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Project Scheduling Constraints – Best methods and practices

Project schedule is often the driver for many projects, and a variety of schedule constraints exist such as imposed date, key resource availability, logical task order and activity duration limitations. The project management challenge is finding the best way address these constraints and keep projects moving forward.

This research involves a systematic comparison of a variety of methods for dealing with project scheduling constraints. First, prescribed techniques from established methodologies such as those of the Project Management Body of Knowledge (PMBOK[®]), Critical Chain, and Agile theories are examined. Suggestions for overcoming the four types of constraints were provided by over 150 practitioners in a structured workshop. These suggestions are compared for both convergence with and divergence from the theories. The results comprise a framework for determining best practices for project scheduling. Furthermore, new methods for working with project schedule constraints using this framework are presented as part of this effort.

Introduction

Project schedule is one of the primary components in the classic project management triple constraint of time, cost and scope. Once the elements in the work breakdown structure (WBS) are defined, creating the schedule and assigning resources to the project brings the end goal further to fruition and to reality. However, in modern business, there are many challenges and threats to the project schedule, including resource constraints, multiple projects and imperative business needs. Addressing project constraints and managing project schedules is thus a complex, multifaceted duty for the project manager.

The topic of project scheduling has been addressed in a multitude of research papers and publications, with a large amount of the literature focused on numerical and statistical methods for resolving resource constraints. Software tools and models created for project management aim to help the practitioner work with constraints (Herroelen 2005). Additionally, researchers have studied and developed predictive models for schedule performance using historical performance data, scenario variation, simulation and other techniques (Ahuja and Thiruvengadam 2004).

The research for this paper takes a different approach in examining project schedule constraints; instead of investigating mathematical models and approaches for optimizing project schedule, we examine project scheduling from a methodology and behavioral standpoint. This paper is organized in the following fashion. First, we define how project schedules are limited and describe constraint types. Then we present an examination of methodologies for dealing with constraints based on published literature. Specifically, we analyze PMBOK[®]-based, Critical Chain and Agile methodologies. Next, we present the results of a survey to practitioners across a variety of industries on how they deal project scheduling constraints. Methods from the literature are compared to in-practice methods. Finally, we derive best practices from the analysis and conclude with recommendations.

Project Schedule Constraint Types

Project schedule development is one of the first things that project managers learn to do, where we take the activities of a project, put them in order (often using Post-It[®] notes), assign resources and Voila! we create the network diagrams and Gantt charts that define a project's

schedule. The pressure to keep a project on schedule is often great, and projects are limited by four types of constraints, defined by Kloppenborg (2009).

- **Key resource availability** constraints are evident at those points in a project when a particular set of skills, person or other resource is absolutely required for the project to proceed. In this age where organizations are streamlined with little surplus capacity, key resource availability constraints can easily pop up in projects when the timing of activities change by even the slightest bit.
- **Activity duration** constraints occur at the WBS task level, and are controlled at the point where we are estimating the task. Project managers can be either overly optimistic in their estimations, thereby risking their task deadlines, or so conservative in their estimations that they have large time buffers in each task that make also make the estimate unrealistic.
- **Logical order** constraints are defined by the sequencing of activities. Project tasks are often dependent on one another, and some efforts simply cannot begin until their predecessors are complete.
- **Imposed date** constraints occur when project sponsors, customers and/or other project stakeholders levy requirements for the project's schedule, either for completion or for certain milestones.

Project Management Methodologies for Working with Constraints

PMBOK[®] -based methods

There is a wealth of information available on PMBOK[®] -based methods for project scheduling and project schedule constraints. Indeed, research into project schedules dates back

to the 1950's, the dawn of project management methodologies itself. The two primary techniques utilized for project scheduling are Critical Path Method (CPM) and Program Review and Evaluation Technique (PERT), which are related methods (Ahuja and Thiruvengadam 2004). Both of these are network-based, derived from the six processes of time management described in the PMBOK® Guide (PMBOK® Guide 2004: 125). These methods require a thorough definition of the project's scope before working with the project schedule.

