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Effective project planning: Making the most of project planning tools

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ABSTRACT

Although project planning tools such as Microsoft Project and Primavera have become indispensable tools for supporting the project planning process in a wide variety of industries and organizations, many companies do not use these tools in the best possible way, resulting in disappointment and frustration as well as a lack of effective project management support. In this article, we propose several guidelines on what to do,

INTRODUCTION

Organizations in various industries are increasingly keen on projects as the way to organize their work. In recent years, more industrial, commercial, and governmental organizations have used project management to achieve their objectives. Membership in various international project management associations is growing exponentially (the Project Management Institute—www.pmi.org—reports a membership base of more than half a million), postgraduate programs in project management are appearing everywhere, and Microsoft (Microsoft 2010) recently said it has more than 20 million users worldwide of its project management software (see sidebar "Growth of Project Management Certification" on page 11). This growing maturity of project management, however, does not seem to be reflected in a growing success rate. Delivering a project on time, within budget, and to the client's satisfaction still seems to be notoriously difficult. The root cause for many of these failures can often be traced back to the project planning phase.

Although most project managers say planning is absolutely essential to generate project success, the project planning process in many organizations leaves a lot to be desired. A multitude of tools are available for assisting in this planning process. Still, claims such as "planning is a waste of time" or "project planning tool X is useless" are common among organizations. Although most project managers would agree that planning is crucial, many also feel that planning is a cumbersome task with limited benefits. After all, as soon as a project plan is completed, it is outdated. And the frequent changes that occur in every project make updating the plan a chore rather than an activity that yields insights or provides decision support.

Often, the issue underlying these sentiments is a misunderstanding of what project planning is supposed to accomplish. If one looks at project planning as an activity designed specifically to produce a plan that predicts exactly what will happen during project execution (in other words, predict who will do what and when), the planning task is misdirected. Since projects are subject to variability, establishing only who/when estimates may cause us to "go through the motions" to create plans, but without believing that what we are doing is useful. In fact, project team members may purposely distort the plan to disguise the fact that they believe whatever they outline may not happen at all. This results in padded activity durations and increasing vagueness and uncertainty. Who/when estimates are a necessary component of a good plan, but not the ultimate goal. The goal of project planning is to increase understanding of the project, highlight potential problems and enable organizations to focus on the most important issues, rather than setting out exactly what will happen.

As Brooks (1995) writes in *The Mythical Man-*

Growth of Project Management Certification
By James H. Patterson

Not only has there been rapid growth in the popularity of project management procedures overall, but as recently reported in the *Wall Street Journal* (Middleton, 2010) there is also widespread growth in project management certification, as the Project Management Institute (PMI) has experienced a 30 percent growth in its awarding of various project management certificates. Firms and their clients are increasingly demanding proof that project managers and participants meet industrywide standards of performance and excellence. Certification boosts public, private, and client trust. NASA's deeply technical missions, for example, require leaders who are not only technically savvy, but who also can balance budgets and launch schedules and stay on track. If a project is deemed too costly or late, it can delay a mission for months. Many companies will only consider new hires for project manager positions or advancing current employees if they have proper project management training and certification, again contributing to the widespread use of project management for accomplishing desired objectives.

Month, the development of a plan, rather than the plan itself, is what is actually useful. Also, the project plan itself should be a managerial decision support tool, not just an action plan. It should support decisions such as prioritization, trade-offs between different objectives, and resource allocation. But to achieve these benefits, a project plan has to be designed in a way that creates insight, provides clarity, enables focusing, and facilitates decision making. This requires discipline, a systematic approach, and in-depth knowledge of how to use project planning tools.

A TYPICAL PROJECT

A few years ago, a major aerospace company embarked on one of its biggest projects ever, a major contract of an international program to develop a major new airplane. A new division was set up especially for this project, and plans were drawn for four major subprojects. Three project managers were assigned, each handling one or two subprojects, and the newly appointed vice president of the division acted as the program manager, overseeing all four subprojects.

Two weeks before the program was planned to start, the program manager began to feel anxious, and asked the project managers whether everything was set to go, and whether they had a grip on potential issues and how to deal with them. At this point, the project managers had developed detailed plans for their subprojects, and sent these to the program manager. The plans contained several thousand activities, with details on their duration, cost, and people assigned to carry out the tasks. The delivery dates in the plans were more or less in line with overall program deadlines. What was lacking, though, was confidence that the plans accurately reflected what would actually happen. When the program manager asked the question, "Do you think we will be able to pull this off?", he did not get any response.

When examining the plans, I was impressed by the level of detail and the abundance of technical information. But after a second, more in-depth look, I noticed something interesting: The plan did not show the project's critical path. Apparently, the project managers realized this, but had no idea why a critical path did not appear. This was rather disturbing, because without knowing what the critical path is, how do you know what to focus on and prioritize? How can you be sure that you can meet deadlines? How can you assess risks?

I quickly discovered that the plans were designed to be a registry of tasks, a schedule to initiate work. They were not designed to ensure the project scope was complete, that the links between tasks would be properly managed, or that critical tasks could be identified. As a result, the plans were not deemed credible, and planning was seen as cumbersome and bureaucratic, without much benefit.

This story is not an isolated one. Over the last 10 years, I have worked with various companies on pharmaceutical projects, oil and gas projects, IT projects, and other aerospace projects where project managers often struggle with exactly the same issues. In this article, we will review some of these

Brainstorming Approaches for Building a Better Work Breakdown Structure
By Nancy Lea Hyer and Karen Brown

Often, project leaders and teams begin the planning process with a schedule, omitting the important definitional work that should precede sequencing discussions. Consequently, their project plans are not sufficiently comprehensive. As the project unfolds, they find themselves continuously surprised by their omissions and oversights. We have discovered, and applied with several hundred teams, a tool known as mind mapping that supports effective team brainstorming about work breakdown structure content.

Mind mapping is an approach to work breakdown structure development in which team members work together to answer the question, "What are all of the things we need to do to complete this project?" The process begins with the project name and a representative symbol in the center of a large sheet of unlined paper that has been posted on the wall. The team brainstorms the high-level deliverables representing major project components, and records each as a separate branch emanating from the central node. The team next brainstorms lower-level activities that will be required for each high-level deliverable. At this stage, team members work in parallel to add detailed activities to the map using a branching format, color, key words, and symbols. Mind mapping engages the team, can generate enthusiasm and commitment to the project, encourages the team to think expansively about the project's activities, gives all team members (including those who are less vocal) an opportunity to contribute, and is fast. While some individuals may resist this sometimes nontraditional, nonlinear approach, project teams that try mind mapping typically find it very powerful. It also offers a solid foundation for the risk assessment and scheduling decisions that follow work breakdown structure development.

recurring issues and how to deal with them, so organizations can transform the project planning task from a sometimes pointless, time-consuming activity into an effective decision support tool.

