SmartPM™

Technical White Paper

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Executive Summary

SmartPM™ is a first in kind data analytics platform for the Construction industry that was designed by industry professionals who specialize in performance management and process improvement. SmartPM™ examines available data extracted from systems utilized on construction projects to generate meaningful analytics and useful insights that stakeholders can rely on to manage, avoid, and overcome challenges related to overruns, delays, and disputes.

SmartPM™ utilizes the most useful and important data set in construction, the project schedule, to analyze the most-costly issues that affect project success. SmartPM™ employs a 5-step approach to analyzing construction schedules from the initial baseline through to the most recent update, providing critical information to support risk management and effective decision making.

SmartPM™ was developed by industry veterans who spent their careers analyzing schedule and project data related to large commercial construction projects to assist stakeholders in identifying issues and root causes for delays and overruns.

Why the Schedule?

Industry studies exist and the numbers speak for themselves; construction projects have continually demonstrated a failure to meet their desired objectives and timelines. The old saying that time is money holds true in construction. According to a recent study by FMI, global construction waste amounts to a financial loss of $1.4 Trillion. In addition, similar industry articles also state that approximately 60% of this loss is reportedly caused by project delays, which is why it is critical to fully understand construction project schedules. But to do so requires a deep analysis of the interdependencies amongst stakeholders and the activities they are responsible for. Only by fully understanding the schedules, can one accurately identify and understand causes and effects of overruns, delays and subsequent cost impacts. The construction schedule is the most useful and informative single data set that exists on most construction projects today to assist project teams and stakeholders in this analysis. The schedule is the only project document that contains a roadmap linking all the stakeholders and their respective activities and responsibilities.

By closely and systematically evaluating the project schedule over time, one can learn a lot about progress, performance, delays, and future risk. This supports stakeholders (Owners and Decision Makers at Construction Management firms) make the most informed business decisions – ones which simply can't be made using a cost accounting system alone. No performance assessment is complete until a full analysis of the schedule has been performed. Further, the schedule is the only document where a comparison of the planned to actual workflow, the identification of key delays and various decisions related to resequencing, can be accurately evaluated. If regularly and appropriately maintained, the schedule paints the most "accurate" picture of progress and performance over time across all activities, which is imperative to understanding costly setbacks, while forecasting future impacts. Since the schedule is typically utilized to support progress payments, there are also inherent controls in place to ensure the schedule remains accurate throughout the construction lifecycle – meaning that schedule data is also the most accurate data.

Quite simply, better scheduling analytics discipline across the project lifecycle results in enhanced accountability, better performance, increased communication, improved decision making, and a higher likelihood of meeting expected outcomes.

> "77% of megaprojects around the globe are 40% or more behind schedule
> -McKinsey Global Institute"

> "Large projects typically take 20% longer to finish than scheduled
> -McKinsey Global Institute"

> "9.9% of every dollar is wasted due to poor project performance
> -PMI's Pulse of the Profession"

The 5-Step-Process of Schedule Analysis Required to Minimize Risk of Overruns and Delays

While the industry generally recognizes the importance of planning and scheduling, the schedule is often overlooked as the key tool to managing projects. Too frequently, schedules are generated at the beginning of a project with unrealistic timelines, inadequate logic or sequencing, undefined activities, inexperienced, incomplete or strained resources, and a lack of team input. As the project progresses into execution, the schedule unfortunately becomes an afterthought or considered a “necessary evil” rather than a tool to better manage the project. Delays occur and often are accepted without clear accountability or transparency; and overly optimistic recovery efforts are forecasted without regard to historical performance. Most project teams start with using the schedule to plan the work but fall short of using the schedule to manage the work well.

> *Schedule integrity should be assessed as the schedule is updated; verifying the integrity of the schedule after each update will ensure that the schedule remains reliable after activities are added, removed, broken down into smaller activities, or sequenced differently from the last period.*
>
> -GAO Schedule Assessment Guide: Best Practices for Project Schedule

Missing in most processes is the continuous and contemporaneous analysis of the project schedule as it pertains to:

- Schedule Quality (was it built using best practices,
- identification of the driving critical activities directly delaying or impacting key milestones,
- recovery decisions that were potentially overoptimistic, aggressive or even haphazard,
- misleading information that may compromise future performance, (ie. what changes were made that were questionable or infeasible – or used to hide delays to the project),
- the amount of compression built into the schedule (and when did it cross the line from being achievable to unachievable),
- updating the project to reflect reality as more information is learned, and
- providing forecasts to delays and delay issues given what is known at the time (since patterns of delay are rarely extrapolated to future activities).

When the schedule analytics above are managed, in part or in total, the results have proven to be very useful in minimizing delays, overruns and potential disputes. Project controls teams, consulting experts, scheduling gurus and dispute advisors that consistently and contemporaneously evaluate the project schedule and implement techniques to monitor and control project schedules have proven to successfully impact project outcomes through these measures. However, this oversight and analysis typically comes at a high cost to a project or an organization – as schedule analytics is a very time-consuming process. Traditionally, performing these analyses properly has been a manual effort, which required significant time, resources, and costs on the part of all stakeholders. A few tools exist that focus on analyzing schedule quality and changes, and one that allows users to run predictive analytics; but, most of these solutions require a specialist, are relatively, poorly designed, and lack automation and objectivity. Further, there is no user-friendly solution that allows users to systematically analyze all the above analytics, along with delay, compression, and feasibility all in one place…until now.

SmartPM™ was developed by consulting experts who spent their entire careers analyzing construction projects forensically to explain why projects were delayed and over budget, or proactively, in order to identify breakdowns in the process and avoid overruns and delays down the road. SmartPM™ analyzes schedules across 5 key areas: Schedule Quality, Recovery, Critical Path Delays, Feasibility, and Predictive Analytics.

Step 1

Schedule Quality

Ensuring that a schedule has been developed with sound quality and best practices is the foundation for project success. This may be obvious, but unfortunately, the industry has yet to master this concept; and typically, the less sophisticated a company is, the greater the chance that a schedule is built mediocre at best.

