SmartPM®

E-Book

Creating Project Controls in Construction with Schedule Data

THE POWER OF PROJECT CONTROLS

Unlock the true potential of schedule data metrics in construction projects. This e-book delves into "The Power of Project Controls," highlighting the significance of Project Controls and essential metrics for managing construction schedules and budgets. Explore schedule quality, crew logic, earned value analysis (EVA), critical path delay & recovery, compression, and schedule forecasting to enhance your project management expertise. Studying and employing the information within this e-book empowers project success for all project stakeholders.

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About the Author

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Meet Michael Pink, a seasoned AEC trailblazer with over 20 years of experience in the industry, primarily within the "Big Four" consulting environment. Having worked extensively with owners, contractors, attorneys, and lenders on intricate consulting projects, he later founded Construx Solutions and, most recently, SmartPM. His vision was to address inefficiencies in the scheduling process within AEC projects, which existing software solutions failed to fully integrate. SmartPM aims to become the go-to data analytics hub for construction, aggregating diverse data sets, including scheduling data from various technology systems, and transforming them into actionable insights. This innovative approach ensures projects stay on track, on budget, and reduces risks, ultimately elevating profit margins for companies involved in commercial construction. With SmartPM's incorporation of AI and ML, Michael Pink's mission is to revolutionize construction project analysis and management, providing meaningful, real-time insights for all stakeholders involved.

About SmartPM

SmartPM® is an Automated Project Controls™ and Analytics Platform™ that leverages billions of data points hidden in your schedule to automate schedule and project reviews while extracting insights so you can mitigate risk, control costs, and increase profitability. The platform seamlessly extracts high-level insights from your MPP or P6 files in real-time, ensuring uninterrupted workflow while allowing you to monitor all your projects and manage project risk effectively.

Dedicated to simplifying schedule information and analysis for all stakeholders, SmartPM® Technologies, Inc. aims to eliminate confusion surrounding project schedules and performance. By fostering enhanced team collaboration, minimizing disagreements, and driving successful project outcomes, SmartPM® introduces a cloud-based Automated Project Controls™ and Schedule Analytics platform that transforms static schedules into dynamic, real-time analytics engines. With its automated schedule analysis, accurate end date predictions, and proactive problem prevention, SmartPM® optimizes efficiency, ensuring projects stay on track and within budget, ultimately minimizing legal disputes and maximizing project success.

For more information about SmartPM click here, or, visit us at www.smartpmtech.com

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THE POWER OF PROJECT CONTROLS

What are Construction Project Controls?

Project controls encapsulate the processes, systems, and tools used to plan, manage, and mitigate cost and schedule issues and any risk events that may impact a project. By providing real-time project data in user-friendly formats, project controls facilitate effective management and decision-making, leading to the successful achievement of project milestones.

The Added Value of Project Controls:

- Reduce Costs
- Minimize Delays
- Mitigate Risk
- Improve Margins
- Increase Productivity

The Importance of Project Controls

Due to the extreme unforeseen circumstances facing the construction industry, project controls play a more critical role than ever in successful project management. It's essential to recognize that project controls are not confined to a specific department; rather, they should be ingrained in the fabric of the entire organization.

When all project stakeholders have access to analytics that provide complete visibility into project performance and associated risks, timely and on-budget project delivery becomes the norm.

Project control systems, as emphasized by the Construction Industry Institute, are integral to the overall project management effort and support the attainment of project objectives.

By utilizing key metrics offered by project controls, construction projects can streamline efficiency, identify risks, expose mismanagement, and address areas of under performance throughout the entire project life cycle.

Despite the straightforward processes involved in implementing project controls, they remain underutilized in the construction industry, preventing them from reaching their full potential.

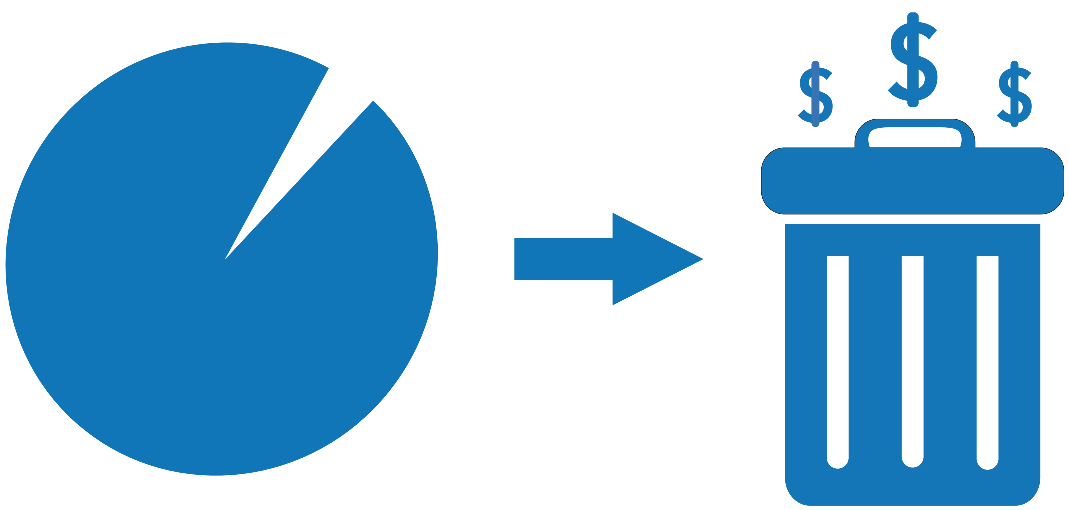
To ensure successful project outcomes, project controls should be adopted across all construction projects, though achieving widespread adoption may present a challenge that needs to be addressed.

THE CURRENT STATE OF PROJECT CONTROLS IN CONSTRUCTION

In the realm of commercial construction, project controls are surprisingly not a top priority for a significant number of companies. Many only consider contingency budgets and schedule padding as their version of project controls.

This concerning trend has not escaped the notice of SmartPM, which has observed the industry closely and made some critical observations:

- < 4% of General Contractors have a dedicated project controls team and/or process in place on their projects.
- The companies that have truly invested in and embraced project controls reside in the upper half of the ENR's top 400 CM firms.
- While numerous commercial construction companies in the United States use project management tools, they fail to invest significantly in project control functions.
- The lack of project controls is a root cause for the industry to reside in a state of significant overruns, delays, and disputes that affect all stakeholders involved in construction projects.



Less than 4% of General Contractors use Project Controls

Wasting $1.6 Trillion, Annually

This poses yet another unfortunate reality: the lack of project controls has a great effect on the **global economy** and the **environment**. According to McKinsey, the construction industry wastes $1.6 Trillion annually in overspending, usually resulting from project mismanagement, delays, and overruns.

WHY IS SCHEDULE DATA THE BEST DATA FOR PROJECT CONTROLS?

Where Does the Data Come From?

Project controls encompass various aspects, but a crucial and unique data source lies within most projects–the project schedule. When thoroughly studied and frequently reviewed, the schedule contains valuable insights that can consistently and effectively manage project outcomes.

It is the Project Schedule

The project schedule, specifically a Critical Path Method (CPM) schedule, serves as the only dataset connecting all construction project elements into a cohesive whole.

It captures information on activity progress, durations, and interdependencies, showcasing how everything is interrelated over time. This makes schedule data a leading indicator, explaining problems before they occur, unlike cost data, which acts as a lagging indicator, reflecting the consequences of issues.

Unfortunately, an estimated 88% of schedules[1] are inadequately constructed, lacking best practices and failing to accurately identify critical paths or calculate float values. Consequently, relying on inaccurate scheduling programs results in mismanaged projects, rendering any analytics based on flawed schedule data unreliable.

To implement an effective analytical process supporting project controls, project teams must start with routine schedule quality checks–an integral part of project control itself.

1 This data is collected from a SmartPM study of analyzing over 20,000 Project Schedules.

Project Controls Key Metrics

Project controls shed light on the wealth of data inherent in construction projects, with the project schedule being a primary source. Out of various avenues available to establish an effective project control process, here are five key metrics derived from schedule data that contribute to delivering high-quality projects.

SUMMARY OF FIVE PROJECT CONTROLS PULLED FROM SCHEDULE DATA

Schedule Quality assesses how well a schedule is built and whether or not best practices are incorporated. This is the most essential part of developing a project control process, as an accurate and reliable schedule is the foundation of all project controls. In other words, it is the structural integrity of the actual schedule.