PROJECT SCOPE

A recent study of more than 1,400 failed IT projects revealed that more than 50 percent of the failures were due to a poor definition of project scope (IT Priorities 2005). Typical issues include incomplete scope, tacit disagreements concerning the project's scope (either internally or with clients) that do not surface until the project is well underway, and scope creep.

Using project planning tools, a project is often scoped using Gantt charts, a process in which tasks are entered one by one, with details on their duration, cost, people assigned, and resources required. Several indented levels can be used to indicate a hierarchy. This, unfortunately, is the main reason why things go wrong. Before any plans are developed, one has to ensure that the scope of the project is complete and agreed upon by all stakeholders. Entering tasks in a Gantt chart typically results in a large number of missing tasks and a lack of review by others because of its complexity.

A better approach is to use a team-based, visual tool to scope out a project, using a work breakdown structure in concert with mind mapping tools (see sidebar "Brainstorming Approaches for Building a Better Work Breakdown Structure" on page 12). By focusing on defining the scope in terms of which tasks have to be performed, rather than being concerned with details concerning when the tasks will be performed, fewer tasks will be omitted. Also, the visual nature of the tools makes spotting omissions easier, and enables better sharing of the scope document with others, including clients. And because these tools can interface with project planning tools, there is no duplication of work, as the scope can be transferred immediately. The tools can also be used when a (partial) scope has already been developed as a project planning tool, by automatically generating a visual work breakdown structure. Also, although projects are, by nature, unique, the work breakdown structure is one of the few pieces of work that can be reused for future projects, perhaps in the form of a template.

An example of a team-developed work breakdown structure is given in Figure 1, for the design and development of a component (circuit) for a major aerospace project.

In the aerospace project mentioned earlier, a few days after I generated a visual work breakdown structure (based on our meetings and earlier discussions) and sent it for editing and review to each project manager, I received updated project plans with hundreds of newly identified tasks. Proceeding to the detailed planning stage—or even worse, to project execution—without properly identifying these tasks would have been disastrous.

TIME PLANNING CHALLENGES

The ultimate goal of constructing a project timeline is to determine whether project deadlines can be met, and if not, which actions can be taken to remedy this. Doing so requires identifying milestones in the project that relate to the deliverables attached to these deadlines, and the critical path or critical sequence leading to each of these milestones. (The critical path also takes into account resource restrictions—see sidebar "Critical Sequence" on page 14.) Obtaining this information, however, requires a disciplined approach when constructing a project timeline.

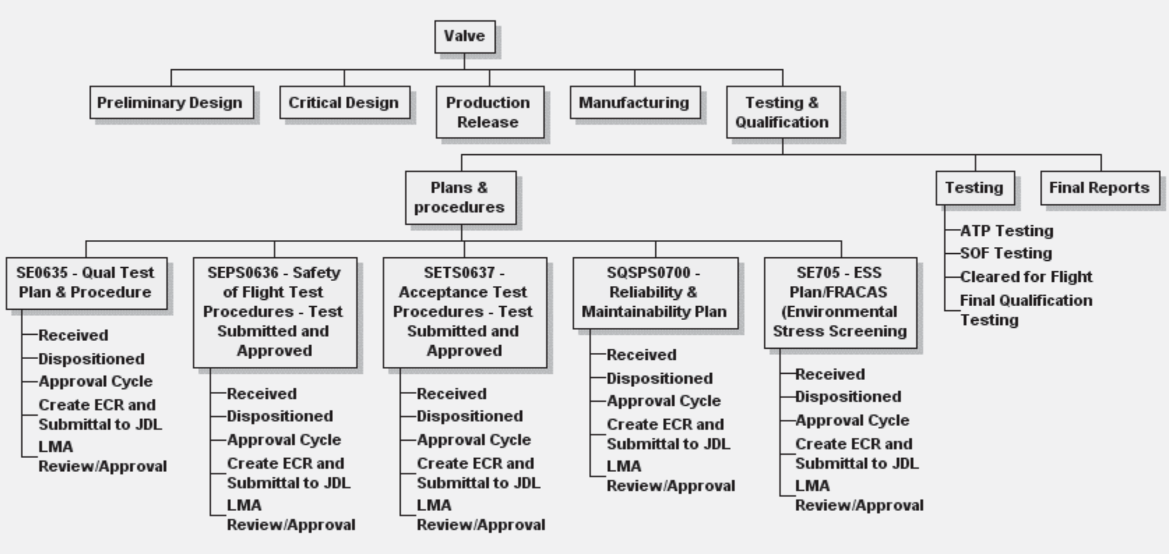
After the scope has been defined and the activities identified, the second step is to identify linkages—the dependencies between the tasks, also sometimes referred to as "precedence relations." This is a crucial step in the project planning process because it will determine milestone delivery dates and which activities are critical. Unfortunately, in my experience, the vast majority of plans do not correctly identify milestone dates or critical path(s).

Here are common practices that work against the benefits of proper planning:

- setting fixed activity start dates
- omitting dependencies between tasks
- improper use of overlapping dependencies
- linking "summary tasks"
- defining activity durations based on their work content
- defining activities with excessive durations
- incorrect specification of project milestones
- incorrect integration of subprojects within a master plan

Many practices identified above result from the user-friendliness of project planning tools, which gives the user a high degree of freedom when outlining a project, making it possible to achieve the same result in many different ways. The problem, however, is that freedom eliminates the need for

FIGURE 1: WORK BREAKDOWN STRUCTURE



A work breakdown structure provides a visual overview of the tasks required to complete the project. In this example, only a few work packages are fully expanded to the task level.

Critical Sequence
By Willy Herroelen and Erik Demeulemeester

The critical path is the longest time sequence or path of activities through the project network. (there may be more than one such path). Each activity on such a path is said to be critical. The length of the critical path determines the minimum time needed to complete the project. When determining the critical path, only the activity durations and their dependencies or precedence relations are taken into account; resource (capacity) restrictions are not considered. The activities on the critical path have to be executed in series because the technological precedence relations force them to do so. Activities, however, not only take time, but also need resources. As a result, activities may be forced to be performed sequentially (rather than in parallel—often permitted by technological-only requirements) because the limited resource capacity does not allow them to be executed simultaneously. The critical sequence is the longest sequence of activities which have to be executed in series forced by the precedence and the resource restrictions (constraints). (Again, there may be more than one critical sequence). A critical sequence is sometimes referred to as a critical chain.

a systematic, disciplined approach to project planning, which is essential for ensuring that the resulting plan meets the designed needs. Therefore, the best way to avoid typical pitfalls when planning a project is to know what not to do and to know the proper sequence for planning a project.