Key Resource Availability - Addressing key resource availability constraints is a shortfall of the CPM technique for schedule development, where even the PMBOK® Guide states that “The critical path method calculates the theoretical early start and finish dates, and late start and finish dates, for all schedule activities without regard for any resource limitations, by performing a forward pass analysis and a backward pass analysis through the project schedule network paths and a backward pass analysis through the project schedule network paths (PMBOK® Guide 2004: 145).” Furthermore, the guide recommends that scarce resources be allocated to the critical path activities and to use reverse resource allocation scheduling, but the downside to such actions is that the resource-leveled schedule may be longer than the original schedule (PMBOK® Guide 2004: 147).

Activity Duration - Activity duration constraints are examined at the task level using PERT, where estimations for optimistic/realistic/pessimistic views on schedule are derived. Uncertainties in activity duration can also be treated as risks, where Monte Carlo analysis of potential scenarios for the project is performed to estimate the impact to the schedule from the result of a particular activity (PMBOK® Guide 2004: 146). It is to note that activity duration constraints are often addressed in concert with logical order constraints.

Logical Order - Logical order constraints can be addressed by examining by using a network-based approach, looking at both the uncertainties in the network structure and the activities themselves (Pollack-Johnson and Liberatore 2005). From this, one may examine task dependencies amongst each other, analyze lead and lag times for tasks and other options for the order of activities based on the network (Kloppenborg 2009).

Imposed Date - There is a dearth of information on how one would work with imposed date constraints in the literature about PMBOK[®]-based methodology. The PMBOK[®] Guide does acknowledge that imposed dates can exist as an activity attribute and can also impact a project's budget when discussing cost management. It also advocates creating alternative schedule models to show changes based on constraint, but it gives no clear guidance on how to work with the constraint. No other methods are presented for imposed dates.

Agile methods

Agile methodologies for project management are derived from concepts first described in the 2001 "Agile Manifesto" for software development. Techniques derived using Agile concepts include Scrum and eXtreme Programming (XP). Within Agile, there is an emphasis on working software, short development iterations, customer collaboration and responsiveness to change; these are considered to be the core values of Agile. Implementing these concepts requires different ways of planning and thinking about projects, and therefore Agile is considered to be an entirely new paradigm for management and development (Kane 2007).

Agile development methodologies are a sharp contrast to PMBOK[®]-based methods, and within this shift in mindset comes different ways to manage projects and even think about projects. This point is stressed because as we look at the differences in how we would work with

project constraints, we need to remember that we are looking at projects and project management as a whole completely differently from an Agile mindset as we would from a PMBOK®-based waterfall project mindset. For example, final deliverable specifications, hence project scope, are not always known at the outset of an Agile project, this would be considered a non-starter for a PMBOK®-based project.

Key Resource Availability – Key resource availability constraints can almost considered as non-issues in an Agile methodology. Projects are planned in an iterative fashion in Agile, driven by short cycles of development for a limited amount of features or User Stories as referred to in XP. Project teams are self-organized, and at the outset of each cycle, planning occurs for what scope the team can accomplish in the short-term, taking into account the priority of requirements, customer needs and resources available. This cyclic approach means that there is almost continuous planning in an Agile methodology, but it allows for a more flexible way to deal with constraints (Buglione and Abran 2007).

Activity Duration – Activity duration constraints are managed in a dynamic sense using Agile. Project teams are empowered to develop their own plans and requirements in collaboration with the customer for each iteration of development. As a result of these short cycles of development and planning at the project team level, a more realistic estimation for time can be obtained. “With agile, instead of predicting schedule performance based on results from a different project with different people, we plan our team velocity continuously based on the actual team’s current performance (McMahon 2005).” Therefore, by having more accurate estimations for activity duration, the project team may work with the duration constraint by examining scope or otherwise working with the customer on a plan.

Logical Order – Within an Agile methodology, there is a focus on continuously having working prototypes at the end of each development cycle or iteration. The deliverables at the beginning of the project may only have limited functionality, but the project team then works in successive development iterations to add features to suit the customer's needs. Since there is frequent planning and also frequent communication with the customer, the logical order for tasks and priority for work is determined during the course of development (Kane 2007). This puts more of an emphasis on the management of scope in Agile than with other methods, but with greater flexibility to deal with both logical order and activity duration constraints.