The Defense Contract Management Agency (DCMA) has established standards for analyzing the quality of a schedule by highlighting the existence and frequency of certain “bad practices” including but not limited to: missing logic, high numbers of constraints, activities with high durations, large amounts of positive and negative lag, among others. What is necessary when building a schedule is assurance that all activities are appropriately tied together to form a “reactive” schedule; one that clearly illustrates impacts and delays, so that problems are accurately diagnosed and can be easily identified. Without this control in place, schedules may be developed with erroneous critical paths, which leads to identifying the wrong items as critical delays; masking where the real problems are likely embedded and misrepresenting the real short-term and long-term effects. While solutions exist that analyze some of these components, most do not explain to what extent a schedule’s deficiencies have reached a level of concern – which leaves individuals responsible for interpreting the data themselves – and people are subjective.

Step 2

Recovery Analysis

Delays frequently occur in Construction. From the beginning of the project to the end. Nothing seems to go as planned, ever. That is just construction. The reality is that the baseline schedule is merely a "plan". Separately, there is the reality of the issues that emerge during execution. To manage reality, a common practice is to make changes to schedules (via the updates) to get the project back "on track". From a high level this appears to be a reasonable approach, but that's only true if the changes made are feasible and agreed to by the parties involved. All too often, changes are made to schedule updates without key stakeholders fully analyzing whether they are realistic or feasible. Rather, these decisions are frequently made with hope and over optimism (and in some cases even manipulation).

While many industry schedulers and PM's think it's ok to be optimistic, they often don't realize that a lot of costly decisions are being made based on the forecasted end date, and many stakeholders are financially dependent and/or tied to important milestone dates listed in the schedule. If that date is incorrect, it is financially damaging to all parties involved. Therefore, it is imperative that there is a control mechanism that allows users to better understand the reliability and accuracy of the recovery decisions that are being made. Unfortunately, for an individual to do this well, it can take hours or days evaluating and analyzing the potential effects of these decisions. Programs like Deltek Acumen Fuse® and Primavera Claim Digger™ are used to accelerate analyses, but none of these systems is built with the intelligence to recommend a path toward a solution. Rather, these systems provide a data dump of all changes without context as to the feasibility and risk level of each change. SmartPM™ does things differently, and better – in an automated fashion.

Unless schedule variances are monitored, management will not be able to reliably determine whether forecasted completion dates differ from the planned dates.

-GAO Schedule Assessment Guide: Best Practices for Project Schedules

Step 3

Critical Path Delay Analysis

Critical Path Delays are one of the key contributors to and drivers of schedule overruns, and overruns related to delays are among the most heavily disputed of all cost overrun issues. One reason for this is that identifying critical path delays is a difficult task. For any given project, there are likely multiple delays occurring at once, and understanding all of them requires significant time to study the data and develop a complete picture. The challenge is wading through all the minutiae to derive supportable analytics on what was delaying the project overall versus what was delayed but didn't impact the end date in a specific period. There are proven methodologies that exist, which consultants utilize to make sense of this data, but they are part of a manual, time consuming, and subjective process, which often leads to further disputes around assumptions and methods. (This is why consultants are paid top dollar to conduct critical path delay analyses.)

The bottom line is that delays will always occur and the parties responsible for the delays that drove the job will continue to be contractually obligated to pay damages. The problem is that with so many delays happening concurrently, no one believes or wants to admit that the delays they caused might be among the critical ones.
One final note on delay analysis; it is obviously affected by the quality and feasibility of the schedule and therefore only reliable when these items are fully understood. This is one of the reasons it is important to discuss delays as they occur, and to make meaningful decisions related to delays in real time. Unfortunately, this doesn't usually happen for a variety of reasons. It could be that one of the parties is unaware that a delay has occurred, because the end date didn't change to reflect it. The most common scenario is that the parties involved cannot agree upon what delayed the job – without hiring a consultant….and doing so is an expensive and often last resort option.

Step 4

Feasibility Analysis

In layman's terms, Schedule Feasibility Analysis is the study of whether the plan laid out in the project schedule is achievable, given the logic and durations of the activities involved. Since so much money is at stake, including both the capital investment and the revenue that will be generated from the asset, it is imperative to study the schedule to ensure it is achievable. At the beginning of a project, when the baseline schedule is submitted, it is nearly impossible to address feasibility – particularly because the durations need to be tested. If they are consistently off, the future durations are affected. If there is missing logic and common sequential activities, then trades stack into levels where resource requirements can't be met. This needs to be studied early and often and throughout the entire construction lifecycle in order to effectively mitigate financial risks related to construction.

Bottom line, when Schedule Quality, Delay Analysis and/or Recovery methods are not done well, Schedule Feasibility suffers. It suffers when a project schedule is of bad quality. It suffers when too much recovery is built in to combat delays. It suffers when consistent delays keep happening and issues aren't extrapolated to future activities. And when Schedule Feasibility suffers, everyone involved loses. Owners suffer from projects not being turned over soon enough resulting in impacts to revenue generation and added construction costs. Contractors suffer from reductions to their profit margins, being unable to effectively plan resources across many projects and by losing credibility in the marketplace. By ensuring that schedules are feasible, stakeholders can be more confident that there is reliable information to plan their business around and to ensure that ROI and business growth is maximized on every project.

Step 5

Predictive Analysis

The industry suffers greatly by not having a simple way to effectively and accurately predict project/milestone completion dates or understand the drivers of risk towards achieving them. Running Predictive Analytics on a project schedule not only helps to inform owners and contractors of the future estimated completion date, which enables parties to plan better, and thus minimize cost exposure due to uncertainty. Predictive analytics also informs stakeholders of the likely path towards the successful achievement of the major milestones. By constantly analyzing historical performance and variance, one can identify key trends, which can then be used to more accurately predict future end dates. FYI – we are not talking about the current scheduled critical path here. We are talking about the likely critical path going forward - given all that we have learned from performance history to date - the good, the bad, the ugly - and running thousands of scenarios to identify the most likely outcomes and the factors that drove them. This type of analysis is probably the most powerful type of analysis in construction. Unfortunately for stakeholders, one must go through the gauntlet of studying quality, performance, delay, compression and feasibility to accurately predict future outcomes. So, it is often the last thing people invest money in.