Fixed Activity Start Dates

Fixing activity start dates is often done to enforce dependencies between tasks—to ensure that a task does not start before a preceding task is finished. Although this appears to do the trick, the practice results in two major problems: (1) modifying the plan results in incorrect activity start times, namely when the preceeding activity is moved without also moving the next activity, and (2) the critical path will not be correctly identified. Although some planners do not consciously set fixed activity start dates, they sometimes "drag" activities in the Gantt chart, which has the same result. In Microsoft Project, the "indicator" column is useful for detecting which activities have been assigned fixed start times. Ideally, this column should remain empty unless there is a good reason for a fixed date to be assigned (for instance, when a date is set for a supplier to make a delivery, or when one knows a key, temporarily assigned resource such as a movable crane is available to the project). But even in those cases, it is good practice to create a milestone and assign the fixed start date to the milestone, rather than assign it to a task.

Missing Task Dependencies

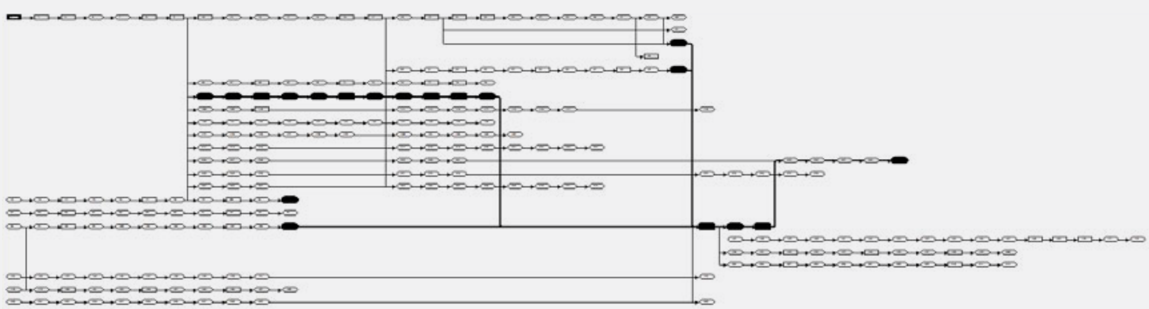
Although project planning tools allow many different ways of linking activities, they do not force the user to define predecessor and successor activities for every task in a project. As a result, large numbers of activities are often not linked to either a preceding or a succeeding task. One could ask that if an activity does not have a successor, then why does this activity have to be done at all? Most of the time, this indicates a missing link. Ideally, every activity should be linked to at least one preceding task or milestone and one succeeding task or milestone, with a milestone used to denote the start and finish of the project. Obviously, the start milestone does not have a predecessor activity or task, and the finish milestone does not have a successor activity or task. These are two important exceptions in a project. The best way to check for missing links is to use the network diagram view available in project management software. Although some planners find it awkward to look at a network diagram for a large project, by zooming out[1] you can easily identify tasks without predecessors or successors and the overall structure of the project. Ideally, the network should start with one milestone and finish with one milestone, with every activity linked to at least one predecessor and one successor activity or milestone. This will ensure that a critical path is correctly identified. Once such a critical path is identified, it should also be examined to see

[1] In Microsoft Project, right-clicking the network diagram and selecting "Hide Fields" provides a useful visual overview of the activities and their dependencies.

whether the critical path makes sense intuitively, by discussing it with the project manager and team members. This process will typically result in several more missing dependencies being identified. An example is given in Figures 2 and 3, with the original network diagram for one of the components (circuits) in the aerospace project in Figure 2, and the modified version in Figure 3.

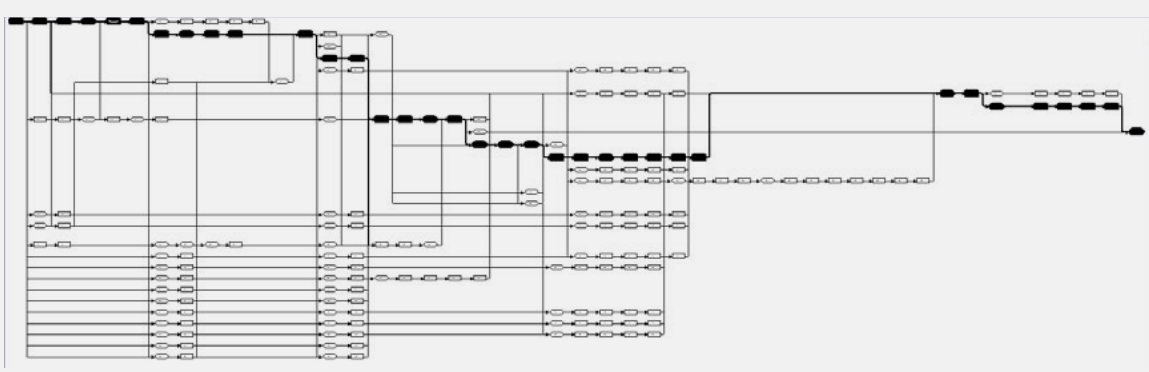
In my experience, in most project plans, many dependencies are not correctly identified. Typically, the reason is not that they were not known, but rather that dependencies are added to the plan only when the Gantt chart shows an activity scheduled to start before the completion of a predecessor. Tasks that are already in the correct sequence are sometimes not linked, because either it is not deemed necessary or because adding dependencies did not result in the link being spotted. The problem with this approach is that as changes are made to the plan, either during its development or during project execution, tasks move across the timeline, resulting in potential infeasibilities. Therefore, a better way to identify links is to ignore the Gantt chart altogether at this stage, and examine the list of tasks, the work breakdown structure, and the network diagram. In my experience, a low-tech approach such as using sticky notes is the best way to accomplish this; only when team members completely understand and agree on the tasks and their dependencies should anything be put into a planning software tool. A similar approach is advocated by Brown and Hyer (2010) and Wysocki (2009).

FIGURE 2: NETWORK DIAGRAM



The network diagram is a great tool for spotting missing links. All tasks with the exception of the start and completion milestones should be connected to at least one preceding and one succeeding task or milestone. If not, the plan will not provide any insight, and will incorrectly identify activities as critical (in bold).

FIGURE 3: IDENTIFYING THE CRITICAL PATH



When all activity dependencies are correctly identified, the correct critical path (in bold) will be identified, running from the start to the finish milestone.