Imposed Date – There is little information found on imposed dates in an Agile methodology. This is perhaps due to the focus on consistently delivering working prototypes using this management method, where each additional development cycle adds features and functionality to the product and it is then up to the customer to determine final acceptability. Additionally, since imposed date constraints are typically addressed in a behavioral sense of working with customers directly rather than using prescribed methods, Agile methodology is well-equipped to handle imposed dates because of its emphasis on customer collaboration.

Critical Chain methods

The Critical Chain methodology is derived from the Theory of Constraints, which is based on the principle that every system has a constraint, and in order to optimize the performance of the system, one must focus on the constraint or bottleneck (Raz, Barnes and Dvir 2003). Whereas in the PMBOK® sense we think of the critical path as the longest duration of linked activities, the Critical Chain is the longest chain of dependent activities when resources are taken into account (Yang 2007). In the Critical Chain methodology, we focus on working

and dealing with the constraint, which is often a particular resource, to accomplish and meet the project's schedule.

Like Agile methodology, Critical Chain represents a different way of thinking about project management and project scheduling. In particular, Critical Chain addresses key resource availability, activity duration and logical order constraints together, rather than addressing each type of constraint in isolation (Yang 2007). We focus on protecting the Critical Chain through the use of buffers, of which there are four types, project, feeding, resource and constraint. Managing these buffers allows us to concentrate on completing the Critical Chain and subsequently the project on schedule (Umble and Umble 2000).

Key Resource Availability – A fundamental element in Critical Chain is trying to optimize a project's schedule to account for the availability of resources. For instance, if there are multiple tasks requiring the utilization of the same resource at the same time, Critical Chain will seek to separate the activities of those tasks so they are not executed concurrently. A Critical Chain schedule is one in which key resources are accounted for (Yang 2007). The use of resource buffers, which are virtual tasks that cue key resources to upcoming Critical Chain tasks and align these resources to the work that is forthcoming, can even help facilitate early starts for Critical Chain tasks (Umble and Umble 2000).

Activity Duration – Critical Chain methodology deals with activity duration constraints through the use of project buffers. The Critical Chain methodology considers traditional estimating techniques for activity duration to be too long, where safety and learning curve time are incorporated into the duration estimate for each task. Instead, under Critical Chain, the time for such uncertainty, learning and safety are removed from the activity estimate and pooled into a buffer added to the end of the project. Activities in the Critical Chain are started and completed

as soon as possible, and the idea is that for every task that is delayed, there is another one that is completed early, thereby offsetting the delay from the first task and protecting the overall schedule (Umble and Umble 2000). For non-Critical Chain activities, feeding buffers are inserted at points where the non-Critical Chain activities merge with the Critical Chain (Raz, Barnes and Dvir 2003).

Logical Order – While Critical Chain methodology is based upon an examination of the logical order and sequencing of dependent tasks to optimize an identified constraint in the project, it does not analyze the dependency and relationships between tasks themselves. This is an interesting distinction, as tasks that do not have logical relationships to other tasks (in either a precedence or successor relationship) are pushed out and delayed in the methodology so that the Critical Chain activities may be completed first. It is recommended that concurrent activities are to be reduced or even eliminated so that resources can be focused on the Critical Chain (Yang 2007).

Imposed Date – Imposed dates can present a firm constraint onto the project, which is managed in Critical Chain methodology using a constraint buffer. Like the resource, project and feeding buffers, a constraint buffer is inserted to protect the imposed date for completion (Umble and Umble 2000). Schedule control is monitored by examining the extent of buffer consumption and penetration (Raz, Barnes and Dvir 2003). Furthermore, case studies by Umble and Umble as well as Yang reveal that projects managed in the Critical Chain methodology delivered faster than those managed in a traditional sense, despite imposed date constraints.

Practitioner Input on Working with Constraints

The next phase of our study examines ideas for dealing with project constraints given by project management practitioners. Data obtained for this study comes from a workshop at the PMI 2007 North American Global Congress, where Kloppenborg introduced the concept of project scheduling constraints, provided some initial ideas for working with constraints and then facilitated discussion (Kloppenborg 2007).