Without trend analysis, management will lack valuable information about how a program is performing. Knowing what has caused problems in the past can help determine whether they will continue in the future.

-GAO Schedule Assessment Guide: Best Practices for Project Schedules

How SmartPM™ Accomplishes the 5-Step-Process of Schedule Analysis

Schedule Quality Methodology and Process

Assessment of a schedule's quality is not as straight forward as most industry professionals believe; and it takes time and experience to do well – if done manually. Many industry professionals evaluate schedule quality by reviewing the order of activities in each respective area and assessing the durations of the activities. They confirm all major scope areas are included, such as design, preconstruction, procurement and construction, and that each area has all the activities necessary to complete the project. Some will go as far as to make sure that the organizational structure (WBS and activity codes) is straightforward and makes sense. While these things are important, there are many other checks that are necessary to ensure that schedules have been set up for success. A schedule that contains the correct level of detail of activities with reasonable durations, spanning across all the Phases, with a top notch WBS structure can still be a schedule that is unusable and ineffective.

In 2005, the US Defense Contract Management Agency (DCMA) developed a 14-point Schedule Assessment protocol to assist in evaluating project schedules, identifying problem areas, and providing a framework for asking educated questions related to the schedule. The DCMA's 14-point Schedule Assessment has become widely regarded and accepted as an industry guideline and best practice to evaluate project schedules for integrity. The DCMA's 14-point schedule assessment establishes thresholds for certain criteria and provides guidance on best practices, including[1] :

1. LOGIC	2. LEADS
3. LAGS	4. RELATIONSHIP TYPES
5. HARD 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 LEGEND INDEX	14. BASELINE EXECUTION INDEX

SmartPM™ has developed a proprietary Schedule Quality Index grading system that leverages the criteria included in the DCMA 14-point assessment metrics to generate a letter grade rating (with A being good, F being poor) by setting parameters and thresholds and subsequently deducting points from 100 for deviations from the criteria to arrive at a Schedule Quality "Grade". SmartPM™ evaluates schedule quality by analyzing the underlying schedule data, activity attributes and logic as compared to established parameters for key characteristics, including[1]:

- Number, frequency of Relationships and Relationship types (e.g. FS, SS, FF, SF)
- Number, frequency of Missing Logic
- Number, frequency of Positive and Negative Lag
- Number, frequency of Constraints
- Number, frequency of High Float Activities
- Number, frequency of High Duration Activities
- Average Total Float, and
- Number, frequency of Activities on the Critical Path

SmartPM™ allows users to set up different filters to analyze parts or the entirety of the schedule from a quality standpoint - providing a level of automation and insight that no other software can provide. SmartPM™'s proprietary grading structure is customizable based on the user's preferences for both point deductions and criteria thresholds. A sample of SmartPM™'s customizable grading system can be found in Appendix I, Table 1.0.

1 Defense Contract Management Agency, Department of Defense, Earned Value Management System (EVMS) Program Analysis Pamplet (PAP), DCMA-EA PAM 200.1, October 2012

Schedule Modification Analysis Methodology and Process

The SmartPM™ Schedule Modification Analysis checks for most of the same items that are recommended by the Association for Advancement of Cost Engineering International (AACEI) Recommended Practice No. 53R-06 titled "Schedule Update Review – As Applied in Engineering, Procurement and Construction". SmartPM™ captures, quantifies, and organizes schedule attributes related to recovery. For each schedule update, SmartPM™ first identifies and logs the schedule changes as compared to the previous update, including:

1. ADDED ACTIVITIES	2. DELETED ACTIVITIES
3. DURATION CHANGES	4. ADDED LOGIC
5. DELETED LOGIC	6. ACTIVITY DESCRIPTION CHANGES
7. ACTIVITY CALENDAR CHANGES	8. ACTIVITY LAG CHANGES
9. PLANNED MANPOWER CHANGES	10. PLANNED BUDGET CHANGES

In addition to capturing and logging all changes from one schedule to the next, SmartPM™ organizes the comparison data into the following categories so the user can quickly navigate, understand and identify high risk changes:

i. Critical changes – This grouping contains all changes that were made on the schedule update that would have been on the critical path had no changes been made. This also includes activity changes that were made to activities that are deemed critical in the current schedule update. In order to accurately identify the activities that would have been critical had there been no changes, a "half-step" approach is utilized to generate a version of the schedule update by incorporating all progress data from the previous schedule into the current update schedule.

ii. Near critical Changes - This category contains all changes that were made on the schedule update that would have had a total float of 1-5 days had no changes been made. This also includes activity changes that were made to activities that are deemed near critical (total float of 1-5 days) in the current schedule update. In order to accurately identify the activities that would have been critical had there been no changes, a "half-step" approach is utilized to generate a version of the schedule update by incorporating all progress data from the previous schedule into the current update schedule.

iii. Activity changes – This grouping includes added activities, deleted activities, duration changes, calendar changes and activity description changes.

iv. Logic changes – This includes changes related to added logic, deleted logic, modified logic, modified lags etc.

v. Duration Changes – This grouping shows all activities that had a change to duration only.

vi. All Changes – This category contains all changes in the schedule, including the total number of changes.

SmartPM™ enables users to quickly grasp and understand the number of changes from one schedule update and the magnitude of risk associated with them. SmartPM™ does this in a simple and user-friendly way, allowing the not-so-experienced users to quickly pinpoint potential aggressive, over-optimistic and misleading decisions that would otherwise result in financial risk and loss.

Delay and Recovery Analysis Methodology and Process

The Association for Advancement of Cost Engineering International (AACEI) has established recommended practices and guidelines for performing forensic analyses of project schedules. SmartPM™ aligns with these practices by automatically performing every type of forensic analysis and calculation they recommend. SmartPM™ performs delay calculations on a daily basis, otherwise known as Daily Delay Measure (DDM). According to AACEI, calculations performed on a daily basis provide significantly more accurate information.[2] SmartPM™ also includes features and options that allow users to perform functions and apply additional methods outlined by AACEI.