Improper Use of Overlapping or Lagged Dependencies

The frequent use of generalized dependencies is also an area of concern. Most project planning tools permit specifying time lags between activities or possible overlaps, using start-start, start-finish, finish-start, and finish-finish constraints. Such dependencies are complex and often result in errors. One such example in the aerospace plan was the following situation: Three tasks are linked. Task A is due 20 days after task B, and task C is due 20 days before task B. The following dependencies were defined: a finish-finish dependency between activity B and A with a lag of 20 days, and a finish-start dependency between activity C and B with a lag of 20 days as well. Although the finish-start dependency between activity C and B was correct, the first one specified that task A could not finish sooner than 20 days after task B was completed, instead of should not finish later. The correct dependency would be a finish-finish link between A and B with a lag of minus 20 days! Such negative time lags, however, are counterintuitive. The general advice is to avoid using such dependencies whenever possible, especially dependencies with a negative time lag. In my opinion, the "regular" dependencies (finish-start links) should be used whenever possible, possibly enhanced with a few start-start links, although these should be used with caution and only when a regular link does not work. Incorrect specification of dependencies will result in potential conflicts and—more importantly—an incorrect critical path. Also, one should not try to model such dependencies using fixed activity start times.

Linking Summary Tasks

Another area of concern is the flexibility in project planning tools, which allow planners to define dependencies not only between tasks, but also between so-called summary tasks in a work breakdown structure. When a so-called "waterfall approach" is used to plan a project, links between summary tasks representing each phase are often used to create the waterfall schedule. Although this can be a simple way to define different phases in a project, it is not advisable to use this option for three key reasons: (1) it can cause team members to overlook across-phase dependencies, (2) it can result in the critical path not being clearly defined, and (3) it may result in lost opportunities for overlapping phases when only some (but not all) activities of a phase need to be completed before activities of a next phase can be initiated. In the aerospace project, there were many such links. A critical assessment of these dependencies highlighted that several important interphase links were omitted, and that phases could be overlapped substantially by investigating in detail which tasks required information or other input from certain tasks in the preceding phase.

Defining Activity Durations Based on Their Work Content

Project planning tools also allow defining work content for a task, next to its expected duration. The work content, typically expressed as person-days, can be used to automatically compute the activity's duration based on an available number of resources. This practice is dangerous, however. It is not because an activity requires only four person-hours that it will be performed in half a day. The difference lies in the distinction between the work required for a task and its calendar time, also referred to as elapsed time (or sometimes lead time), which is typically much longer. Instead of defining duration in terms of work required, one should think of a realistic lead time for an activity to be turned around. In the aerospace plan, I noticed several activities that were planned with a duration of 15 minutes, since that was the time estimated to be required to do the work (essentially the time estimated for someone to quickly review and sign off a document). But it is unrealistic to assume that the next team will receive the result of this activity 15 minutes later; in fact, it might take a day or more.

Excessive Activity Durations

The opposite problem is excessive activity durations (see sidebar "Estimating Activity Durations" on page 17). The presence of activities in a project plan with long durations typically indicates that the activities should be broken down further into components. People tend to be more accurate when providing duration and cost estimates when

Estimating Activity Durations
By Wendell P. Simpson

Task duration estimation should take into account how the schedule is being used. If project control will be accomplished by establishing task-level due dates and driving accountability for hitting those task due dates, then estimates should include allowances for the interruptions and multitasking present in the environment. Professor De Reyck is correct: Setting task due dates 15 minutes apart in this situation is unrealistic.

One downside is that padded task times tend to be self-fulfilling. By increasing duration from 15 minutes to say, one day, my experience is that few if any of these 15 minute tasks will ever take less than a day. Work tends to expand to the time allocated.

If completing the project as quickly as possible is important, then you want to avoid these self-fulfilling padded task times, especially when they are on the longest path. A critical chain schedule like the one Professor De Reyck describes later in this paper is a way to avoid the dilemma presented by padded task times. Instead of increasing the task duration from 15 minutes to one day, the tasks are left at 15 minutes, but a buffer is added at the end of the chain to account for disruptions. So the task time remains optimistic, but the overall project duration is realistic. For this to work, enforcing task due dates cannot be the primary mechanism for project control.

they estimate smaller portions of a task. Also, excessively long activities prevent effective monitoring of progress during the task's execution. Long activities in a plan can also point to another problem: Projects often include ongoing activities that include tasks that are regularly repeated. Although such activities could be defined as long, continuous tasks, this will hide the real critical activities that are performed simultaneously. Ideally, such tasks should be removed from the plan, as they are not project activities but rather processes for which project planning tools are not designed. Ideally, activity durations should not exceed one month for major, multiyear projects or two weeks for shorter projects. In very small projects that take only a few weeks, activity durations should probably not exceed a few days.

Incorrect Specification of Project Milestones

Milestones are a useful tool to highlight phases in a project, and they can also be used for project monitoring and tracking. But it is advisable to define only milestones associated with deliverables— activities that need to be delivered on time, by agreed-upon due dates. Otherwise, there might be a proliferation of milestones, resulting in the important deliverable-related ones being swallowed up. In the aerospace project, several milestones were of the type "end of design phase," and those milestones were not important when monitoring whether the project was on time. More important were milestones such as "test flight" or "documentation submitted to regulatory bodies," as these milestones had to be carefully monitored.

When using deliverable-related milestones, it is useful to know which activities are critical with respect to each deliverable. This requires the identification of multiple critical paths, one for each milestone, and can be done in project planning tools by showing multiple critical paths. For instance, in Microsoft Project, this option can be found in the "Calculation" options. If this option is selected, then every task or milestone without successors will generate a critical path. Therefore, a planner needs to define only deliverable-related milestones as milestones without successors.

Incorrect Integration of Subprojects within a Master Plan

Often, projects are a part of a program, where the program contains the deliverables. In this case, it is not useful to know which activities are critical in each subproject, but rather which activities are critical with respect to the program milestones. Unless the different projects are correctly integrated into a master program, these critical activities will not be correctly identified. Project planning tools allow for different project files to be uploaded into a program file, with activity links running between the different subprojects. When every task in every subproject is properly linked to one milestone in the program file, the correct program-critical path will be identified.

RISK ANALYSIS

Most projects are inherently risky ventures. Therefore, an essential ingredient of planning is an analysis of these risks, together with an action plan of how unacceptable risks can be mitigated. Unfortunately, risk analysis is rarely given the attention it deserves, as project managers are constantly pushed to "get on with it," which gives rise to the mentality of "let's cross that bridge when we come to it." This type of thinking is a major mistake, as any time spent on managing risks before the project starts is repaid tenfold during project execution, as less time is required to resolve problems. Project risks can never be eliminated, but planners can take actions to reduce the likelihood of risks materializing or to mitigate their impact if they do.