Kloppenborg's initial ideas for working with project scheduling constraints provided fodder for discussion amongst the workshop participants, who spanned a variety of experience levels and industries. Over 150 practitioners were seated at 18 tables for this morning session workshop. Once presented the framework for project scheduling constraints, each table was asked to come up with recommendations for dealing with constraints and to document them on flip charts. The methods that each table considered to be most important were also noted for each of the four types of constraints. The results included both live examples as well as recommendations. Each table then presented their ideas to the rest of the workshop.

The workshop yielded over 150 ideas for working with project scheduling constraints, including Kloppenborg's original set of ideas. Following the workshop, these ideas were then grouped into categories, where ideas for each constraint are presented below for each type of project scheduling constraint.

Key Resource Availability Ideas

Ways to deal with external people
<ul style="list-style-type: none">• Work with project sponsor
<ul style="list-style-type: none">• Use a rotating senior advisor for projects
<ul style="list-style-type: none">• Work with functional manager in a matrixed organization
Consider where a project fits in a company portfolio
<ul style="list-style-type: none">• Establish a dedicated resource to manage resource-loaded schedules on multiple projects

<ul style="list-style-type: none"> • Examine organization's project portfolio and resource needs
<ul style="list-style-type: none"> • Prioritize project as a whole within organization and potentially postpone
<ul style="list-style-type: none"> • Lower resource utilization for those performing on multiple projects
Ways to increase resource capacity
<ul style="list-style-type: none"> • Utilize overtime or weekends
<ul style="list-style-type: none"> • Cross-train employees
<ul style="list-style-type: none"> • Outsource and utilize consultants or contractors
Ways to deal with team members
<ul style="list-style-type: none"> • Use staffing management plan
<ul style="list-style-type: none"> • Onboard all team members
<ul style="list-style-type: none"> • Establish dedicated project teams
Ways to deal with key resources
<ul style="list-style-type: none"> • Plan for use of key resources first
<ul style="list-style-type: none"> • Identify key resources based upon task rating
<ul style="list-style-type: none"> • Use key resources early in project
Tools to understand resource use
<ul style="list-style-type: none"> • Use individual resource calendars
<ul style="list-style-type: none"> • Document resources and availability
<ul style="list-style-type: none"> • Use resource leveling tools
<ul style="list-style-type: none"> • Use resource histogram and Gantt chart
Tools to manage tasks more specifically
<ul style="list-style-type: none"> • Postpone non-critical tasks
<ul style="list-style-type: none"> • Reorder tasks
<ul style="list-style-type: none"> • Finish tasks early to pass to next worker
<ul style="list-style-type: none"> • Split tasks and conduct resource tradeoff
Ways to potentially reduce project work
<ul style="list-style-type: none"> • Verify whether constraint really exists – method for resource allocation
<ul style="list-style-type: none"> • Reduce scope
<ul style="list-style-type: none"> • Use historical records

Activity Duration Ideas

Ways to estimate
<ul style="list-style-type: none"> • Use bottoms-up estimating of activity duration from team members at lower levels
<ul style="list-style-type: none"> • Use peer review and expert review of activity duration estimates
<ul style="list-style-type: none"> • Use PERT estimations of low/med/high for duration
<ul style="list-style-type: none"> • Estimate duration while taking into account other efforts and activities
<ul style="list-style-type: none"> • Assume normal conditions for estimating first
<ul style="list-style-type: none"> • Create initial schedule without reference to deadlines
Project management process improvements
<ul style="list-style-type: none"> • Use common/standard units and clear communications
<ul style="list-style-type: none"> • Use templates
<ul style="list-style-type: none"> • Investigate industry standards & best practices