SmartPM™ allows users to perform both Prospective and Retrospective analyses of schedules as well as employ both Observational and Modeled methodologies to schedules to generate meaningful comparisons. SmartPM™ compares and evaluates project schedules on an activity-by-activity basis from one schedule update to the next; meaning, the attributes of a given activity in one schedule are compared to the attributes of the same activity in a subsequent schedule. Audit logs are generated comparing each activity from one schedule to the next, allowing users to see the attributes that were changed – as well as track delay based on the original and changed data.

Traditional Static Logic and Dynamic Logic can be employed to analyze schedules, by either comparing as-built schedules to as-planned or by observing the variations in logic that were incorporated during the project. SmartPM™ performs a side-by-side comparison of schedules and identifies changes in a project schedule from one update to the next; further, users are able to accept, reject, or alter the changes that may have been made to the underlying logic. Additive Modeling and Subtractive Modeling can also be accomplished by allowing users to insert or remove activities and logic, creating scenarios with rule sets, and analyzing delay through SmartPM's proprietary Scenario / What If features.

How Delays are Calculated in SmartPM™

Delay is defined as a state of extended duration of an activity or a state of an activity not having started or finished on time, relative to its predecessor. Delay evaluations utilizing CPM scheduling techniques are preferred for the identification and quantification of project delays. Both delays to the overall project (i.e. "Critical Path Delays" or "Longest Path") and delays to specific activities are calculated in SmartPM™. Delays identified in SmartPM™ are independent of the responsibility for the variance, however the system has built in features to document causation for delays. Further, the delays quantified and identified in SmartPM™ will guide and support the user in preparing a cause and effect analysis that may require additional project documentation to identify and assign responsibility.

Delay in SmartPM™ is calculated using a Windows / Contemporaneous Period Analysis approach and comparing progress on a day-by-day basis, utilizing an automated "half-step" methodology as a basis for measuring delay.[3] Delay calculations are made by comparing schedules and the activities progressed by taking the reported average progress completed in the period, spread across the activities' calendar workdays in order to compare to the planned average per day. Quite simply delays are calculated as follows:

> Overall Project Delay or "Critical Path Delay" is calculated by identifying activities that were on the schedule's "Longest Path" at specific points in time, and measuring delay days for the period which said activities are on the longest path. SmartPM™ has proprietary algorithms that compare progress points of activities at different points in time, in order to calculate delay days.

For more on the alignment of SmartPM™ with AACEI 29R-03, see Appendix II, Table 2.0.

2 AACEI International Recommended Practice No. 29R-03, Forensic Schedule Analysis

3 The "Half Step" methodology is an AACEI accepted methodology where actual (as-built) data is extracted from the later schedule update and inserted into an earlier schedule update in order to analyze delay. This enables the user to capture delay based on the plan at the time, using as-built data up until the subsequent period where the schedule data (logic, durations, etc.) may have been modified. This is called a "Half Step" analysis by AACE.

Source validation is essential to assuring the underlying reliability and accuracy of the analysis. The best accuracy that an analyst can hope to achieve is in the faithful reflection of the facts as represented in contemporaneous project documents, data, and witness statements.[4] While SmartPM™ relies on the data input into the schedule, SmartPM™ has controls built-in to better understand the integrity of the underlying data within the schedule to alert the user of areas that may require investigation to improve the quality and integrity of the data. SmartPM™ does not modify the original schedule, rather it enables the user to perform "What-If" analyses to improve the accuracy of the data.

> *Arithmetic calculations performed on a daily basis can provide significantly more accurate information if the as-built data is available at the appropriate level of detail*
>
> - AACEI International Recommended Practice No. 29R-03, Forensic Schedule Analysis

Feasibility and Predictive Analysis Methodology and Process

SmartPM™ analyzes Feasibility through its Compression Analysis and Project Completion Predictor. Compression Analysis is performed by comparing the remaining amount of work required to be completed in the remaining project duration with the reported performance data from the baseline schedule[5] up to the most recent schedule update. By comparing these data sets, SmartPM™ produces a compression index (%), where an index of 0% means no compression, greater than 0% indicates increased levels of compression and less than 0% means the schedule is decompressed.

In addition, SmartPM™ utilizes a proprietary algorithm that analyzes historical performance data and extrapolates average variances onto similar schedule activities that remain incomplete as of the data date of the last schedule that was imported. Essentially, historical performance is used as an indicator of future productivity without consideration of additional resources. SmartPM™ compares the predictive date with the current scheduled completion date in order to guide the user to understanding potential Schedule Feasibility risk – and to what extent.

The Project Completion Predictor represents an estimate of project completion if the project performance remains consistent with historical project performance up to the latest data date of the series of schedules loaded. There is no guarantee that the date predicted over time will actually be the date of project completion, rather the calculation serves as a "indicator" for future delay risk and/or serves as an index that will guide the user to form an opinion based on the accuracy and integrity of the current schedule.

4 AACEI International Recommended Practice No. 29R-03, Forensic Schedule Analysis

5 SmartPM™ identifies the "Baseline" as the schedule with the earliest data date of a series of schedule updates imported.

How SmartPM™ Overcomes Data Integrity ("Garbage In / Garbage Out") issues and allows users to model delay information to better understand cost and schedule variances

While the old saying "Garbage In Equals Garbage Out" holds true for many systems, SmartPM™ allows the user to make modifications to the data to amend, correct, and improve the data imported – all while maintaining the original integrity of the data.

When data is imported into SmartPM™, that data is what is used as a basis for analysis. This "Original Data" is maintained in the system in the file format that it was imported and is not corrupted in any way by SmartPM™. Once the data is stored in the system in its original form, the system allows the user to make copies of the data into separate "What-If" analyses where the following data points can be manipulated:

i. Activity Data – SmartPM™ allows users to change start dates, finish dates, progress and calendar data of all existing activities in the schedule, for purposes of analysis. SmartPM™ also allows users to add and remove activities from the analysis.
ii. Logic Data – SmartPM™ allows users to add or remove logic at different points in time, from any existing activities, for analysis purposes.
iii. Change Data – SmartPM™ performs a complete audit of all changes that were made in the schedule from one update to the next. Any and all changes to schedule data from one schedule to the next can be accepted, rejected or moved to an earlier or later period – for purposes of analysis.