Qualitative Risk Analysis

Dealing with project risks essentially contains three components: identifying risks, assessing their severity, and managing them. Risk identification is the responsibility of everyone participating in a project, including senior managers, the project sponsor and project manager, team leaders and members, client representatives, and other stakeholders (see sidebar "Brainstorming Project Risk" on page 18). By identifying risks beforehand, organizations can remove the factor of surprise, making dealing with the consequences more effective and efficient. Useful tools for risk identification include brainstorming sessions, industry checklists, post-mortem reports of previous projects, expert analysis, and careful analysis of all assumptions in the project plan. The result of the risk identification phase is typically captured in a risk register, containing a detailed description of identified risks.

In most projects, risks are so numerous that they cannot (and should not) all be managed with the same rigor. In the risk assessment phase, identified risks are classified according to their severity, which is comprised of (1) their likelihood of occurrence, and (2) their impact in case they do materialize. The purpose of this assessment is to prioritize them. The framework in Figure 4, referred to as a likelihood-impact matrix, provides a guideline on how to focus your efforts, by distinguishing between extreme (E), high (H), medium (M) and low (L) risks. The result is a prioritized risk register.

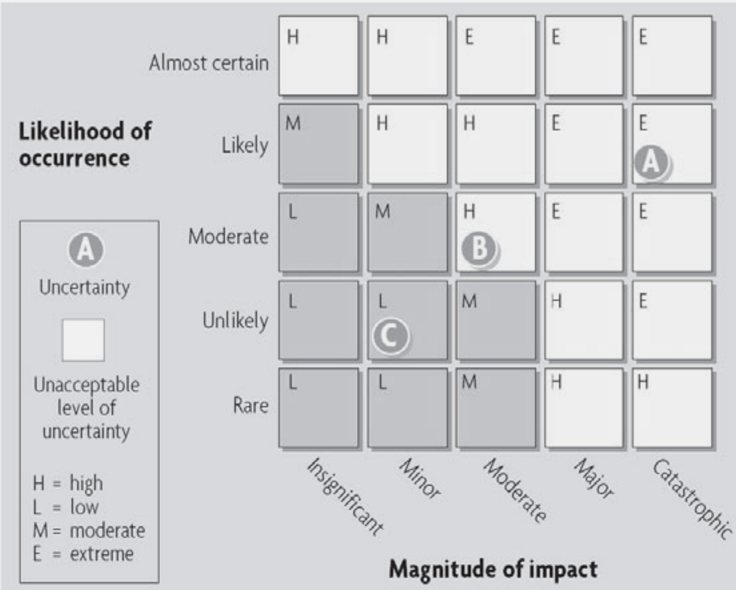
Brainstorming Project Risk
By Nancy Lea Hyer and Karen Brown

Some project leaders overlook the importance of inviting and facilitating input about risks from team members and critical stakeholders early in the project. Often, the leader is enthusiastic about the project and does not want to "rain on the parade." But those who have been involved in developing the project plan, along with those whose lives will be affected by it, can offer useful insights about potential surprises that could derail the project on its way to achieving its goals. A tool we have adapted from La Brosse (2001) has proven especially useful for engaging a team in a discussion about project risks.

In this method, a facilitator, writes the name of each major deliverable on the wall and instructs team members to work individually to think of as many risks as they can for each deliverable. After five to ten minutes, everyone gathers around the wall and affixes their notes to the associated deliverable. After similar risks are combined, members work individually again to affix colored dots expressing their opinions about the likelihood and impact of each risk on each deliverable. The team then discusses which risks are deserving of preparation, and place them into a likelihood-impact matrix such as the one shown in Figure 4. For the risks falling into the A and B categories in Figure 4, the team develops a prioritized risk register such as the one shown in Figure 5.

Benefits of this method include (1) using the power of the team to uncover potential project derailers while there is still time to plan for them, (2) offering an opportunity to revise the work breakdown structure to account for risks before the team moves to the scheduling stage, and (3) providing an opportunity for concerned stakeholders to have a voice.

FIGURE 4: LIKELIHOOD-IMPACT MATRIX



In a likelihood-impact matrix, identified risks (examples labeled A, B, and C) are categorized depending on their expected impact and likelihood of occurrence, enabling prioritization of risk mitigation efforts. In this example, risk A, an extreme risk, has highest priority, followed by B (a high risk) and finally C (a low risk).

In the risk management phase, action is taken to prevent or mitigate risks. These actions can include contingency plans, risk avoidance plans, risk mitigation measures, risk transference, or risk acceptance. Contingency plans do not tackle a risk directly, but provide ready-to-implement plans to mitigate risks in case they occur. Risk avoidance implies taking a different route altogether that does not have the same level of risk. Risk mitigation measures can reduce the likelihood of a risk materializing, or minimize the impact of a risk if it occurs, or both. An example of reducing the likelihood is prototyping, where major issues can be identified while developing a scaled-down version of the product or service. An example of minimizing the impact is a backup system that kicks in when a developed system is not yet operational.

To illustrate, when the city of Denver was building a new multibillion-dollar international airport, technical problems repeatedly pushed back its opening date, resulting in a 16-month delay and a cost overrun of more than $2 billion, almost bankrupting the city. The delays were mainly caused by a malfunctioning state-of-the-art baggage handling system. A backup system, costing around $10 million, could have prevented these delays and cost overruns. Unfortunately, the city of Denver decided to implement a backup system only six months after the planned opening date. Interestingly, similar problems plagued London Heathrow's new Terminal 5 when it opened in 2008 with a high-tech automated baggage system.

The final deliverable of the risk analysis process is a prioritized risk register with assigned responsibilities and action plans. An example such a risk register for the design and manufacture of wheel and brakes for a new major airplane is shown in Figure 5.