<ul style="list-style-type: none"> • Capture and use baseline metrics for tasks
Ways to monitor and control work
<ul style="list-style-type: none"> • Use more upfront investigations
<ul style="list-style-type: none"> • Force a time crunch at the beginning
<ul style="list-style-type: none"> • Use accountability sessions
<ul style="list-style-type: none"> • Use gate reviews for reevaluation
<ul style="list-style-type: none"> • Manage schedule aggressively
<ul style="list-style-type: none"> • Use frequent update meetings
Resource methods
<ul style="list-style-type: none"> • Use alternate resources
<ul style="list-style-type: none"> • Use a more experienced team
Ways to deal with risk
<ul style="list-style-type: none"> • Understand basis for how duration was estimated
<ul style="list-style-type: none"> • Identify categories of activities for risk and phase and estimate accordingly
<ul style="list-style-type: none"> • Resolve risks
<ul style="list-style-type: none"> • Identify alternative tasks for critical tasks
<ul style="list-style-type: none"> • Develop a risk matrix of the overall framework
<ul style="list-style-type: none"> • Incorporate filler tasks for potential opportunities
Evaluating individual tasks
<ul style="list-style-type: none"> • Build contingency / concurrent activities for each task
<ul style="list-style-type: none"> • Define exit criteria for task clearly
<ul style="list-style-type: none"> • Rate each task's complexity and risk
<ul style="list-style-type: none"> • Identify flexibilities in duration
<ul style="list-style-type: none"> • Document assumptions related to each task's estimate
Planning tools
<ul style="list-style-type: none"> • Use a visual progress chart posted where everyone can see it
<ul style="list-style-type: none"> • Use rolling wave planning with progressive elaboration
<ul style="list-style-type: none"> • Develop a risk matrix of the overall framework
<ul style="list-style-type: none"> • Use Monte Carlo
<ul style="list-style-type: none"> • Utilize software tools
<ul style="list-style-type: none"> • Keep historic data for templates and estimating
<ul style="list-style-type: none"> • Determine key milestones
Ways to evaluate overall schedule and manage schedule reserve
<ul style="list-style-type: none"> • Use feeding buffers
<ul style="list-style-type: none"> • Use resource buffers
<ul style="list-style-type: none"> • Use project buffers
<ul style="list-style-type: none"> • Track and manage slack
<ul style="list-style-type: none"> • Carefully authorize start of non-critical tasks
<ul style="list-style-type: none"> • Stagger start dates for tasks
<ul style="list-style-type: none"> • Subset tasks
Ways to deal with external people
<ul style="list-style-type: none"> • Develop strong relationships with all stakeholders
<ul style="list-style-type: none"> • Create contractual incentives

Logical Order Ideas

Ways to evaluate logical order
<ul style="list-style-type: none">• Dependency review & risk assessment
<ul style="list-style-type: none">• Identify soft skill dependencies
<ul style="list-style-type: none">• Activity network review with graphical representation
<ul style="list-style-type: none">• Identify & use leads/lags with dependencies
Ways to evaluate and communicate progress
<ul style="list-style-type: none">• Use a recorder or administrator for the project
<ul style="list-style-type: none">• Continually review logic and provide feedback as project progresses
Ways to plan activities
<ul style="list-style-type: none">• Reverse phase scheduling
<ul style="list-style-type: none">• Define & focus on key milestones
<ul style="list-style-type: none">• Avoid multitasking
<ul style="list-style-type: none">• Try to overlap activities or make tasks parallel
<ul style="list-style-type: none">• Peer review / expert review in planning
<ul style="list-style-type: none">• Unconstrained networking
<ul style="list-style-type: none">• Apply lessons learned from prior projects
Ways to work with stakeholders
<ul style="list-style-type: none">• Obtain buy-in with management and team on logical order and constraint upfront
<ul style="list-style-type: none">• Build incentives for logical order when contracting
<ul style="list-style-type: none">• Education benefits
Ways to change things in-progress
<ul style="list-style-type: none">• Change planning methodologies
<ul style="list-style-type: none">• Compress schedule

Imposed Date Ideas

Ways to work with external stakeholders
<ul style="list-style-type: none">• Secure help from sponsor and powerful stakeholders
<ul style="list-style-type: none">• Communicate early need for relief
<ul style="list-style-type: none">• Communicate constraints with supporting data
Ways to manage scope
<ul style="list-style-type: none">• Make ideal plan, identify tasks at risk and make tradeoffs
<ul style="list-style-type: none">• Reduce scope and change baseline
<ul style="list-style-type: none">• Identify what part of the scope can be completed within the time limit
Ways to evaluate risk and impact
<ul style="list-style-type: none">• Examine cost feasibility
<ul style="list-style-type: none">• Correlate specific tasks with risk
Ways to manage project activities
<ul style="list-style-type: none">• Finish some tasks early to free up resources
<ul style="list-style-type: none">• Use a phased approach