SmartPM™ also has built-in indicators, such as the Schedule Quality Index, Schedule Recovery, Change Audit Log, the Compression Index and an End Date Predictor to guide the user towards correcting data deficiencies in the schedule that could otherwise result in an erroneous analysis.

By utilizing the Schedule Corrections and Scenarios' features, users are also able to analyze specific subsets of schedule data contained within the original data set. Users can remove various aspects of the project schedule, whether it be Phase, Area, Trade, or Network Logic preceding a specific activity or milestone.

Once schedule "Corrections" or "Improvements" or "Changes" have been made, for purposes of analysis, SmartPM™ runs all the same analytics on the revised set of data as the original data – in the same manner as outlined in the methodology and process sections above.

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SmartPM™ Use Cases

SmartPM™ is a system that is designed to provide schedule analytics that support the entire construction lifecycle. SmartPM™ not only performs powerful analytics, but it also converts this information into digestible intelligence for the user. This means that SmartPM™ is not just a tool to assist seasoned schedulers and analysts in performing more in-depth analytics more quickly, but it is also designed to assist non-schedulers in better managing risk of overruns and delays through informational intelligence. More specifically, SmartPM™ is utilized for the following:

i. Schedule Review/Approval – SmartPM™ provides key insights that may be difficult to detect in the baseline schedule and update review process. To date, SmartPM™ is not a system that tells you if the schedule has the correct activities, with the correct durations, in the correct order, rather SmartPM™ informs you if the schedules have been built with best practices. SmartPM™ analyzes the structural integrity of the schedules to ensure that they are properly constructed to effectively manage a complex commercial construction project. This is the hard part of baseline and update schedule analysis and should be an iterative process throughout the construction lifecycle. SmartPM™ ensures that quality is evaluated and maintained throughout construction execution and allows the users to develop a historical trend of the quality of schedule updates. In addition, SmartPM™ analyzes schedule changes over time and organizes changes in an intelligent manner, allowing users to detect high risk and/or infeasible changes; changes that were specifically designed to significantly mitigate historical delay that weren't necessarily vetted properly – resulting in compression, inefficiencies and more delays going undetected.

ii. Project Governance, Performance Oversight and Risk Management – Without intense analytics of iterative and cumulative activity progress and performance over time as compared to the original plan, stakeholders are forced to rely on high level (often unsupported) progress metrics, opinions of the project team, and/or gut intuition to gauge progress, performance, and impacts thereof. This reliance on high level explanations without supporting data analytics is not an optimal method to oversee performance of high dollar, high risk undertakings. SmartPM™ transforms the analytical process into a simple format by automatically performing delay analyses, schedule feasibility checks and predictive analytics with key performance indicators to direct stakeholders to identify root causes of performance and develop action plans to mitigate future issues. With relatively little effort, stakeholders are prepared to discuss schedule quality, project performance, project delay issues, recovery strategies and data-driven "expected" milestone completion dates (as opposed to relying simply on what the schedule says). This information is very useful throughout all of construction and relevant to all stakeholders, particularly because this level of understanding and insight ensures transparency, objectivity, accountability and greatly enhances collaboration across all levels.

iii. Dispute Avoidance and Resolutions – The aforementioned applications of SmartPM™ are designed to minimize the risk of delays and overruns – which in turn minimizes the risk of disputes. However, when disputes are unavoidable, SmartPM™ has the capability to perform forensic schedule analyses to support the dispute resolution process, either after the fact or if there is a current question about delays during project execution. Since a large portion of disputes have a delay component, SmartPM™ is useful to all project stakeholders in identifying root cause issues that ultimately resulted in delays and overruns. SmartPM™ has been utilized by stakeholders throughout the construction project lifecycle to settle time extension requests and as a basis for settling delay, disruption, inefficiency and acceleration claims.

While the above use cases alone are very powerful, the most powerful aspect of SmartPM™ is the level of accuracy and the objectivity that it provides. In an industry where stakeholders spend a lot of time on expressing opinions, which quite often are argued ad nauseum, SmartPM™ provides a means to supporting and rejecting opinions through intense and objective data analytics.

Customization of Analytics

SmartPM™ has features and functions that allows users to customize analyses in many ways. Below are some of the current and planned customizable features:

Schedule Quality Index	Current	Allows users to establish various thresholds and grading criteria for metrics built into the schedule.
Project Analysis – SmartPM™	Current	Allows users to make changes to various schedules, add, or reject historical changes and select which subsets of data to be analyzed. This allows users to view data analytics output in different ways for different evaluation purposes.
Activity Metrics	Current	Users can modify activity progress data, start and finish dates within the program.
Activity Attributes	Current	Allows users to set “retained logic” and “progress override” on an activity by activity basis.
Organizational Structure	Current	Allows users to set the organizational structure of schedule summary graphics, based on WBS structure, activity codes, or user-defined criteria.
Filters	Current	Allows users to filter activities by characteristics (e.g. critical, high duration, etc.) or user-defined criteria.
Near Critical Parameters	Planned	Allows users to set parameters for “near critical” in terms of the number of days of “total float” that would constitute a near critical activity.
Predictive Analysis	Planned	Allows users to determine the criteria for which activities should be associated. This includes identification of like activities based on WBS structure, Activity Codes, or a user-defined system of association.

The SmartPM™ Value Proposition

It has been well-documented that the Construction industry is viewed as one of the more inefficient and least digitalized industries that exists today. This rampant inefficiency has led to an industry epidemic of delay and cost overruns, which impacts project stakeholders in different ways. For Owners this translates into paying more for assets delivered long after their projected end date, significantly undercutting ROI. Contractors risk not being paid for additional time spent on projects that were delayed for reasons outside of their control, negatively impacting profitability. For public and government entities, delays and cost overruns translate into additional burdens on their constituents. Stakeholders of these groups and others have developed methods for managing these risks, but they are all manual, time-consuming, and/or costly.

SmartPM™ automates these processes, which delivers significant value to all project stakeholders. While the specific benefits differ slightly for each stakeholder group, they all fit into three types of value propositions: Cost Savings, Time Savings, and Scalability.