Quantitative Risk Analysis

The qualitative analysis above can be complemented with a quantitative risk assessment of the time and cost objectives as follows. To ensure on-time completion, the first step is to assess the potential impact of delays. To accomplish this, a best-case and worst-case duration estimate for each activity is determined, next to a most likely duration. This enables planners to investigate the worst-case outcome, which gives a first, rough-cut idea of the problem's potential scale. In the second step, likelihood assessment, the likelihood of meeting the proposed deadline is assessed. This can be accomplished by specifying a distribution, such as the triangular distribution, which specifies that the duration of an activity can be anything between its best-case and worst-case estimates but probably

FIGURE 5: PRIORITIZED RISK REGISTER

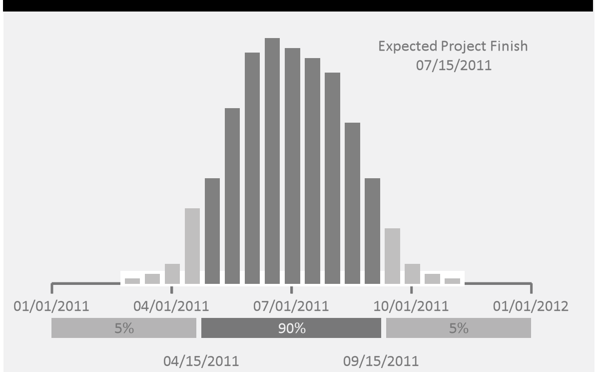
Risk	Severity	Area	Type	Likelihood	Impact	Risk Mitigation Plan
1	Extreme	Lead time on major plant and equipment items	Schedule	4	4	Close dedicated management of suppliers using U.S. Division previous suppliers or dual sourcing where possible. Installation and commissioning will be a dedicated sub-project with full-time resources and detailed project plans.
2	High	Brake performance shortfall with DMS 669 Carbon	Technical	3	3	Brake system design
3	High	Loose flange wheel: potential problems with increased weight and forging/ quenching	Technical	3	3	Early manufacture of wheels. Develop A frame alternative.
4	High	Thick. Thin rotor/stator configuration: uneven wear	Cost	2	4	Build in adequate clean-up allowance. Develop spreader plate design.
5	High	Excessive wear rate	Cost	2	4	Implement Taxi Select managed wear.
6	High	Process qualification on new site	Technical	2	4	Prebonded sample discs will be provisioned from facility C to allow additional optimization/validation.
7	High	Skilled personnel availability and training	Schedule	2	4	Large local aerospace talent pool. Strategic relocation of key company personnel. Well-defined training methodology.
...	...	...	...	...	...	...
21	Medium	Electronic parts obsolesce	Technical	1	5	Careful obsolescence management. Lifetime buys of obsolescence components. Include contingency for re-design of EMAC in financial model.
22	Medium	Electrical power variability/outage	Schedule	1	5	Implement alternate local/ decentralized power supply in the form of standby generators.
23	Medium	Environmental regulations	Schedule	1	4	ISO 14001 registration. On-site Environmental Coordinator. Facility design from the ground up to include all necessary environmental control methods and machinery.

A prioritized risk register should also include risk action plans.

centered on the most likely duration, with the likelihood varying according to a triangular shape. A simulation analysis can then be performed, examining literally thousands of different scenarios in which durations of the activities vary according to their distribution. Software tools such as @Risk developed by Palisade Corporation or Monte Carlo developed for Primavera can be used for this analysis. Figure 6 displays an example of the result of such a simulation analysis. The project distribution shows an expected project completion date of July 15, 2011, whereas the 90 percent completion date—meaning the organization is 90 percent sure it can meet it the deadline—is September 15, 2011. In other words, we need a three-month project buffer between the expected project completion date and the project deadline to assure a 90 percent likelihood of meeting the September 15 completion date. Note that it is possible that the project takes even longer, with a worst-case observed outcome of January 1, 2012, but this is quite unlikely.

A simulation analysis can also reveal which activities are largely responsible for potential delays. Although the concept of critical activities is extremely useful, and enables the project manager to focus on a limited set of activities in a project instead of scattering his or her focus over the entire project, unexpected events may change which activities are critical. A simulation analysis provides a so-called criticality index, which is the likelihood that an activity will become time critical, based on the number of scenarios in which it was observed to be critical. The criticality indices can then be used to prioritize attention when monitoring activities for possible delays. A simulation analysis can also reveal which activities contribute most to delays. Activities that score highly in this respect are sometimes called crucial activities to distinguish them from critical ones. A tornado diagram is typically used for identifying crucial activities. For example, Figure 7 shows the criticality and cruciality of 16 activities. Criticality is expressed as a percentage or likelihood of becoming critical during project execution; cruciality is shown as a bar with a size proportional to the activity's impact on potential delays. For this project, procuring process equipment is the most crucial activity, although it is not certain that it will be critical, indicated by its 70 percent criticality index. This is due to the large uncertainty of its duration. In other words, if this activity becomes critical, its impact on the project completion date can be significant.

FIGURE 6: PROJECT COMPLETION DISTRIBUTION



A project completion distribution shows the likelihood of completing the project on various dates.

Ranges and Buffers

What makes simulation analysis interesting for analyzing timeline risks is its simplicity. The only required data are ranges for activity durations, rather than single estimates. Although in some organizations this is difficult to obtain, especially when people are used to working in a more traditional project management environment, this should make it easier because in many cases it is hard to predict exactly how long something will take.

But there are pitfalls when estimating activity durations and ranges, namely overconfidence and anchoring. As observed by Kahneman and Tversky (1974), when people are asked to provide a range for an estimate, the likelihood that the actual result is within the range is typically rather small. In other words, most people are overconfident in

Buffer Management
By Wendell P. Simpson

Buffer management is accomplished by weekly updating the status of tasks, then calculating the amount of buffer that has been consumed as a result. Each week, the longest path that is causing buffer consumption is established as the priority tasks for the week.

The percentage of project buffer consumption can be plotted against the percentage of the critical chain completed to assess overall progress. This so-called "fever chart" (Simpson 2010) reflects the health of the project. Consuming the project buffer faster than completing the critical chain can indicate that the planned completion date is in jeopardy. When this exceeds a predetermined threshold, it triggers a buffer recovery exercise for the project team. In this exercise, the team finds ways of modifying the project plan (breaking links, crashing durations, adding resources) that reduces the level of buffer consumption. Effective buffer management enables project teams to finish on time or early.