<ul style="list-style-type: none"> • Reward those who communicate imposed date troubles
<ul style="list-style-type: none"> • Make frequent updates
<ul style="list-style-type: none"> • Identify intermediate milestone dates
<ul style="list-style-type: none"> • Provide incentives or penalties for meeting or missing the imposed date deadline
Understanding the imposed date
<ul style="list-style-type: none"> • Understand the customer schedule and involve customer with project
<ul style="list-style-type: none"> • Determine business launch date
<ul style="list-style-type: none"> • Understand the reason behind the imposed date
<ul style="list-style-type: none"> • Ask questions and challenge the imposed date
Understanding project within company portfolio priority
<ul style="list-style-type: none"> • Keep historic data
<ul style="list-style-type: none"> • Reprioritize project in organization
<ul style="list-style-type: none"> • Document rationale for imposed date

Comparison of Methodologies to Practitioner Input

In comparing the literature and theory to practitioner input on the subject of project scheduling constraints, some interesting observations are found. In many cases, the project management theory aligns quite closely with practitioner results, yet in others the practitioners bring up ideas that are new and do not align with any methodology. For the most part, practitioners looked at using methods in working with the project team and stakeholders more so than using structured technical methods as often described in the literature. Behaviorally-oriented ideas, such as working to understand customer requirements and fostering stakeholder relationships were common responses.

Additionally, the practitioner responses seemed to address project schedule constraints in a much more holistic sense, where they were thinking in context of the organization as a whole and its portfolio of projects, rather than a project and its constraints in isolation. While the literature certainly addresses projects in a portfolio fashion, the research into constraints tends to examine issues on a single project basis. Furthermore, the practitioners addressed business practices of the organization and looked for solutions towards optimizing business processes as a

whole, such as establishing standards, using lessons learned data or recruiting assistance from external sources.

When examining contrasts between the methodologies and the practitioner input, practitioners have a different frame of reference in thinking about project management. What is used in practice may not fit any specific method, or may align with many of the methods. The following analysis reviews each of the four types of constraints

Key Resource Availability – The project management theory seems to address key resource availability constraints by one of two methods, either focusing on the critical path or critical chain of activities (PMBOK[®]-based and Critical Chain) or planning scope around not utilizing the key resource (Agile). In practice, many of the workshop respondents stated that while they would work to focus on accomplishing priority activities using the key resource, either by performing some activities early or planning around the resource, in accordance to methodology, they would also employ alternatives such as outsourcing and adding resources, as well as working with the project sponsor. Practitioners offered broader solutions as well, such as carefully monitoring resource utilization across multiple projects and managing overall staffing, these ideas are more organizationally based than method-based.

Activity Duration – In terms of working with activity duration constraints, each of the methodologies analyzed vary sharply. Where PMBOK[®]-based methods advocate using PERT and Critical Chain methodology utilizes project buffers, Agile methodology pushes estimating responsibility down to the project team, who plans frequently at the beginning of each development iteration. In practice, we see many ways that project managers work with activity duration constraints; it was in this type of constraint where there were the most responses from the workshop (over 70 ideas). Practitioners utilize many methods for estimating, from bottoms-

up team member estimation like Agile to PERT to encouraging schedule urgency upfront like Critical Chain. Thus, methods to work with activity duration constraints seem to converge in practice, though not in the literature.

Practitioner input into activity duration constraints revealed that risk is often analyzed and assessed during estimation, and several ideas were presented aimed at reducing risk. These included using a more experienced team to conduct estimations, peer review of the estimates, alternative task creation, as well as increasing communication. It is in this area where project managers recommended facilitating stronger relationships with stakeholders, having more reviews and using industry standards, all activities focused on reducing risk.