Value Proposition For Owners

An Owner may be defined as the entity that is funding the construction of a commercial asset, has a vested interest in the constructed asset, or takes ownership of the asset upon completion. An Owner's risk of a delayed project comes in three forms: 1) funding the overrun and delay, 2) lost revenue of the asset, and 3) dispute resolution costs, liquidated damages, and consultant fees.

Put simply, Owners are at risk of spending or losing revenue in the millions on even a small commercial project. As project budgets increase, these risks grow exponentially. In order to effectively manage these risks, schedule analytics are imperative throughout the construction lifecycle. SmartPM™ provides a full suite of analytics specifically designed to manage the risk of delays in an automated fashion.

The number of hours that a specialist would need to perform the same level of analytics as SmartPM™ on a $25M-$50M project over a 24-month construction duration may be estimated as follows:

Analysis	Estimated Hours	Total Estimated Hrs
Schedule Review / Approval	• 40hrs for Baseline Review • 8hrs per month for project duration	240
Project Governance, Oversight & Risk Management	• 32hrs per month to effectively oversee progress, performance of a project, while analyzing delay, feasibility and performing predictive analytics	760
Dispute Avoidance & Resolution	• 400hrs+ to analyze both time extension requests and perform delay analysis across the entire project duration and all schedule updates • This does not include analyzing delay and disruption claims	300+

Based on the above example, in order for an Owner to effectively manage a $2.5M+risk on a $25M-$50M project, it would require roughly 1000 hours over a 2-year period with the possibility of at least 300 additional hours to manage a dispute. Generally speaking, most owners don't hire enough people or engage enough consultants to manage this process effectively. Owners continue to be affected by this and cope with it through a contingency budget.

SmartPM™ changes all of this. SmartPM™ can perform the same level of analytics in roughly 2 hours per month on a $25-$50M project – or a total of 50 hours over a two-year period – making it possible for owners to manage this process in house and/or engage a consultant at a price that is digestible. Further, SmartPM™ analyzes larger more complex projects in relatively the same time as the example, thereby increasing the value of using SmartPM™ on larger, more complex projects.

SmartPM™ reduces the time spent to achieve the same level of analytics, which translates into time savings, cost savings, and scalability to oversee a greater number of projects. Additionally, existing inefficiencies from the scarcity of resources to effectively manage this process will be reduced drastically. Extrapolating this from a project by project basis to a portfolio of projects, the ROI increases exponentially when using SmartPM™.

Value Proposition For Construction Managers

For Construction Managers, the risks associated with a delayed project are not only the cost of the overruns, in terms of extended general conditions and overhead costs that may not be recovered from the Owner, but also includes damages on delays they didn't cause but are unable to prove were not their fault. For simplicity sake, assume that this can total the same $2.5M+ risk on a relatively small $25-$50M project. This risk value grows exponentially as the project budget grows. In addition to cost risk, the damage to a business that does not effectively manage delay, including its relationships, its reputation, future lost business, and its brand, is significant and difficult to quantify.

Through the same process of Schedule management, oversight and analytics that SmartPM™ provides, Contractors can effectively manage these risks. This would require a similar amount of manhours (1000+) to effectively manage. However, using the SmartPM™ system, project controls and scheduling personnel can accomplish in 50 hours what would require 1000 hours for even a seasoned analyst to complete. In addition, SmartPM™, if utilized effectively throughout construction will minimize any time spent (for consultants) preparing, reviewing and responding to claims by at least 10X as well.

Based on the above, it is easy to see that SmartPM™ can provide at least a 10X return on investment to a firm that currently invests heavily in project analytics, and this number is much greater for organizations with room for improvement in these areas.

Value Proposition For Financial Institutions and Insurance Companies

Organizations that are tied into projects financially, such as financial institutions, hedge funds, REITS, Asset Managers and Insurance companies, are also at risk due to overruns, delays and disputes. By utilizing SmartPM™ as a portfolio analytics tool, these types of organizations benefit as follows:

a. By enforcing the system to be utilized by Owners and/or Contractors, the risk of delays, overruns and resultant disputes is reduced greatly.
b. Visibility of performance of entire portfolios in one place provides owners with the ability to know where to focus their attention.
c. SmartPM™ provides an early warning system on identifying projects that have heightened levels of risk (before it's too late).
d. In the event additional money is requested for delays, overruns, etc., these institutions will have a quick way to analyze the data to ensure that such requests are supported by the schedule data.

Value Proposition For Consultants

Consultants who are regularly hired to perform these functions are accustomed to performing most of the analytics available in SmartPM™ in a manual fashion. By using the SmartPM™ system, in lieu of analyzing the data manually, consulting firms benefit as follows:

a. Staff Level professionals are able to perform analyses instead of the more senior people.
b. SmartPM™ allows consultants to perform the same analytics in one tenth the time; this enables consultants to gain a competitive advantage on price while achieving higher margins through fixed fee / value-based arrangements.
c. SmartPM™ enables consulting firms to offer large program oversight services at a price that is affordable and scalable.
d. Visibility into all projects contained in a large program enables consultants to identify real problems to fix across the entire portfolio, which may not have been visible otherwise.
e. SmartPM™ allows consultants to perform “What-If” scenarios on delay analyses that otherwise can’t be performed because they would take too long and cost too much – thus minimizing assumptions and resultant inaccuracies of data.

Disclaimers About SmartPM™

CPM Scheduling

SmartPM™ has a fully functional CPM scheduling engine that has been designed to mirror the same process, procedures and methodologies as the programs from which they were imported. SmartPM™ does, however, have a few variances from these programs as well, which are as follows:

Critical Path Calculations	The Critical Path in SmartPM™ is the same as the longest path, based on the network logic contained within the group of activities in the schedule being analyzed. Only the activities that have a total float of 0 days are considered "critical path" activities in SmartPM™.
No Finish Constraints	SmartPM™ does not allow finish constraints to exist in its schedules. Therefore, there is never any float value less than 0 in any schedule contained in the SmartPM™ system.
No Hourly Calculations	SmartPM™ does not allow users to choose specific hours of the day work activity can be performed. Therefore, all remaining duration calculations are in full "days" only, and not partial days. In addition, activities extending until midnight do not show a next day completion.
No Incomplete Activities past the data date	SmartPM™ does not accept actual start or completion dates after the data date.
No Started dates on activities that are 0% progressed	SmartPM™ does not accept the start date on an activity before it has progressed more than 0% for the first time.
Changes in Start/Finish Dates	When a user changes the start and finish date of an activity in a later update, SmartPM™ replaces this data in the previous schedules, and uses the updated information to update previous analyses.