Earned Value Analysis (EVA) measures a project's cumulative progress at any given time to serve as an early warning sign for potential challenges in progress or performance. This metric ensures projects are not going "off the rails."

Studying Critical Path Delay tracks the number of days that have been delayed due to impacts on the critical path. Recovery entails the processes and changes made to overcome critical path delays. Knowing what is delaying a project, and what decisions are being made to overcome those historic delays is imperative for successful management.

Schedule Compression is a gauge of how much work is being fit into the remainder of the project duration and how that work compares to the plan. If work is getting delayed, or pushed off, and end dates aren't changing, then chances are compression is happening. It is crucial to keep an eye on compression as having a KPI that accurately estimates the extent of schedule compression leads to better decisions regarding project acceleration.

Schedule Forecasting utilizes historical performance data up to a given point in time to predict future end dates of key milestones and the trades that have the most influence on them. Knowing which trade(s) are driving the job or will likely drive a job, regardless of what the critical path says today, is crucial for delivering projects on time and within budget parameters.

CONSTRUCTION CHALLENGES WITH CPM SCHEDULING

Critical Path Method: The Basics

Critical Path Method (CPM) is a scheduling technique that depicts the relationships between construction and non-construction activities essential for project completion. CPM Schedules visualize activity durations and interdependencies, calculating the longest path to project conclusion–the critical path. Additionally, they reveal the amount of "float" or flexibility each activity possesses, allowing for potential delays.

CPM diagrams serve as the ultimate road map for achieving project deliverables. It is imperative to maintain a high-quality project schedule because a CPM schedule forms the foundation for all project controls. Given the industry's challenges, including supply chain complexities, implementing a project control process becomes crucial, with a CPM schedule serving as the ideal foundation for effective project management.

SMARTPM ANALYZED OVER 20,000 PROJECT SCHEDULES & FOUND:

88% of projects had low-to-medium quality schedules at risk of delays & overruns.

64% of projects were compressed.

82% of projects were delayed.

70% of projects did not keep up with originally planned progress over time.

What Does this Data Mean?

The commercial construction industry often fails to fully harness the potential benefits of CPM schedules and project control processes. Low-quality CPM schedules lead to the absence of accurate road maps for resource and activity management, subsequently causing a cascade of issues that affect projected end dates.

Therefore, prioritizing the development of high-quality CPM schedules is essential, enabling a better understanding of the data hidden within and providing valuable insights to navigate the current challenges in the construction industry.

THE IMPORTANCE OF SCHEDULE QUALITY

Why Schedule Quality is the Top Project Control:

Project Controls allow project teams to systematically and accurately measure project performance throughout the project by putting metrics and checkpoints in place to ensure intended progress and performance levels are being met.

Schedule quality: 1) ensures that all data calculated in the schedule program itself is accurate, useful, and supports the decision-making process, and (2), arguably more important, ensures project controls can be used to their fullest potential.

Good schedules following best practices, then, are what allow project controls to leverage the rich data pulled from a construction schedule to gauge performance, risk, delays, impacts, and inefficiencies.

What is Schedule Quality?

Schedule quality refers to the structural integrity of the schedule, or, the level at which best practices have been incorporated into the CPM scheduling program when developing and updating the schedule.

A construction schedule not only lays out a plan over time but also calculates a prioritization plan for managing your project to an end date. It is important to remember that schedule analysis is a constant cycle of planning, scheduling, optimizing, and repeating.

The DCMA-14 Point Check

The DCMA methodology outlines 14 steps, or items, that should be assessed for ensuring that the level of quality is high.

1. Missing Logic
2. Leads
3. Lag
4. Relationship Types
5. Constraints
6. High Float
7. Negative Float
8. High Duration
9. Invalid Dates
10. Resources
11. Missed Tasks
12. Critical Path Test
13. Critical Path Length Index (CPLI)
14. Baseline Execution Index (BEI)

However, this methodology does not consider only construction scheduling. In fact, different items can be missing or added to this list to help in creating an effective and realistic project plan. Projects differ in size and scope. Using only this methodology might give a project a "low" quality schedule grade when the points deducted don't apply to its scope.

Best Practices for Creating a High-Quality Schedule

Creating a high-quality schedule requires attentive input from all levels of a project, particularly around trade flow, resource constraints, and logic. Most importantly, high-quality schedules must have accurate float calculations.

Total float (or slack) is the number of days an activity can be delayed before it impacts the end date of a project. It is what enables project teams to prioritize resources, hence the necessity of crew logic to be embedded into all project schedules.

Essentially, when creating and updating a schedule, all logic needs to be accurate, all durations need to be estimated correctly, and best practices need to be followed.

Take a look at the percentages and ratios below to consider when creating and updating project schedules[1]:

SCHEDULE QUALITY CHEAT SHEET

Metric	Good	Okay	Bad
Total Relationship Ratio	≥ 1.5	1.5 - 1.25	< 1.25
Finish to Start	> 80%	70% - 80%	≤ 70%
Start to Start	≤ 10%	10% - 15%	≥ 15%
Finish to Finish	≤ 10%	10% - 15%	≥ 15%
Start to Finish	≤ 0%	0% - 0.2%	≥ 0.2%
Missing Logic	≤ 1%	1% - 2.5%	> 2.5%
Negative Lag	≤ 2.5%	2.5% - 5%	> 5%
Positive Lag	≤ 2.5%	2.5% - 5%	> 5%
Constraints	≤ 2.5%	2.5% - 5%	> 5%
High Float Activities (> 44 Days)	≤ 20%	20% - 33%	> 33%
High Duration Activities (>44 Days)	≤ 5%	5% - 10%	> 10%
Critical Path %	10% -20%	5% - 10% or 20% - 30%	< 5% or >30%
Average Total Float	15 - 44	7.5 - 15	< 7.5 & ≥ 44
Resource Loaded	≥ 80%	65 % - 80 %	< 65%

1 This table has been developed based on SmartPM's years of experience meeting with many customers and studying project risks and outcomes.

MISSING CREW LOGIC: THE SILENT KILLER OF CONSTRUCTION SCHEDULING

Got Logic?

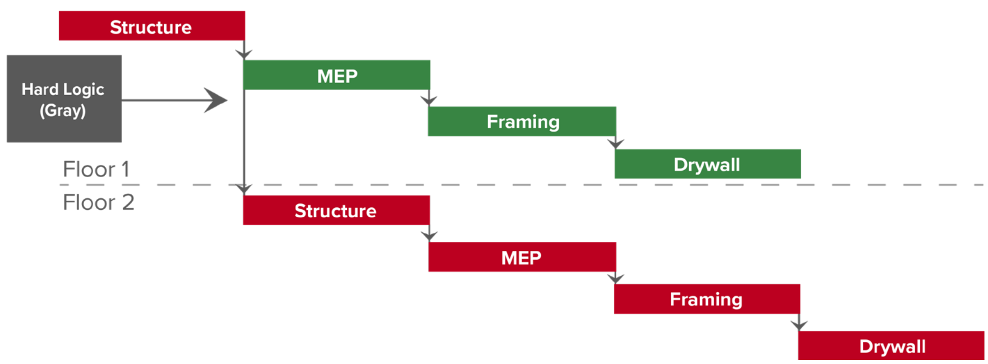
Logic is the reason CPM scheduling programs can run calculations as it explains the order of the program, which is sometimes referred to as the project road-map. This order is how the program calculates float values, start dates, finish dates, and so on.

It is critical for schedules to be built with quality in mind and high-quality schedules ensure that all the logic within them is accurate. However, the first schedule created often has incomplete logical information.