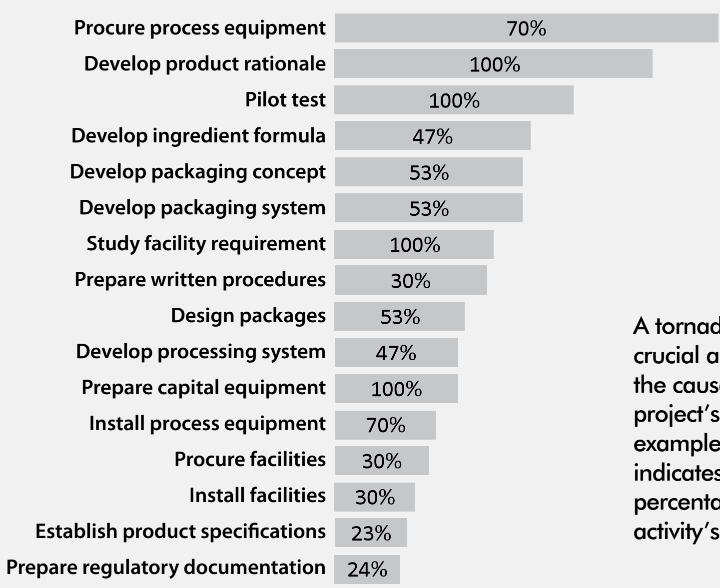
their ability to predict the unknown. Therefore, to implement this methodology successfully, it is crucial that the people participating in the project planning process are either trained in avoiding overconfidence, or that the project managers adjust ranges to account for the inherent overconfidence. Simulation tools can assist with this process by offering distributions that automatically adjust for overconfidence. Anchoring refers to the fact that when people are asked how long something will take (or cost), they typically provide a different answer depending on whether an anchor is included in the question. For example, the question "How long will this activity take?" typically produces a different response than does the question, "Do you think it will be possible to complete this task in one week?" Therefore, anchoring your project team members should be avoided, although this form of questioning could actually be useful in a negotiation setting.

Besides adding a time contingency or buffer at the end of the project between the expected completion date and the deadline, time buffers can also be inserted at specific points in a project's schedule to prevent the impact of an unexpected delay affecting the rest of the project and potentially impacting project delivery (see sidebar "Buffer Management" on page 21). Such buffers could, for instance, be inserted whenever noncritical activities link into critical tasks (in other words, when critical tasks require noncritical work to be completed). In that case, one should ensure that some safety time is inserted between the noncritical task and the critical task that depends on it. These so-called feeding buffers prevent delays in noncritical paths of the project spreading to the critical path. The result is that the project manager can restrict his or her attention to monitoring these feeding buffers. Similarly, the project buffer can be used as a monitoring tool. An example of a project with feeding buffers and a project buffer is given in Figure 8.

Buffer management to prevent project delays is an essential part of critical chain project management, a novel way to manage timeline risks developed by Goldratt (1997). Several tools are available for supporting this process, including Prochain (www.prochain.com) and Concerto (www.realization.com).

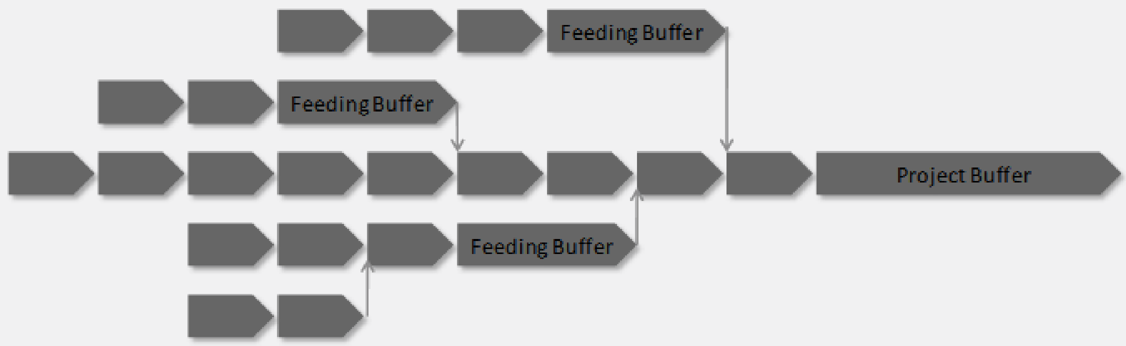
Between 1993 and 2000, the Swedish-Danish Øresund Consortium was responsible for building the world's largest cable-stayed bridge, connecting the Danish capital of Copenhagen with Malmö in

FIGURE 7: TORNADO DIAGRAM



A tornado diagram highlights the crucial activities—those that are the cause of uncertainty in the project's duration or cost. In this example, the magnitude of the box indicates the activity cruciality, the percentage inside the box the activity's criticality index.

FIGURE 8: PROJECT AND FEEDING BUFFERS



Project and feeding buffers protect the deadline and the critical activities from disruptions in the project.

Sweden. Although clearly an engineering marvel, the project especially stands out for the fact that it was completed within budget and five months early. From the beginning, team members worked to identify uncertainties, quantify their probable impact, prioritize risks as the basis for action planning, and establish contingency plans. Focus was set on the opening date, considered the most critical element to project success. Simulation was used to assess and manage timeline risks, with an initial risk analysis performed in 1993 showing that the chances of opening in 2000 were less than 10 percent. Plans were put into place to mitigate major uncertainties, with subsequent risk analyses showing a higher and higher chance of completing on time. After a fourth risk assessment exercise, positive results prompted senior managers to push the opening date forward by five months, which was finally realized when the bridge opened on July 1, 2000. To fully implement risk management, the project required both external consultants (1,200 hours) and internal resources (2,000 hours), but the cost was only a fraction of the benefit of opening a full five months ahead of schedule.

RESOURCES

Undoubtedly, the most frequent reason cited by project managers for project delays is lack of resources. Although some projects are carried out without sufficient resources, a more frequent cause of delays is not the lack of resources, but the lack of proper resource planning. Although most project planning software offers functionalities for planning resource usage, such software can be ineffective when used as an administrative tool rather than as a planning tool. Although software can record in detail who is assigned to work on a specific task, and how many hours each assigned resource is supposed to spend on it, this in itself will not resolve any issues of chronic resource shortage or temporary bottlenecks that could result in a missed deadline. Effective resource planning identifies whether there is a chronic lack of resources, and how many additional resources (and of which type) are required to meet the project deadline.

To achieve the full benefits of resource planning, planners must observe several guidelines. First,

Resource Shortfalls

There can be a chronic shortage of resources, despite the fact that the overall number of person-hours available exceeds the required number. This can be caused by the fact that the activities in a project are subject to dependencies, which means that they sometimes cannot be done at the time when the resources are available, resulting in times in which resources are abundant, and other times where resources are short. This is sometimes not well understood, and is often used as motivation by senior management to deny project managers additional people ("Why are you asking for more resources, because you are not utilizing your people 100 percent anyway?")

when defining resources, one should identify not only which individuals are preliminarily assigned to the task, but also which groups of people have similar skills or expertise. This allows crossfunctional people to work on different tasks, which can be assigned when needed for task execution. Planning without allowing for alternate resource usage removes flexibility that organizations may need during project execution. Second, although it is popular to assign resources by defining the required work content of the task, this is sometimes not advised because it implicitly assumes that, for instance, twice as many people will complete the task twice as fast. This, of course, is almost never the case. Instead, one should determine the lead time for each task, and separately assess the resources required. When resources are added to a task to speed it up, a realistic assessment needs to be done to predict likely time savings resulting from the additional resources.