Schedule Quality Analysis

The Schedule Quality Analysis feature is based on a combination of the DCMA methodologies and the industry best practices as recommended by the membership of the AACEI organization. These default settings for thresholds of acceptance and the grading "scoring" criteria in SmartPM™ are proprietary in nature and based on a combination of the previously outlined recommended best practices, the experiences of the product designers and recommendations from the client base.

Critical Path Delay Quantification

Delay is quantified by measuring duration variances of activities that are deemed critical at the point for which they were in process, had a total float of 0 days and were also on the "longest path" of the project at the time of its performance. Delay calculations are in "calendar days" and are calculated by comparing progress over time for the period that it was ongoing and critical at the same time. SmartPM™ uses a windows style approach to analyze performance whereby producing a "half step" schedule and comparing criticality of activities by incorporating and comparing future "as-built" data that has been incorporated into the previous version of the schedule. SmartPM™ has the ability to also analyze delay for a subset of activities as part of a larger set of activities in a schedule. When analyzing a subset of data, the critical path is defined as the critical path of only the activities in the subset being studied and not necessarily the critical path for the overall schedule.

Compression Index

The SmartPM™ Compression Index is calculated through a proprietary algorithm that compares the amount of work remaining over the remainder of calendar days in the most recent update, based on percent complete, to the remaining amount of work left in the same remaining time frame in the baseline. The Compression Index is calculated in terms of a percentage value that indicates how much more or less work needs to be done in the remaining time frame as compared to the baseline schedule.

Project and Grouped Percent Complete Calculation

The percent complete calculations of grouped or project level data are calculated first through a cost basis, next through a resource basis and finally through a duration basis. Therefore, if the schedule is 100% cost loaded, all percent complete values will be based on Earned value Principles where the weightings are determined by activity based on cost. If a schedule is not cost loaded, yet resource loaded, SmartPM™ will use the resource values as a basis for weighting activities to calculate percent complete using Earned Value Principles. If a schedule is not cost or resource loaded, percent complete at the grouped or project level is calculated by comparing the number of earned activity days using the cumulative value of all activity duration days as a basis for calculation. In cases where some activities are cost or resource loaded, and some activities are not, the program will break out the data into subsets of cost loaded, resource loaded only, or neither cost nor resource loaded to calculate overall percent complete.

Non-Corruption of Data

SmartPM™ takes data corruption and manipulation very seriously, and on its own does not change any data from its original state. When schedules are loaded, all data contained within the original schedule is maintained in its original format and a resultant analysis of this data is saved and titled “Original”. From there, users are able to modify various aspects of the data and reanalyze, but the analysis of the Original data is saved, stored and undeletable in its original format.

Weather Data

Weather Data is pulled for every weather station for the shorter of its existence or the last 30 years, as per NOAA. This data is pulled from NOAA and is updated daily. Weather data associated with a project is based on the zip code or location data that was entered into the system by the user when the project was created. SmartPM™ selects the closest weather station for which NOAA collects the data, based on the location chosen by the user.

Predictive Analytics

SmartPM™ uses its own proprietary algorithm to calculate a project’s predicted end date. The algorithm uses historical progress data and compression data, along with years of analytics experience in the field of commercial construction as a basis for calculating a project’s predicted end date. SmartPM™ does not guarantee that any project will finish on the date predicted, which changes at different points in time. It should be only used as a guide for planning and/or assessing the feasibility of a project schedule.

SmartPM™ is not an expert witness, rather a guide for expert witnesses

SmartPM™ is designed to perform expert grade level schedule analytics, including performing forensic delay quantification. SmartPM™ on its own can not assess damages, nor can it determine causation and responsibility for delay issues identified. Nor can it guarantee that the data contained within is accurate. As such, SmartPM™ should only be used as a guide to understanding and measuring impacts and other risk.

Whitepaper Disclaimer :

This SmartPM™ Technical Whitepaper should be viewed as a “living document” subject to change at any time. As such, before using this whitepaper as a resource to assist in litigation or for any other purpose, all parties involved are advised to confirm they are referring to the most current version, which can always be found by contacting SmartPM™ at info@smartpmtech.com.

Appendix I

Table 1.0 – SmartPM™ Sample Rating Table

SmartPM™ Sample Customizable Rating Table			
Metric	**Criteria**		
	Good Threshold	**Acceptable**	**Unacceptable**
Total Relationships	> = 1.5	> = 1.25	< 1.25
FS	> 90%	80% - 90%	< = 80%
SS	< = 5%	5% - 10%	> = 10%
FF	< = 5%	5% - 10%	> = 10%
SF	< = 0%	0% - 0.2%	> = 0.2%
Missing Logic	< = 2.5%	2.5% - 5%	> 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)	< = 2.5%	2.5% - 5%	> 5%
Critical Path %	10% - 20%	5% - 10% or 20% - 30%	< 5% or > 30%
Average Total Float	15 - 44 days	7.5 - 15 days	< 7.5 days or > = 44 days

APPENDIX II

Table 2.0 – Alignment of SmartPM™ with AACEI Recommended Practice 29R-03 Forensic Schedule Analysis