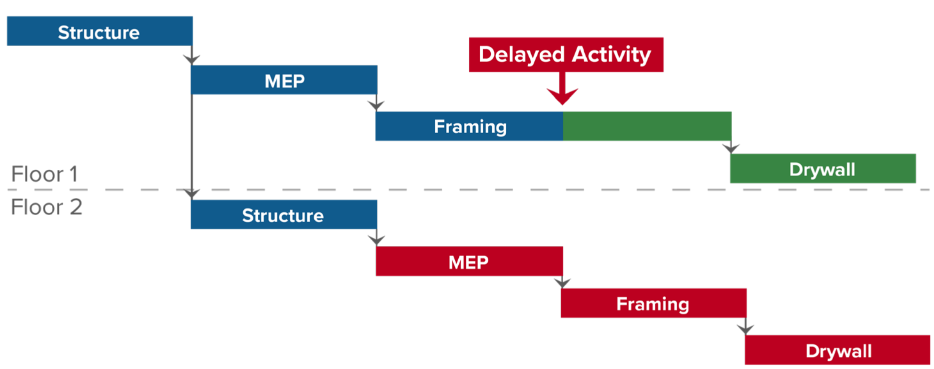
What does this mean? Within CPM scheduling, there are two kinds of logic: hard logic and crew logic.

All About Hard Logic

The first schedule created usually has accurate hard logic information, meaning the project scheduler has thought about what is physically possible according to the flow of things that need to get done. Hard logic represents logic that cannot be done in any other way.

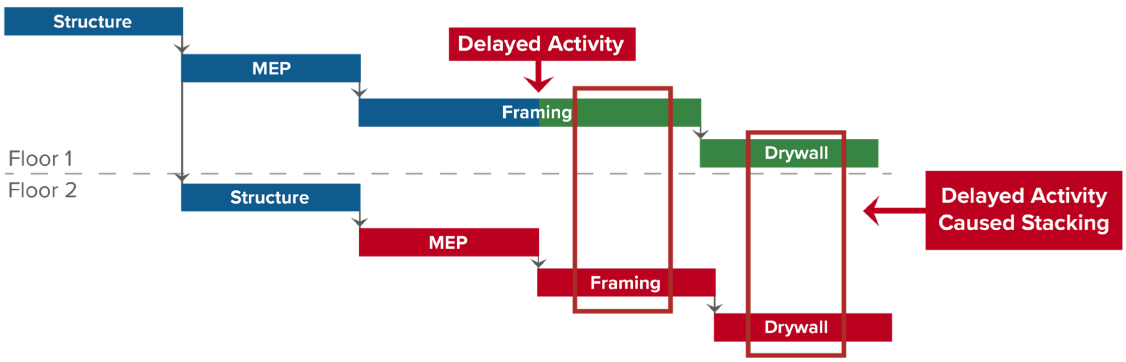


The hard logic in this CPM schedule is explaining that you cannot begin Mechanical, Engineering, and Plumbing (MEP) work on floor one until you have completed the structure on level one. Similarly, you cannot start the structure of the second floor until you are done with the first floor's structure because you cannot build on thin air; you need the structure below to do so.



Hard logic represents how project schedules are wired. But, what happens when an activity gets delayed?

The schedule above depicts that the framing activity on the first floor was delayed. And, without crew logic present, the schedule is indicating that framing on the first and second floors is going to happen simultaneously, otherwise known as **trade stacking.** The issue here is, without an additional crew, the framing activities would be impossible to complete within their time parameters.



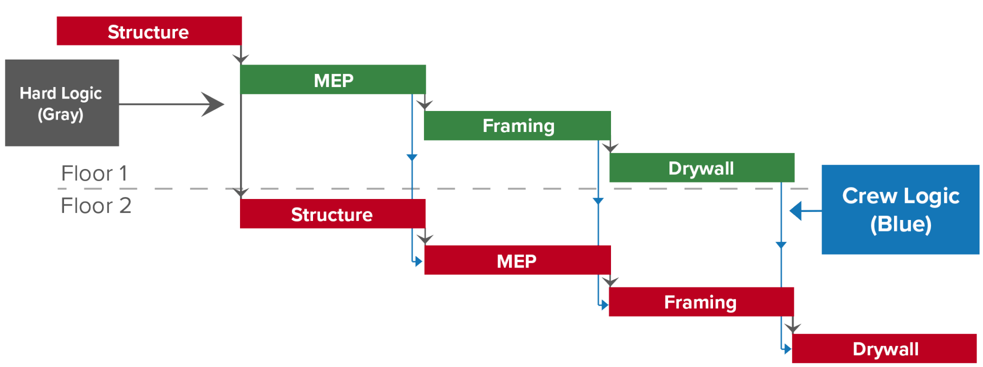
Furthermore, trade stacking on top of delays does not reflect a feasible reality, especially considering the overbearing amount of resource and crew restraints happening in the built environment right now. Additionally, when activities automatically stack on top of each other, float becomes consumed. And, when float is consumed, everything becomes compressed by design.

When everything is compressed, inefficiencies result, especially when you do not add people and are not sure if the area (or trade) is truly critical or not. This is where missing crew logic becomes "the silent killer." So, now let me explain what crew logic means and why it is critical for project success.

What is Crew Logic?

Crew logic is a form of "soft logic" that assigns relationships to activities that are reflective of where a crew is going to move next, based on means, methods, and crew constraints. For example, you might want your crew flowing from floor to floor or area to area.

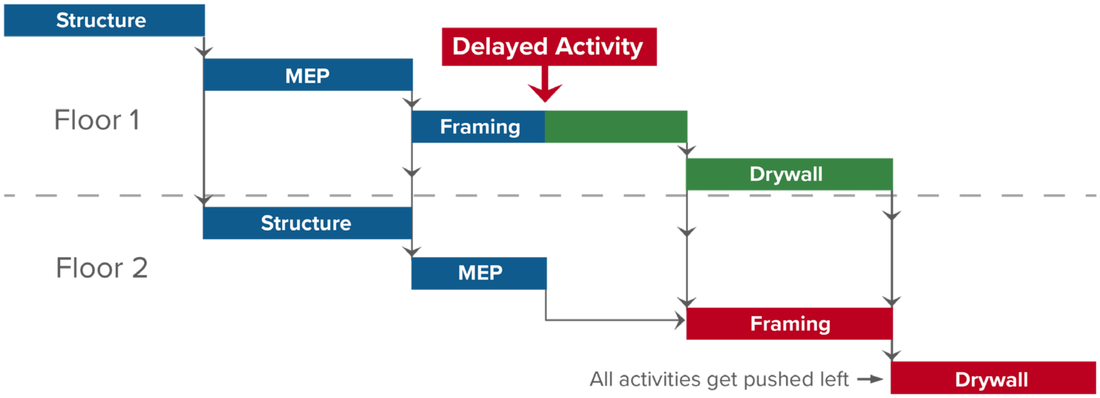
Let's take a look at the same original project schedule with the same hard logic, but this time, with crew logic added to it:



Now, the schedule has crew logic (featured in blue) embedded within it. The crew logic notifies the scheduling program that, for example, you cannot start framing on floor two until the framing is complete on floor one.

Why is Crew Logic Important?

Crew logic identifies crew constraints reflected in the plan, makes the schedule more reactive, and generates a more reliable and accurate critical path. You know, because the program is telling you, that you cannot begin framing on the second floor until it is finished on the first floor.

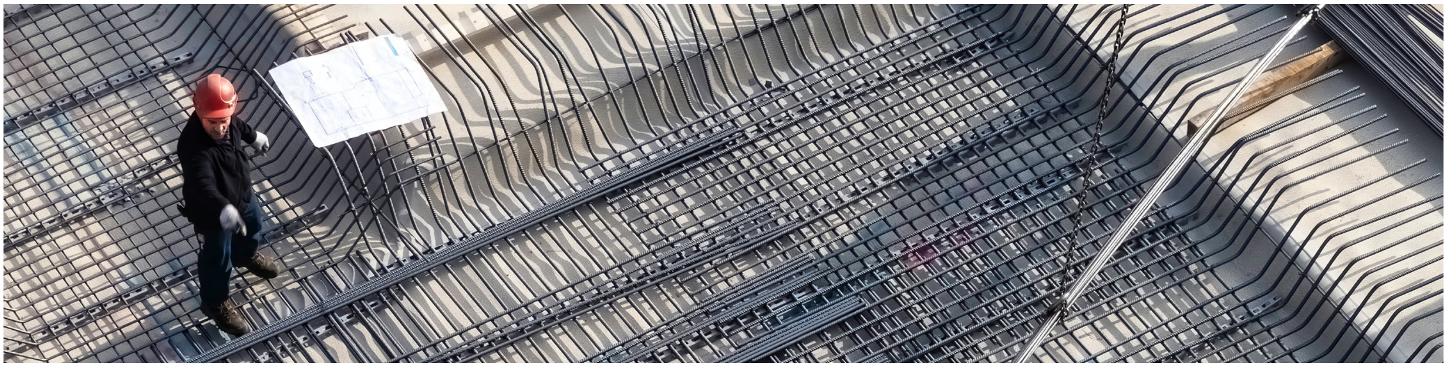


Without it, when an activity gets delayed, it overlaps with other activities on different floors. This means you will need additional crews to complete the stacked trades, which would otherwise get lost in the schedule files unless the PM and Super were paying very close attention.

