Mechanical Completion	01-May-25		0	0

Figure 10: Critical Path Example Based on Linear Schedule With Proper Activity Sequences

With a clear critical path that adheres to the factual principles of construction, the CPM schedule can be used as a basis to evaluate progress and measure delay. In carrying out an FSA based on linear schedules, this process will likely need to be repeated for each of the contemporaneous CPM schedules, which were developed based on unvalidated, estimated logic.

9. Conclusion

Linear schedules and linear charts provide analysts with a powerful framework for clarifying, validating, and communicating forensic schedule analyses in ways that traditional CPM bar charts alone cannot. By depicting work progress as a function of time and location, these tools illuminate production rates, highlight discrete impact periods, expose out-of-sequence work, and reveal inconsistencies in planned logic — insights that often remain obscured in Gantt-based representations.

The first application demonstrated how linear schedules can be used to graphically illustrate delay and disruption within FSAs. By translating validated CPM schedule data and production records into linear charts, analysts can identify the precise timing and location of impacts, assess changes in production rates, and communicate causation more clearly. Using a vertical construction project, this application showed how linear charts serve as an effective complement to CPM analysis by enhancing transparency and strengthening the narrative linking cause and effect.

The second application, the horizontal pipeline example, illustrated how linear scheduling techniques can extend beyond supporting causation analysis to provide a practical means of identifying, quantifying, and communicating delay — especially when CPM schedules do not contain a reasonable, reliable critical path. In such cases, validated contemporaneous linear schedules can help determine an accurate critical path, from which progress can be extracted and linear charts developed. This enables experts to reconstruct a defensible, fact-based understanding of the longest path and to measure delay even when CPM logic is incomplete or flawed.

Together, these two applications underscore the value of integrating linear schedules into both contemporaneous project controls and retrospective FSA. When applied thoughtfully and supported by reliable data, linear representations enhance analytical rigor, improve clarity, and equip analysts to present a more complete, compelling, and accurate account of project performance.

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Andrew Leavitt, PE PSP
Ankura Consulting
andrew.leavitt@ankura.com

Brian Celeste, PE CFCC
Ankura Consulting
brian.celeste@ankura.com

Tim Hampson, PE CCP PSP
Ankura Consulting
tim.hampson@ankura.com

Michael Cleary, PE
Ankura Consulting
michael.cleary@ankura.com