AACEI Methods					Common Names	SmartPM™ Alignment
Retrospective	Observational	Static Logic	3.1 Gross	Gross	As-Planned vs. As-Built	SmartPM™ analyzes delay between every two successive schedules imported. To analyze the delay period between any two schedules, SmartPM™ assigns the first schedule as the "Plan" and analyzes all work performed in the period between the data date on the Plan with the data date on the second schedule. SmartPM™ updates the data in the Plan (activities, logic, calendars, etc.) with the progress data from the second schedule. SmartPM™ then creates a daily schedule update for every day in between the Plan data date and the second schedule using the logic, calendars, constraints, etc.) from the original schedule. To analyze this in an "As-planned vs. As-built" comparison, the user can: a) import the "As-planned" schedule and the latest "As-built" schedule, or b) load all contemporaneous schedule updates and create a Scenario that analyzes only the first and last schedule imported.
			3.2 Periodic	Fixed	Window Analysis	SmartPM™ automatically creates a "Window" for every actual day (from data date to data date) in the period and allows the user to view and track delay at any point in time. This alleviates the need to analyze for specific "fixed" or "variable" periods.
				Variable		
		Dynamic Logic	Contemporaneous 3.3 As-is or 3.4 Split	All Periods	Contemporaneous Period Analysis, Time Impact Analysis, Window	SmartPM™ allows users to import a baseline schedule and all subsequent updates and analyzes delay based on the schedule data contained in the most recent schedule update. For every period being analyzed, the previous schedule data serves as the Plan for the "Period" or "Window" and the progress data is inserted, compared and analyzed to that Plan to produce an analysis for the Window of time. SmartPM™ requires that all original data entered into the program be analyzed in its original form.
				Grouped Periods	Contemporaneous Period Analysis, Time Impact Analysis, Window	SmartPM™ allows users to select schedules to be included or excluded from an analysis. When a user imports all schedules for a specific project, the user can create Scenarios that include or exclude specific updates to be analyzed. All progress data from schedules that have been imported and are not utilized will still be incorporated into the analysis (or not). These analyses will differ slightly in that there will be some cases where the daily progress is calculated differently on activities that are performed in more than one successive period.
			3.5 Modified	Fixed	Contemporaneous Period Analysis, Time Impact Analysis	SmartPM™ enables users to make virtually any change, modification and/or correction to the underlying data in any and all schedules for basis of analysis. This is achieved by creating "Rules" to be incorporated (all or in part) into a separate "Scenario" or analysis. All changes are documented and when changes are made, entirely new "Scenarios" are created as a completely separate analysis from the original data. SmartPM™ automatically creates a "Window" for every actual day (from data date to data date) in the period and allows the user to view and track delay at any point in time. This alleviates the need to analyze for specific "fixed" or "variable" periods.
				Variable	Window Analysis, Time Impact Analysis	
	Modeled	Additive	3.6 Single Base	Global	Impacted As-Planned, What-If	SmartPM™ allows users to add schedule data and incorporate added data into any schedule update for purposes of performing "Additive" analyses. This is achieved by adding schedule activities, logic ties, etc. directly into the most recent schedule via SmartPM™. Users first insert the schedule activities in planned format; once complete, users enter the "As-built" data. From there, users can re-run the analysis with the fragnets added to the schedule. SmartPM™ then determines if the activity was ever critically delaying the project; and if so, for how many days. SmartPM™ performs this in a global or in stepped manner, for fixed or variable periods by allowing users to select schedules and creates a Window for each day of the project.
				Stepped	Time Impact, Impacted As-Planned	
			3.7 MultiBase	Fixed	Time Impact Analysis	
					Window Analysis, Impacted As-planned	
		Subtractive	3.8 Single Simulation	Global	Collapsed As-Built	SmartPM™ allows users to perform a "Subtractive" modeling exercise by creating Scenarios where activities are subtracted or removed from the analysis and comparing end date variances between the original and the newly created Scenario. This is accomplished by lining up each schedule (original and Scenario) to the same data date before the original As-built start date of the activities that were removed. SmartPM™ performs this in a global or stepped manner, for fixed or variable periods as the program allows users to select schedules and creates a Window for each day of the project.
				Stepped	Time Impact Analysis, Collapsed As-Built	
			3.9 Multi Simulation	Fixed	Time Impact Analysis, Collapsed As-Built	
				Stepped	Time Impact Analysis, Window Analysis Collapsed As-Built	

About the Author

Michael Pink possesses over 17 years of experience in the construction industry providing Program Management, Risk Advisory and Dispute Resolution Services. Michael has provided these services on capital construction programs and projects all over the globe representing an assortment of industries, both public and private, including Power & Renewable Energy, Gas/Pipeline, Industrial and Manufacturing, Commercial and Residential buildings, Healthcare, Education, Transportation, Entertainment & Retails sectors.

Michael specializes in data analysis, with a specific focus on schedule management & analysis. Most recently, Mr. Pink has developed technology designed to regularly analyze schedule quality, delay, compression,feasibility and risk on commercial construction projects.

Mr. Pink received his BS in Industrial Engineering from Georgia Tech and his MBA from The Stern School of Business at New York University. He has spent most of his career working as a consultant in the “Big Four” consulting environment working closely with owners, contractors, attorneys, and lenders on complex consulting assignments. Mr. Pink is currently certified as a Planning and Scheduling Professional (PSP) and a Certified Cost Engineer (CCE) and has authored multiple published articles on the subject matter.

John is an experienced Construction Industry executive with 20+ years of experience providing strategic analyses, advice, and guidance to owners, developers, investors, and contractors undertaking growth and expansion initiatives with large capital programs and projects. John possesses a diverse background across nearly all market sectors and extensive experience on projects ranging from $5M to $2B+. Prior to joining SmartPM™ as Vice President of Customer Success.

Mr. Tuskowski spent over 15 years in the “Big Four” consulting domain working closely with clients and providing key stakeholders with insights and analyses to support critical decisions throughout the program and project lifecycles. John served as the Southeast lead for construction advisory services and was responsible for developing and maintaining client relationships as well as leading client engagement teams. John’s experience encompasses the construction, real estate, risk management, accounting, valuation, and tax domains with a focus on project governance and controls, risk management, process improvement, claims and dispute support, construction auditing, construction accounting and tax planning, and transaction advisory.

John received his undergraduate degree in Civil Engineering from Bucknell University and is currently a LEED Accredited Professional, a member of the PMI Institute, and a member of AACEI. When he’s not facilitating the success of clients, John enjoys spending time with his wife and two children and is a board member for a non-profit special needs school in Marietta, Georgia.