Creating a Reactive Schedule

Without crew logic, impacts are not clear. Trades become stacked by design, critical paths shift, and float becomes consumed- all of which are a recipe for delays, inefficiencies, and future disputes.

Essentially, crew logic makes the schedule much more indicative of when impacts are happening and the immediate effect of those impacts. This not only helps right the ship before its too late, but also aligns with your crew's own constraints. If you take the time to know precisely what your crews can accomplish along with their plan to be successful, then implement that information into the schedule, your project will inevitably run smoother.



Five Quick Steps to Develop a High-Quality Project Schedule

Crew logic is a form of “soft logic” that assigns relationships to activities that are reflective of where a crew is going to move next, based on means, methods, and crew constraints. For example, you might want your crew flowing from floor to floor or area to area.

Let’s take a look at the same original project schedule with the same hard logic, but this time, with crew logic added to it:

1. Every activity needs one predecessor and successor, except project start & completion milestones.
2. Constraints should be minimal and Finish Constraints should not be used.
3. No activity should last longer than 20 working days because activities longer than 20 days are hard to accurately status.
4. Major trades need “Crew Logic” (or logic from area to area for each trade) for accurate float values to be calculated.
5. Most importantly, if something seems “off” with the schedule, then it probably is.

Weaving these practices into the schedule creation and updating process is highly beneficial for all project stakeholders. Always remember, high-quality baseline schedules provide project teams with:

- A reliable plan that decisions can be made from
- An accurate and reliable critical path
- The information needed to deploy a successful project control process

UNDERSTANDING PROGRESS WITH EARNED VALUE ANALYSIS (EVA)

What is Earned Value Analysis (EVA)?

Earned Value Analysis (EVA) is an industry-standard method of measuring a project's progress and performance at any given point in time.

Conducting EVA answers many questions heavy on the minds of executive teams and project management, such as questions concerning total project cost and estimated completion dates.

Key Values of EVA

Once you have established a high-quality baseline schedule, you can pull two values from it that can be combined with planned versus actual cost to determine whether or not work is being accomplished as planned.

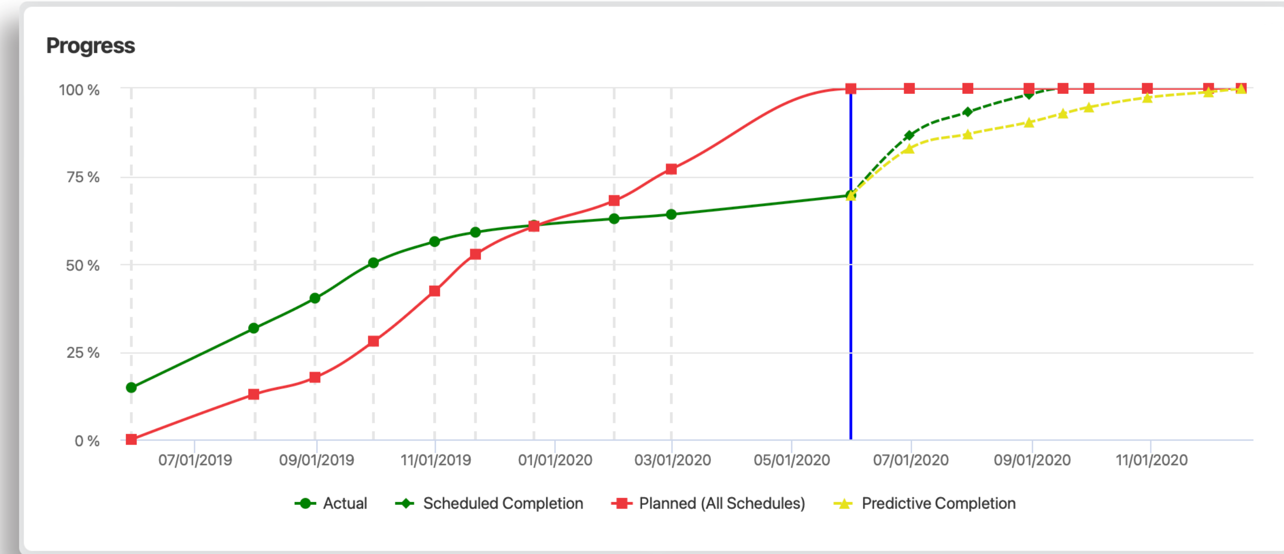
- **Planned Value (PV)** - the planned progress scheduled to be completed at a specific point in time, represented as a percentage of the project's overall completion.
- **Earned Value (EV)** - the progress actually achieved at a specific point in time, represented as a percentage of the overall completion of a project.
- **Budgeted Cost (BC)** - the total budgeted cost of a project.
- **Actual Cost (AC)** - the amount of money or effort spent in a specific time period.

After these values are determined, they can be integrated into an earned value analysis management process. This can be accomplished by reviewing schedule and cost performance indexes, or graphically by plotting the baseline curve (PV) and budgeted cost curve (BC) against the earned value (EV) and actual cost (AC) curves. The result of which determines the expected sequence of work and gives an understanding of project progress up until a specific time period.

Visualizing EVA Graphically

As a result of the overwhelming amount of data available to us in modern times, visualization of data allows information to be more digestible and accessible across project teams. Automating project control processes enables the automatic status of project progress to take place by giving graphical representations of earned value analysis information seen in the graph below:

VISUALIZING PROGRESS WITH EARNED VALUE ANALYSIS



Visualizing Earned Value Analysis

At this project's data date, which is just before June 1, 2020, the project is not progressing as planned. However, if this project's current data date was December 1, 2019, the project would be ahead of the plan.

You can tell this by looking at both curves and seeing which one is above the other. When the actual progress curve (green) is above the planned progress curve (red), the project is ahead of its planned progress.

On the other hand, if the actual progress curve is below the planned progress curve, the project is behind in its intended progress.

However, before conducting EVA mathematically through schedule or cost performance indexes, you have to understand how a project's schedule data is structured. There are three main ways this can be done, either according to costs, resources, or short of both of those options, durations.

After looking at the pros and cons of each, you can determine which is the best way for your project to begin conducting earned value analysis to better understand your project's progress at any given point in time.

COST-LOADED SCHEDULES

Cost-loaded schedules provide project management with the most accurate picture of project progress. Cost data adds a whole new dimension to the weighting of activities in terms of progress which is especially useful when conducting EVA. This is achieved by assigning a planned cost to each activity in a schedule, as shown below.

Cost-Loaded Schedule

Why Cost-Loaded Schedules?

Figuring out planned value (PV), earned value (EV), budgeted cost (BC), and actual cost (AC) using a cost-loaded schedule ensures that work is well defined, meaning progress can be accurately measured and controlled according to budget and time constraints.

Both owners and contractors strive for the best possible return on investment (ROI). As a result, it is always recommended that project schedules be cost loaded.

While there is considerably more work to ensure each activity gets an accurate cost estimate, there is no better way to get a precise understanding of project cost than cost-loading the schedule.

RESOURCE-LOADED SCHEDULES

Resource-loaded schedules are the next best way to conduct EVA. As opposed to using budgeted cost per activity, resource-loaded schedules use the level of effort or workforce per activity. This is achieved by assigning a planned number of resource hours to each activity in the schedule, as seen below.