Logical Order – PMBOK[®]-based methods are the only rational comparison to practitioner input for the logical order constraint. Agile addresses logical order constraints through continuous review, planning and prototyping, where Critical Chain simply recommends non-concurrent activities, so there is little to compare from those two methodologies. However, the idea of analysis of the network of project activities from PMBOK[®] is consistent with what was recommended by practitioners in the workshop. Analysis of the network can include reviews of task dependencies, reverse phase scheduling, understanding lead and lag times and finally identifying ways to compress the schedule. Other than analysis and review of the network though, the practitioners again offered organizational solutions such as peer review, management buy-in, applying lessons learned and education, among others. Furthermore, project managers even suggested changing planning methodologies as a solution.

Imposed Date – Information on project management theory on working with imposed date constraints is rather sparse overall, though these are constraints frequently observed in practice. PMBOK[®]-based and Agile methods do not explicitly address how to work with an

imposed date, and Critical Chain simply recommends the use of a constraint buffer and monitoring the consumption of the buffer. It is perhaps for the imposed date project scheduling constraint where the practitioner input is most valuable. Solutions offered by project managers centered on facilitation, behavioral and soft skills, where communicating with the project sponsor, customer and others is necessary. By having an imposed date, the project manager needs to ask questions, assess the scope, understand requirements and business needs and work with others to accomplish project goals, which could involve a reduction in scope. These are activities that practitioners describe clearly, but are not present in the theory.

Best Practices Assessment

While comparing project scheduling theory to practice is a fairly straightforward process, it comes to pass that in the course of our study we aim to find the best ways to work with project scheduling constraints. To assess best practices, we first need to determine the criteria for comparing ideas and develop a framework for our assessment. Thus, it follows that we:

- **Review methodology and reference point for the idea** – We need to be open-minded toward shifts in paradigm, where what works under the guidance of one methodology may not in another due to background, culture and mindset of the project manager and project team. First and foremost, we need to examine how we approach and think about the problem constraint before we go forward with deriving the solution.
- **Examine the frequency in which the idea appears** – If a particular idea for overcoming a project constraint is recommended by multiple methodologies or by

multiple practitioners, thereby demonstrating convergence, then it is a reasonable assumption towards a best practice.

- **Examine historical success or failure of the method and experiences of using the method** – Are there case studies in which the idea was implemented? If there is evidence of implementation application of a particular solution, this lends further credence towards its likelihood of future success.
- **Assess application for the method** (breadth of project size/industry/organizational culture, etc.) – There are many factors leading to evaluating the potential success of a solution. For example, an ideal solution for a large manufacturing organization may not be the best for a small software company.

Key Resource Availability - From the framework above, one may quickly observe that the PMBOK[®]-based methods and Critical Chain approach key resource availability constraints in a similar manner, focusing on the key resources impacting the critical path or Critical Chain. This is consistent with practitioner responses as well. Therefore we can assess that careful monitoring of a project's critical path activities is an important part of managing a key resource availability constraint. However, the organizational issues brought forth by practitioners, such as managing staffing plans and considering outsourcing, cannot be ignored and must be considered in context to a specific project and specific application. This need for customization for applying methods for the resource constraint is also perhaps why Agile methods do not align with other methods; the progressive elaboration in Agile is like extreme rolling-wave planning, where plans are tailored specifically to the needs and constraints at the time.

There is a wide body of existing project management research into the topic of resource constraints, and this analysis of best practices would be incomplete if not for a brief examination

of existing literature and methods. Research into resource constraints has led to the development of a number of software tools and models. These tools are largely statistical and mathematical-based, where developed algorithms attempt to optimize the project schedule solution based on a number of constrained inputs. Researchers have approached the development of computer models using exact, heuristic and meta-heuristic methodologies (Zhang, Li and Tam 2006). However, despite all this research, Herroelen found that there is little interest by practitioners in this area; indeed this was confirmed by little mention of optimizing tools by workshop participants in our study. This is perhaps due to the needs expressed by practitioners of having to consider organizational and behavioral issues in managing resource constraints.

Activity Duration – Activity duration constraint methods are another area in which a convergence between PMBOK[®]-based methods, Critical Chain and practitioner input can be observed, where PERT and the use of project buffers occur during activity duration estimation, along with assessments of risk for each activity. The volume of responses from practitioners is an indication of their experiences in this area, and presumably their successes using the methods recommended. Thus, by comparing the data available, it appears that activity duration constraints are best addressed by improving estimation methods. Such improvements can be done by using a variety of techniques, such as pushing estimation down to the project team level as in Agile, expert review or peer review. Per the suggestions by workshop participants, overall estimation can be improved by facilitating relationships with stakeholders and improving communication.