When a resource analysis shows that there is indeed a shortage of resources, one should first investigate whether this shortage is chronic or not. After all, temporary peaks in resource requirements are normal, and can often be remedied by offloading work to a time when resources are again available. Note that this should not be done by assigning activity fixed start times, but rather by adding a lag, or by adding additional dependencies as a way of postponing the task until sufficient resources are again available to complete the task. If additional dependencies are added, planners should remember these are "soft" links that don't represent a technological necessity for the tasks to be in sequence, but rather a decision made because of resource limitations (a different color or note attached to the link can be used to highlight this).

When offloading work can be done without affecting the project deadline, lack of resources is not problematic. If it is impossible to adhere to the deadline unless additional resources are provided, however, a chronic lack of resources is revealed. Note that there can be a chronic shortage of resources despite the fact that the overall number of person-hours available exceeds the required number (see sidebar "Resource Shortfalls" on page 23). Planners need sufficient quantities of resources available when the resources are required by the project. As the need for different resources changes throughout the life of a project, the need for appropriate resources changes as well. Achieving 100 percent utilization of resources in projects is impossible, and in fact is undesirable!

To determine whether a resource shortage is chronic or not, project planning tools offer functionalities in the form of resource leveling tools. I have observed that resource leveling tools are almost never used by project managers, although they can be extremely useful. Often, steps taken by the software to resolve resource conflicts are not well understood by managers, who are often reluctant to use a procedure they do not understand[2]. But even if managers are reluctant to use a tool that automatically makes changes to a plan they have developed, resource leveling tools can be extremely useful as what-if tools, showing the impact on the deadline if resource conflicts are resolved by offloading work above and beyond the resources' capabilities. Additionally, such software can also be used to determine how many additional resources would enable the project to be delivered on time, and this may be one of the software's most useful functions in effective project planning—anticipating resource problems and solving them before it is too late and a deadline is missed.

There is one caveat, however. Some leveling tools that come with the standard project management software such as Microsoft Project have limited capabilities for estimating the impact of resource limitations on the project duration. They almost always are too pessimistic, in the sense that when a project plan is leveled, the project duration increases by more than it would when resources are more cleverly assigned to tasks. In other words, if a leveling tool increases a project duration from, say, six months to nine months because of limited resources, it may be possible to complete the project in only eight months if resources are assigned to tasks in a better way. Leveling tools are available that do a better job at optimally allocating resources and estimating the project duration, including

2 Some software makes resource smoothing or leveling procedures quite clear; other software is quite difficult to follow, even by someone familiar with other features of the software.

the RESCON tool developed by Herroelen and Demeulemeester (2010), which is referred to in another article in this issue.

SUMMARY

This article has presented an overview of critical issues and approaches that affect the success of managing a project using software tools. To summarize, an effective project planning process should contain the following elements:

- a visual work breakdown structure, developed by a team and reviewed and agreed upon by all key stakeholders
- activity duration estimates based on lead times rather than work content, avoiding excessively long activities
- a network diagram, with all tasks connected to at least one preceding and one succeeding task or milestone, no links between summary tasks, and a critical path from project start to finish
- a project timeline without fixed activity start or finish dates
- a program plan with integrated project plans, containing multiple milestones representing deliverables if appropriate, each with its own critical path
- a qualitative risk analysis based on a likelihood/impact assessment and a quantitative risk analysis based on activity ranges, resulting in the likelihood of meeting the deadline via a simulation analysis, criticality indices and cruciality estimates, and appropriate buffers to protect the deadline and the critical tasks from uncertainty
- a resource analysis, highlighting chronic resource shortages and possible solutions

A project plan containing all the above elements is a powerful tool that can—and typically will—make the difference between project success and failure.

FOR FURTHER READING

Borfitz, D. 2009. Lilly: New operating model will speed tailored therapies to market. *eCliniqua: Innovative Management in Clinical Trials*. www.ecliniqua.com.

Burns, J.M. 1978. *Leadership*. New York, NY. Harper & Row Publishers, Inc.

Collins, J. 2001. *Good to great: Why some companies make the leap…and others don't*. New York, NY. HarperCollins Publishers, Inc.

Covey, S.R. 1989. *The 7 habits of highly effective people: Restoring the character ethic*. New York, NY. Simon & Schuster, Inc.

Herroelen, W. 2007. Generating robust project baseline schedules. *INFORMS Tutorials in Operations Research 2007* (ed. T. Klastorin). Hanover: INFORMS: 124-144.

Herroelen, W. and E. Demeulemeester. 2010. Forensic project management: Avoidance and analysis of project schedule delays. *Production & Inventory Management Journal 46* (2): 44-55.

Herroelen, W. and R. Leus. 2005. Project scheduling under uncertainty – survey and research potentials. *European Journal of Operational Research* 165 (2): 289-306.

Newbold, R.C. 2008, *The billion dollar solution: Secrets of ProChain project management*. Lake Ridge, VA. ProChain Solutions, Inc.

Van De Voner, S. E. Demeulemeester and W. Herroelen. 2008. Proactive heuristic procedures for robust project scheduling: An experimental analysis. *European Journal of Operational Research* 189 (3): 723-733.

REFERENCES

Brooks, F.P. 1995. *The mythical man-month: Essays on software engineering*. Reading, MA: Addison-Wesley.

Brown K.B. and N.L. Hyer. 2010. *Managing projects: A team-based approach*. Boston, MA: McGraw-Hill.

Goldratt E.M. 1997. *Critical chain*. Great Barrington, MA: The North River Press.

IT Priorities 2010. http://download.microsoft.com/download/8/a/3/8a35d153-571c-4311-8fff-87924ef4c555/2005ITPriorities.pdf (accessed April 26, 2010).

La Brosse, M.A. 2001. *Accelerated project management*. New York: HNB Publishing.

Microsoft 2010, www.microsoft.com/presspass/features/2010/apr10/04-01MicrosoftProject2010.mspx (accessed April 20, 2010).

Middleton, D. 2010. Exam time: More firms are requiring test-taking. *The Wall Street Journal*, April 1 http://online.wsj.com/article/SB10001424052702304739104575154014179882070.html?KEYWORDS=project+management+certification)

Simpson, W.P. III. 2010. Project planning and control when time matters: Focus on process to synchronize and drive results. *Production and Inventory Management Journal 46*(2): 26-43.

Tversky, A. and D. Kahneman. 1974, Judgment under uncertainty: Heuristics and biases. *Science 185* (4157), 1124-1131.

Wysocki, R.K. 2009. *Effective project management: Traditional, agile, extreme*. New York, NY: Wiley.