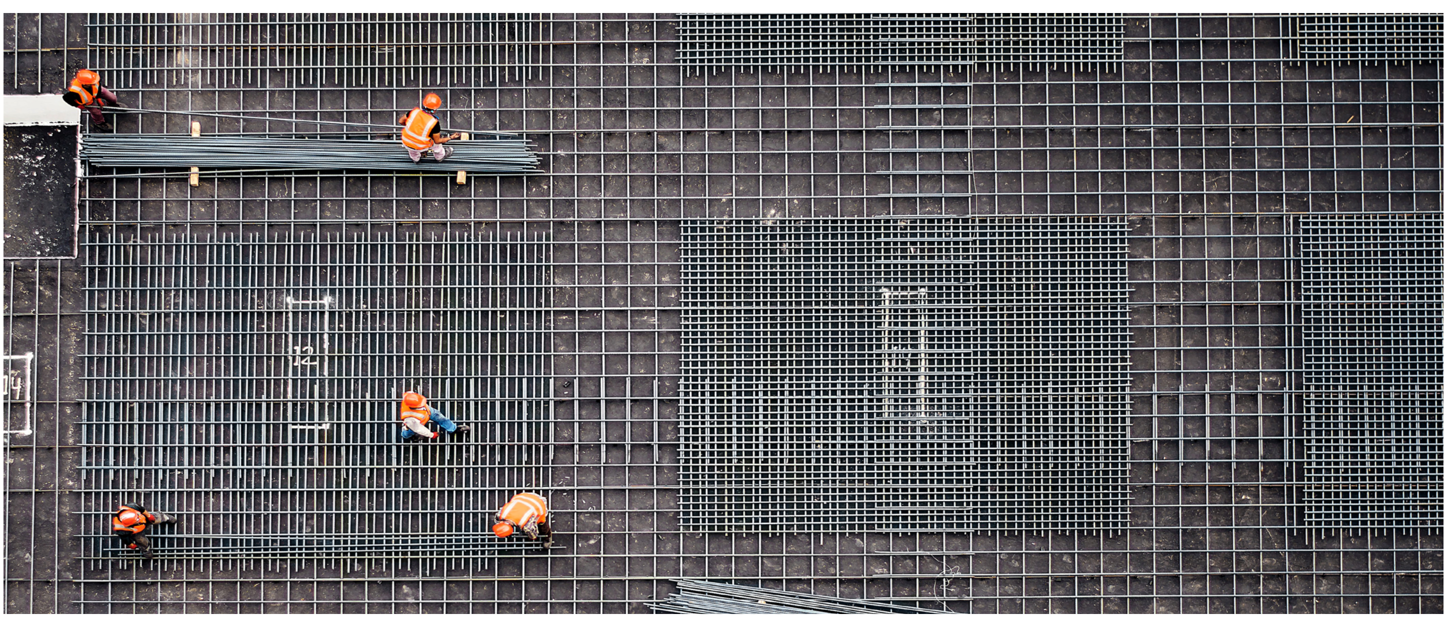
Resource-Loaded Schedule

Benefits of Resource Loading Your Schedule:

Resource loading schedules in this way is useful for project managers and superintendents as they manage the workforce on projects. Additionally, EVA is simplified using resource-loaded schedules, as measuring progress in terms of monetary value takes more effort to accurately measure.

By estimating the hours planned and establishing an hourly rate for each resource, the budget can still be measured using this method as well.

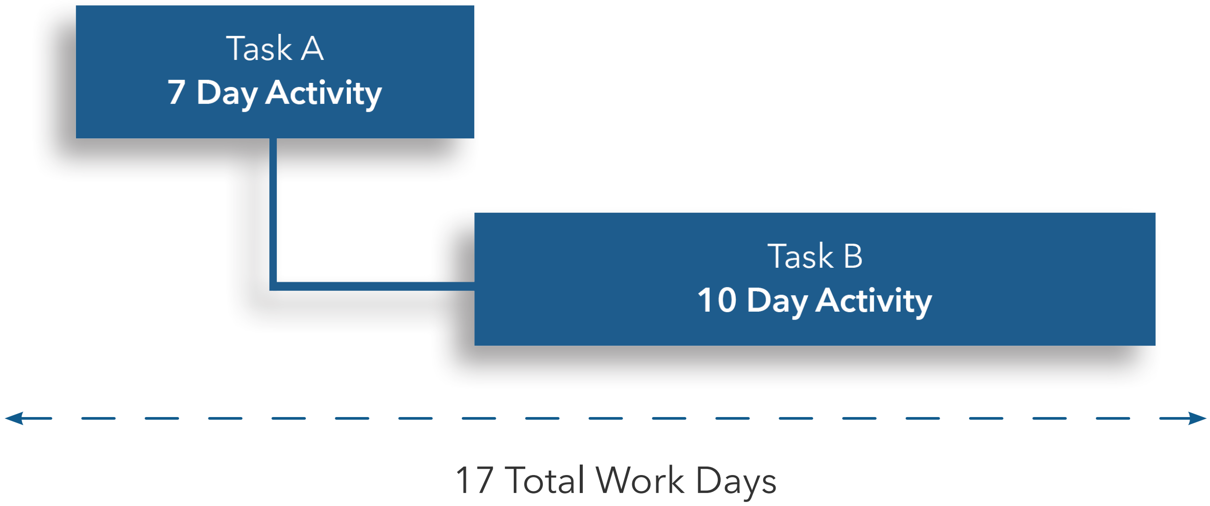
As PMI points out, resource-loaded schedules are not government-certified. However, they do provide an alternative way for conducting EVA without the hassle of having accounting systems.



DURATION-BASED SCHEDULES

When a schedule lacks cost or resource data, schedule programs must rely on duration data the most to calculate earned value. Conducting EVA using solely a duration-based schedule is not recommended but can still offer valuable insights in terms of understanding progress to date. So, it's better than doing nothing.

Duration-Based Schedule



Risks Associated with Duration-Based Schedules

The reality is, each activity in the schedule can represent different values of work in place, yet the durations can be the same. This and other factors can skew progress calculations and misrepresent any progress calculation at any point in time. To perform EVA effectively with duration data alone, one must tally up the total number of work days across all activities and calculate earned work days based on progress data in the schedule.

Example of EVA using Duration's Only

For simplicity, if a schedule contains 100 activities that are each 10 days of work, the total number of work days is equal to the sum of all workdays across all activities. In this example, it is 100 activities multiplied by 10 work days per activity or 1000 total work days.

The progress calculations per activity should substantiate the total earned work days, allowing EVA to be a simple calculation of earned work days divided by total planned work days. So, if 20 activities are 100% complete, the total earned man hours would be 200 (20 x 10) and the resultant EV would be 20% (or 200/1000) of total man-hours.

Unfortunately, estimating progress based on duration alone does not allow best project control practices to be exercised as the schedule is poorly defined and only partially complete. That being said, analyzing EVA with schedule duration data alone is better than not doing it at all, as it does still gives an apples-to-apples look at progress versus a plan.

EARNED VALUE ANALYSIS INDEXES

Once an understanding of Earned Value is established, you can begin calculating key performance indicators (KPIs) or indexes that further explain where the project stands in one number. Two commonly used indicators are the Schedule Performance Index (SPI) and the Cost Performance Index (CPI).

Schedule Performance Index (SPI):

The Schedule Performance Index (SPI) tells you how far ahead or behind the project is according to the schedule and is calculated into a ratio by dividing earned value by planned value.

$$\text{Schedule Performance Index (SPI)} = \frac{\text{Earned Value (EV)}}{\text{Planned Value (PV)}}$$

- If SPI < 1, less work has been completed than originally planned, meaning the project is behind schedule.
- If SPI > 1, more work has been completed than originally planned, meaning the project is ahead of schedule.
- If SPI = 1, the project is progressing as planned and is on schedule.

Cost Performance Index (CPI):

The Cost Performance Index (CPI) tells you where you are in a project according to the budget and is calculated into a ratio of earned value with budgeted cost and actual cost.

$$\text{Cost Performance Index (CPI)} = \frac{\left(\text{Earned Value (EV)} \times \text{Budgeted Cost (BC)}\right)}{\text{Actual Cost (AC)}}$$

- If CPI < 1, the project is earning less value than what has been spent, indicating the project is over budget.
- If CPI > 1, the project is earning more value than what has been spent, indicating that the project is under budget.
- If CPI = 1, the project is earning the expected value according to what has been spent, meaning the project is on budget.

STUDYING CRITICAL PATH DELAY & RECOVERY

Critical Path Delay & Analysis Techniques:

Historic Critical Path Delay measures the number of calendar days a project's end date has been delayed due to impacts on the critical path. By definition, anything delayed on the critical path delays the end date of a project. By studying critical path delays throughout a project's life cycle, you can determine what drove the project's end date back and develop a plan to recover against any crucial delays by fixing problems along the way.