Logical Order – Analysis of the network of activities is a reasonable method in working with logical order constraints; this was advocated by PMBOK[®]-based methods and the practitioners. Beyond examination of task dependencies and perhaps eliminating non-concurrent

activities as in Critical Chain, however, exact methods for managing the logical order constraint are few. Practitioners offered some suggestions to understand the dependencies and perhaps split or create new tasks or monitor tasks, but other methods were behavioral, for example working with management on the constraint. This presents a challenge when analyzing the best practices for the logical order constraint, and therefore we sought to examine this constraint further.

Going back to the first step in our framework, where we are examining our frame of reference and paradigms, we need to consider the differences in how PMBOK[®]-based methods and Critical Chain approach the logical order constraint. Agile for now is ignored as its paradigm is completely divergent from the other two. Recall that PMBOK[®]-based methods utilize CPM, and the schedule constraint from CPM will be derived from the critical path. Project managers can improve upon the constraint by using such time-saving mechanisms as adding resources and crashing the schedule, while not changing the logical order of tasks. Likewise Critical Chain begins with identifying the key bottlenecks, which will drive the Critical Chain, in the schedule. Efforts should then be taken to reduce the constraint as much as possible through the use of buffers, but again the logical order of tasks does not necessarily change. In many cases, these two methods yield the same answer for managing the logical order constraint, where we must examine the dependencies in more detail as well as the network in a holistic sense (Trietsch 2005). This lends itself back to more behaviorally-based approaches such as working with the project sponsor on alternative tasks or methods as proposed by the practitioners in our study. This is inherent in Agile, with its iterative approach, customer involvement and focus on working prototypes.

Imposed Date - As noted in the previous section, most of our input on methods to managed imposed date constraints comes from practitioner input, where the project manager

should understand the business reasons for the imposed date and try to work with key stakeholders and the project sponsor on a solution. Working with the imposed date constraint is heavily dependent on the project manager's communication and facilitation skills, where he/she must determine with the sponsor firm business requirements, create an ideal schedule for the project and negotiate scope tradeoffs. By fostering good relationships with the sponsor, this can pay dividends in working with the constraint, where the sponsor can champion the project and work with upper levels of management if he/she needs to (Turk 2005).

Summary and Conclusions

Meeting the project schedule is critical to the success of the project, and it is no surprise that there are many challenges that can impede a project manager from meeting the schedule. In this analysis, we have described the four types of constraints on a project's schedule, how three different project management methodologies work with these constraints and how surveyed practitioners work with these constraints. We compared the theory to practice, and found that many of the solutions offered by the theory line up to real-world application. However, we also noted that the methodology did not offer solutions that were more facilitative in nature, whereas the practitioners provided behaviorally and organizationally-oriented ideas for working with constraints as well as process-oriented ideas.

By comparing theory to practice, we noted that as many solutions converged, it can be concluded that in dealing with project scheduling constraints, best practices, regardless of what methodology a solution is associated with, dominates. This seems to be a practical conclusion, and one in which project managers use the best methods available, rather than focusing on an exact procedure prescribed by a methodology. A similar conclusion about using best practices

and solutions was reached by Herroelen when studying the use of project management software in his 2005 study. In this context, we reviewed other methods and ideas for working with constraints in a study of best practices.

This analysis focused on project scheduling constraints upon the single project. However, as noted by the practitioner participants in the workshop, at any one time there are multiple projects occurring in an organization. Additional research is needed to examine project scheduling constraints in a multiple project environment, where project managers and portfolio managers must decide how to work with prioritizing projects, requirements and balancing resources across the organization. Using this research and research methodology as a basis, one may analyze portfolio management theory, follow-up with a survey to practitioners and compare results. In addition, further research into ideas and solutions to project constraints, such as alternate groupings of ideas by senior project management experts or further research into best practices, can be performed. Lastly, as the popularity of alternative methodologies for project management grows, an examination of how those methodologies work with constraints is also a worthy effort.

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