To begin doing this, your project team must decide the best way to track, monitor, and quantify critical path delays. Doing so saves an abundance of time in the long run and empowers project teams with the information they need to recover. There are several industry-accepted ways of conducting critical path delay analysis. AACE lists several delay methodologies that you can review to decide which works best for you and your organization, which are summarized below:

	Definition	**Risks**
As-Planned vs. As-Built	Compares the current "as-built" schedule to the original baseline schedule.	Runs on the assumption that the baseline schedule was static & unchanging, making the analysis at a high risk of being inaccurate with potentially subjective findings.
Collapsed As-Built Methodology	Takes into account all changes in the schedule from the beginning of the impact period through the current date of the project, then reverts all changes to the baseline schedule for analysis.	Runs on the assumption that all changes to the schedule are accurate and reflect reality; Requires a project to be finished before analysis; Heavily contested in courts, used to discredit the party deploying it.
Time-Impact Analysis (TIA)	Inserts a series of activities representing delays and impacts into the schedule to quantify the delay, either prospectively or retrospectively. TIA works if delayed activities are tracked to completion before the delay is quantified and approved.	If conducting this analysis prospectively, the delays haven't happened yet, making the analysis subjective and therefore arguable. If performed retrospectively, this method may assume that the "as-built" data reflects what was known at the time, thus misrepresenting delay.
Window Analysis	Delay is analyzed between two successive updates, using an as-planned vs. as-built approach but accepts changes in the second update as the basis for the analysis in the next period, or "window."	If there are elevated levels of accepting changes to the schedule, then it can be rendered unrealistic due to the likelihood of skewed results. However, this approach is the industry's most accepted methodology.

RECOMMENDED PRACTICES FOR STUDYING CRITICAL PATH DELAY

Using Critical Path Method analysis properly, you should be tracking activities to completion and analyzing the impact of the delays in each update period **using the Windows Analysis technique.** If something is critically delayed, it is recommended to quantify the delay that the impact caused to the critical path as well as determine causation in real-time. That way, two years down the road, you won't be scrambling to find which event caused the project to go off course.

Collaborate Over Critical Path Delay

Regardless of which delay analysis method you use, it should always be a collaborative process where delays are discussed monthly amongst project stakeholders with accuracy and transparency. These meetings can be straightforward; here is a recommended approach:

- Update and analyze the schedule for delays & impacts before a monthly meeting without making any changes to the schedule.
- Present schedule findings and discuss them with all parties.
- Discuss schedule changes and their mitigation or recovery strategies. Once agreed upon, incorporate these changes into the plan moving forward.

The meeting's goal should be transparency and honesty regarding any changes made to the proposed schedule, especially the ones designed to mitigate the historical delay. With all of the unforeseen delays impacting the construction industry today, discussing and studying critical path delays through analysis and collaboration may be the only way to save a project from reaching a point of no return.

STUDYING CRITICAL PATH RECOVERY

Critical Path Delays happen

The critical path is dynamic, and re-prioritizing resources is usually needed to get projects on track. This is typically achieved through modifying the go-forward plan as part of the schedule updating process.

Making changes to overcome historic delays typically compresses the go-forward plan by changing logic, durations, and even entire calendars. This reality presents a risk of schedules becoming overly optimistic and potentially unachievable–which can often lead to more delays, overruns, and ultimately, disputes.

Because of this, stakeholders must study critical path recovery efforts built into the schedule, which encompasses looking at how project schedules are changed to meet contractual deadlines. These changes should be scrutinized as they pose the most significant risk to completing projects on time and must be understood thoroughly. Furthermore, studying recovery at every update shows what recovery methods are working and which ones are causing more problems than they are solving.

Studying Schedule Changes for Recovery

It is important to note how critical paths have changed after updates so you can effectively manage your resources. Things will change as your project progresses and the critical path will likely change as well.

Knowing when that happens means you can effectively manage your resources in that area to make sure things are getting done on time.

When Studying Schedule Changes, Bucket Them into Categories:

- ### Critical Changes

  Studying changes/recovery on the critical path is necessary as the mode of recovery may change the critical path completely. The critical path is where you need to prioritize your resources; studying the changes there is crucial for successful decision-making. This is also where changes have the greatest impact on a project's end date.

- ### Near-Critical Changes

  Even though it has room for delay, the near-critical path should be treated like the critical path because it could quickly become the critical path over time. In addition, changes to the critical path frequently pull the date so far back that the near-critical path becomes the critical path.

- ### Non-Critical Changes

  Non-critical changes are changes that do not impact the end date of the project, unless the changes to the critical and near-critical path activities cause so much acceleration in the schedule that non-critical activities become the critical path. Studying these types of changes is typically the last area of focus when studying recovery efforts.

Following Up with Schedule Changes

After deciphering which type of changes occurred within the schedule, begin quantifying these changes using a half-step methodology to understand where the critical path was before the changes. Understanding where the critical path lies is crucial for allocating resources and staying within time and budget parameters.

QUANTIFYING SCHEDULE CHANGES WITH HALF-STEP METHODOLOGY

What is Half-Step Methodology?

Half-Step Methodology distinguishes past performance delays with the responses to those delays to mitigate the risk involved in schedule changes. It is a process that essentially updates the schedule with no changes made to it and then compares it to a schedule inclusive of any future changes. Here is how to do it:

1. Save a copy of the previous schedule update and add "actual" dates and/or percent completed for all activities progressing in the period. Do not change anything and save this file as the half-step schedule.

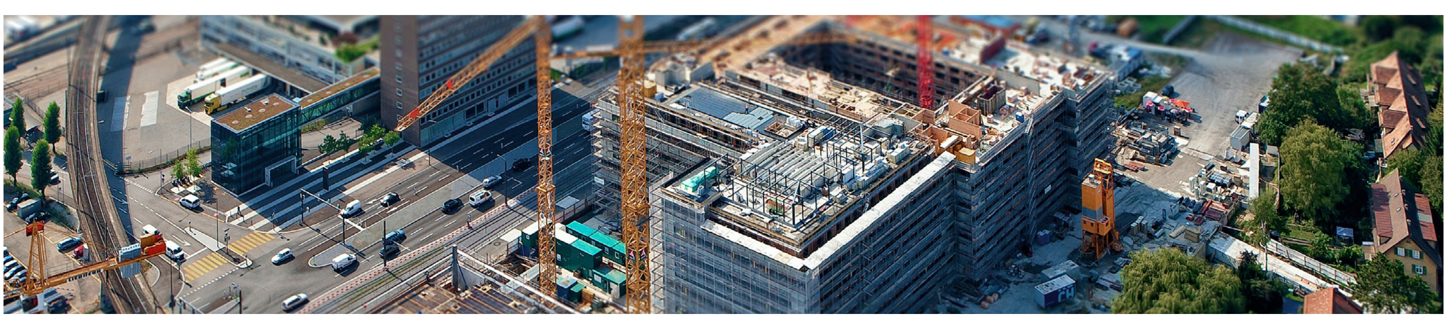
2. Create a copy of the half-step schedule and impart recovery strategies and any other necessary changes to this version. The new schedule will include all changes and serve as a contemporaneous schedule update.

3. Compare the end dates between the "half-step schedule" (step 1) and the contemporaneous schedule update (step 2) to calculate recovery.

What Information Does Half-Step Methodology Provide?

If the critical path and end date change between the contemporaneous schedule update and the half-step schedule, the date changes result from schedule changes in the period in question. This process can also quantify delay by comparing the previous and half-step updates' end dates. It also enables an understanding of the recovery result by comparing the change in the projected end date and the critical path between the half-step schedule and the contemporaneous update.

Project teams must emphasize studying delay and recovery to understand the true critical path. All parties should know where the critical path is at all times and how any changes to it will be quantified. If done correctly, studying critical path delay and recovery across your project portfolio monthly minimizes the risk of future delays and, more importantly, disputes.



MONITORING SCHEDULE COMPRESSION

What is Schedule Compression?

Schedule compression happens when decisions are made to shorten activity durations or re-sequence logic without changing the overall scope of the schedule, to meet contractual deadlines or other milestones. In other words, schedule compression results from projects progressing slower than initially planned and the desire to keep the end date from changing to a great extent. The inevitable result? More work has to be completed over less time than initially planned.

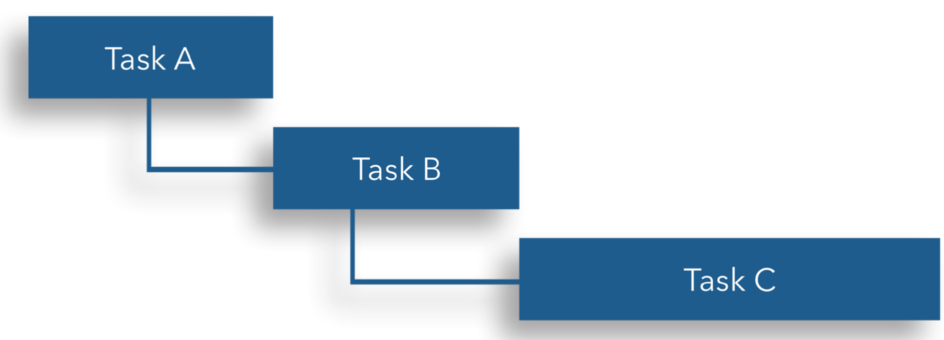
This may seem like an ideal way to recover against delays & under performance, meet deadlines, avoid disputes, and accomplish other project objectives. However, in reality, compression should only be incorporated when it's achievable, understood, and doesn't put the project at risk.

What is Schedule Compression?

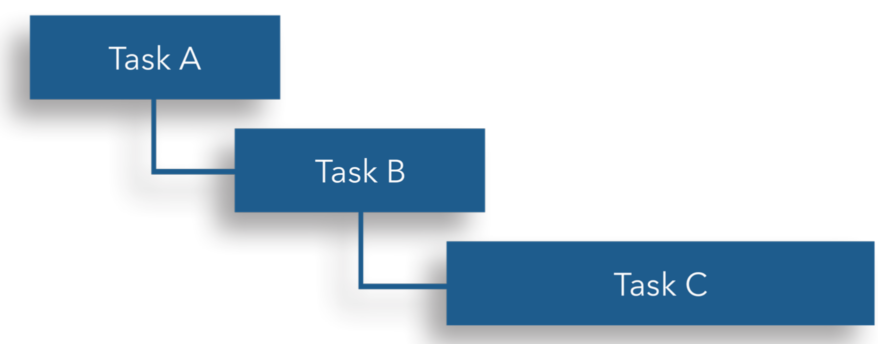
Compressing project schedules is risky because project teams are trying to squeeze more work in less time than originally planned. SmartPM has been studying schedule compression for years and has found some interesting data that points out the criticality of understanding schedule compression.

Having studied over 20,000 project schedules, SmartPM found that approximately 70% of projects earn less than 90% of their originally planned progress at any given point in time. So, on average, most schedules require compression to get done on time at one point or another. With this in mind, it is crucial for project teams to always be aware of the level of compression throughout the project to manage time and budget more effectively. Otherwise, projects will endanger quality, safety, and trade contractor performance.

Logic without Schedule Compression:



Logic Changes with Schedule Compression:



CALCULATING SCHEDULE COMPRESSION

How to Calculate Schedule Compression:

To understand compression, one needs to quantify it. Calculating compression levels offers an opportunity to effectively manage and avoid the instability associated with highly compressed construction projects. Take a look at how you can calculate the level of compression within your projects to better understand the associated risks:

1. **Calculate Earned Value**
   Calculate how much of the project has been completed using the Earned Value (EV) of the most recent schedule update.
2. **Calculate the Expected Days Remaining**
   Calculate how many calendar days are expected between the most recent schedule update and the projected completion date.
3. **Determine Planned Progress**
   Using the original baseline schedule, determine the date where the current earned value (EV) should have happened.
4. **Calculate Planned Remaining Duration as Per the Original Plan**
   Calculate what the remaining duration of the project should have been in the baseline schedule from the date that the project should have achieved the "earned" percent complete (step 3) and the planned completion date in the baseline schedule.
5. **Calculate the Compression Factor**
   Divide the planned remaining duration calculated in step 4 by the current remaining duration obtained in step 2 to calculate the compression index.
6. **Determine the Compression Index Factor**
   Subtract 1 (or 100%) from the compression index to determine how much less (or more time) is allocated to completing the remaining work as compared to the baseline schedule.

According to the Project Schedule:

Step 2:

There are 150 days between the current data date and the forecasted end date.

Step 4:

The baseline schedule indicates that the project would need 200 days to complete after it hit the 60% mark.

Step 1: EV = 60 %

Step 2: Expected Days Remaining = 150 days

Step 4: Original Planned Remaining Days at 60% = 200 days

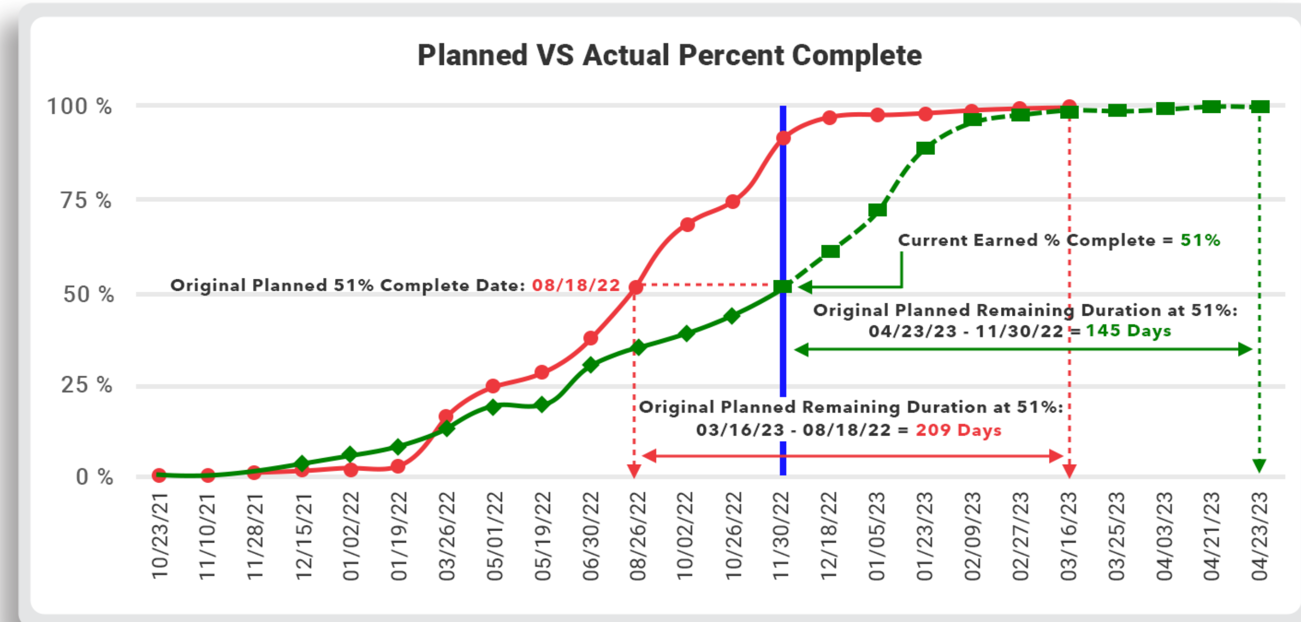
Step 5: Compression Factor = $\frac{\text{200 days}}{\text{150 days}}$ = 1.25

Step 6: Compression Index Factor = (1.25-1) = 0.25 / 25%

Developing an understanding of the compression levels within a schedule ensures acceptable levels are not exceeded. This is critical for an accurate estimate of the work remaining and the time left to finish a project.

HOW TO CALCULATE COMPRESSION USING PROGRESS CURVES

See the example below and follow the calculations for a visual and mathematical representation of calculating a compression index using the planned versus actual progress curves.[1]



In the example above, the data date is 11/30/2022. The actual percentage completed at the time is approximately 51%, and the estimated completion date is 4/23/2023 (or 145 calendar days from the data date).

According to the planned progress curve, the baseline schedule indicated that 51% would be achieved around 8/18/2022, and the estimated completion date per the baseline was 03/16/2023 (or 209 calendar days later).

Using these numbers, you can calculate the Compression factor, equal to 209 calendar days / 145 calendar days, or 1.45.

By subtracting 1 from the Schedule Compression factor, you get 0.45, or 45%, which is the Schedule Compression Index. This means the schedule indicates that the remaining work will need to be completed in 45% less time than the original baseline allotted.

Once the Compression Index is calculated, one must determine what an acceptable level of compression is for their particular project. The Rule-of-Thumb at SmartPM is that anything over 15% is worth considering taking acceleration measures, especially on schedules that seem unfeasible, to begin with.

1 It is recommended that the plan versus actual progress curves be generated using a resource or cost-loaded project schedule. If the schedule is not resource-loaded, a model should be developed that factors in weighted averages based on activity durations to estimate planned versus actual progress.

DETERMINING HOW & WHEN COMPRESSION OCCURS

To better understand how a schedule becomes compressed, you first need to understand the various ways compression is achieved in a construction schedule. From most common to least common, the reasons are:

1. **Consuming Float**

   The most common way schedules become compressed is by decisions to consume float by choosing to delay the start of non-or-near-critical work activities that could otherwise start.

2. **Mitigation of Historical Critical Path Delays**

   The second most common way schedules become compressed is by the decision to mitigate historical critical path delays through changes made to the schedule on critical and near-critical path activities.

3. **Added Scope without Extra Time**

   The third most common way schedules become compressed is through the decision to add scope to the project using change orders without adding extra time into the schedule.

Concluding Compression:

A compression level of 20% means the schedule indicates it will complete the same amount of work originally intended in 20% less time. This level requires extra workday per week is required, or 20% more workforce is needed to reach a deadline. And that's only if intended productivity is being met on the critical & near critical trades.

Calculating schedule compression allows stakeholders to save large amounts of money in unnecessary spending by avoiding the costly risks associated with inefficiencies, delays, overruns, and resultant disputes. With the opportunity of cash savings in mind, it is in the best interest of all stakeholders to understand schedule compression thoroughly so they can focus on this metric throughout the project life cycle.

FORECASTING WITH EARNED VALUE METRICS

What is Schedule Forecasting?

Schedule Forecasts are predictions of project completion or key milestones in the future based on information available at the time of the most recent update.

How Does Forecasting Accurately Predict Future Project Completion?

By utilizing historical performance data to determine the average production rate, the production rate can be measured for the overall project or at individual trades. Then, you can use this rate to predict a project's future outcome if productivity remains the same. It should be noted that the more granular your data, the more reliable your forecasting will be.

As your project progresses and the schedule is updated, the forecast can also be updated by taking into account any changes in productivity. When the forecast is updated, it becomes a critical component in risk mitigation. Adjusting the schedule based on historical performance and not over-optimistic guessing gives the best gauge for when a project will finish and what is driving its completion.

Schedule forecasting can be done in many different ways. However, forecasting can be done automatically by utilizing Earned Value Analysis (EVA) metrics and extrapolating that data on a future planned curve based on historical performance. To do this analysis, you will need the project's Schedule Performance Index (SPI), which, as explained above, is calculated by dividing the project's earned value by its planned value.

What is Schedule Forecasting?

The SPI ratio tells you where you are in terms of progress. For this example, let's say you conducted this analysis when you were 72% done with your project. However, you had originally planned to be 99% done at the current point in time.

$$\mathbf{SPI} = \frac{\mathbf{EV}}{\mathbf{PV}} = \frac{\mathbf{72}}{\mathbf{99}} = \mathbf{0.742}$$

Recall that:

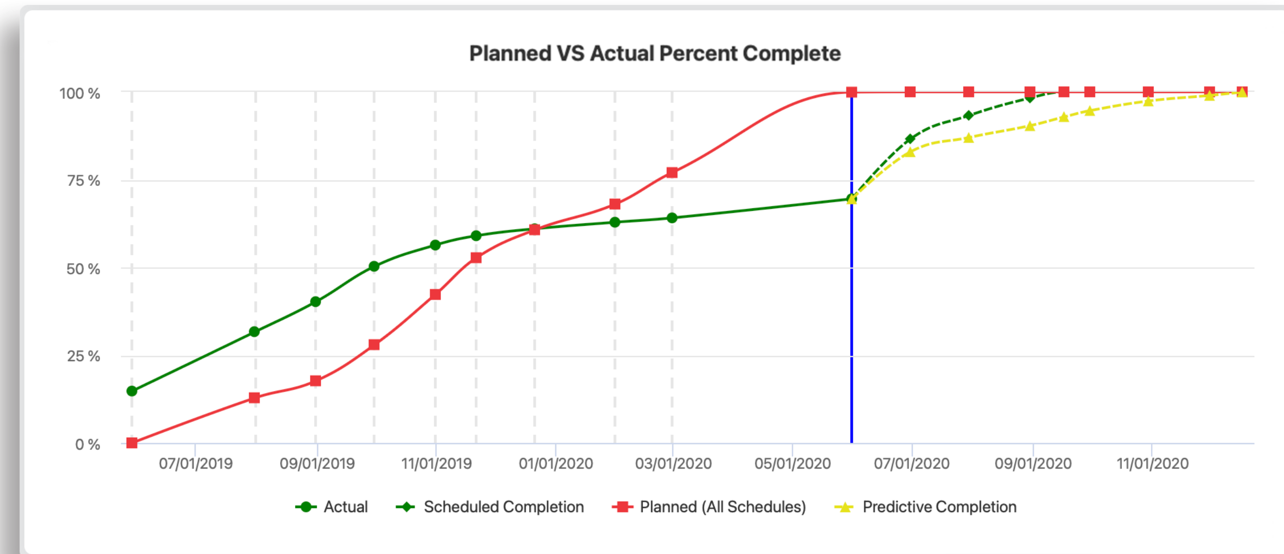
- SPI > 1 : Ahead of Schedule
- SPI < 1 : Behind Schedule
- SPI = 1 : On Schedule

Therefore, in this example, the SPI of 0.742 means that the project is achieving 74.2% productivity and is behind schedule. In other words, for every ten days of work, the project only earns 7.42 days of its planned work. So, if an activity has an original duration of 10 days, it will actually take roughly 13.4 days to complete as the production rate is slower than originally planned.

How to Calculate Schedule Compression:

A project's schedule performance index (SPI) becomes a reliable representation of performance midway through the project because, at this point, there is enough data to assume that any anomalies have minimal impact on this performance metric. This is because, at different phases of a project, there are very different activities with very different parties responsible for the work being done. It would not be fair/wise to use delays during the pre-construction phase to adjust the construction phase, as the problems you encounter would differ

Halfway through the job, or, in this case, 72% through the job, project teams can forecast how they will perform by looking at the entire schedule up to date, using historical information to predict the future. As far as this example is concerned, by looking at the SPI of approximately 0.742, the estimated duration remaining will be about 34% longer because, historically, the project is consistently under-performing by about 34%.



As depicted in the graph above, the project's progress curve is extrapolated by using the SPI to adjust the scheduled completion, shown by the yellow line. The yellow line is the schedule forecast, predicting the project will be 100% completed about four months later than what the scheduled completion date is telling you and six months later than the baseline plan indicated.

Knowing this, decisions can be made to increase productivity (or workforce to accelerate), or the project will be delayed. If acceleration measures are met, the SPI will decrease, making the forecasted end date improve as a result of cured performance improvement.

This is important as keeping track of your SPI and project forecasting gives companies an early warning sign for potential end-date slippage and an opportunity for mitigation strategies. Additionally, combining forecasting with other data-driven project control metrics throughout the entire duration of a project gives an unbiased gauge of actual end dates.

SUMMARY

Project controls may require some initial understanding, but they offer substantial long-term benefits by serving as the foundation for successful project delivery.

Efficient project management relies on project controls to enhance efficiency, identifying risks, mismanagement, and areas of under-performance through key metrics. In the dynamic world of commercial construction projects, monitoring project health through schedule data is an integral part of the project controls process. High-quality construction schedules enable project teams to leverage schedule data to reveal critical metrics and make accurate, data-driven decisions.

Given the challenges in today's built environment, all stakeholders should analyze their schedule data and allocate resources to implement a project controls process into project management.

The SmartPM team is ready to support this endeavor by providing automated project controls through SmartPM's platform, assisting in calculating and understanding essential project control metrics.

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