Project Management Institute

CPM Scheduling for Construction

Best Practices and Guidelines

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Section 1

Pre-Project Planning Phase

The pre-project planning phase establishes the foundation for how the project will be executed. It is important to dedicate the appropriate amount of time and focus to pre-planning in order to properly define, plan, develop, and initiate key components of a project. When pre-planning is executed properly, projects run smoothly and typically have higher rates of success. This section discusses the development of an entire project control team, of which the planning and scheduling roles are an integral part of the organization. This section helps explain the role and interaction of the planner/scheduler with the rest of the project team based on the best practices that have been identified by project controls practitioners.

1.1 Selecting the Project Controls Team

Selecting the project controls team is vital to the pre-project planning phase. The team should be selected and start contributing to the project during the pre-planning phase. Many project managers wait too long to engage the right resources which shifts the focus of the team to always reacting and trying to "play" catch-up. If the project controls team is in place at the right time, however, they can establish the right tools, processes, and procedures and contribute proactively to the success of the project.

Selecting the project controls team comprises the following topics:

1.1.1 Roles and Responsibilities
1.1.2 Evaluation of Capabilities
1.1.3 Team Formation

It is important to clearly define the roles and responsibilities of the project controls team because it provides the framework for how the team will work together in accomplishing the project goals and objectives. The roles and responsibilities must be documented and communicated to the team so there is a clear understanding of responsibility, accountability, and level of authority.

It is also important to properly evaluate the capabilities and competencies of the project controls team members to ensure the proper talent is assigned to the team. The evaluation of capabilities and competencies is the process of assessing the current knowledge and skill of team members as well as their future potential to successfully perform the responsibilities in project controls.

Team formation defines the specific positions within and the structure of the project controls team. The organizational structure also defines how the project controls team is related to the rest of the project team, defining clear lines of communication and authority.

1.1.1 Roles and Responsibilities

Defining the roles and responsibilities of the project controls team is part of the pre-project planning phase and should be revisited periodically throughout the project. They must be documented and communicated to the team so there is a clear understanding of responsibility, accountability, and level of authority.

Guidelines

Definitions

The roles and responsibilities define the relationship between the project controls team members and the work to be performed.

The role is the position or function of the team member, which can also be described as "the part one has to play" (American Heritage Dictionary, 2009) to support the goals and requirements of the project.

The typical project controls team includes the following roles:

- Project controls manager
- Estimator
- Scheduler
- Cost engineer
- Document controller

Responsibility defines the work and activities the project controls team members are expected to perform.

The project controls team performs the following general work functions:

- Estimating
- Budget development
- Schedule development
- Schedule management
- Cost control
- Change management
- Earned value management
- Document management
- Collaboration and workflow management
- Analysis and decision support
- Project reporting
- Risk management

The work, activities, and deliverables can be defined broadly or very specifically. Per the above list, the work could generally be defined as schedule development or it could be further detailed into specific work elements, such as "develop WBS" or "create baseline schedule."

Purpose

It is important to clearly define the roles and responsibilities of the project controls team because it provides the framework for how the team will work together in accomplishing the project goals. The proper definition and team buy-in of the roles and responsibilities will optimize the teams to be more productive, effective, and harmonious.

For individual team members, it provides a clear expectation of their responsibilities, how they will support other team members, and how other team members will support them.

Finally, an effective definition of roles and responsibilities will provide a clear framework of accountability for each role.

Default Condition

Roles and responsibilities should be clearly defined, communicated, and utilized on every project. Even the smallest projects should set clear expectations for the participants. If no effort is put into defining the roles and responsibilities, each team member will work on the activities they believe or assume to be their responsibility. This may result in misunderstandings, missed deliverables, miscommunications, and inefficiencies.

Best Practices

The process of defining roles and responsibilities should start after the requirements of the project, project criteria, and goals for project controls are defined. It supports the selection process for the project controls team. The first step is to define the required level of project control necessary to support the type of project and the goals and objectives for the project.

The level of project control varies with each project, depending on the variety of characteristics, or criteria. For example, "complex and high risk projects require more control than simple projects." The following criteria should be considered to help determine the appropriate level of project controls for any given project.

Project Criteria

Project dollar value	Importance to management
Production impact	Proximity of project team
Contract strategy	Project duration
Importance of success	Estimated risk of change
Project type	Estimated volume of project documents
Visibility of project health	Estimated risk with suppliers
Management strength	Project location

Note: Adapted from "Effective Project Controls: Designing the Team," by Stephanie Thatcher, 2010, page 9.

Every company can develop its own list of criteria as the appropriate criteria may vary across organizations.

Defining the roles and assigning the responsibilities starts with a leader, usually the project manager or project controls manager, who determines the high level expectations and responsibilities for project controls.

The responsibilities should then be defined with the appropriate level of detail. For example, is it sufficient to define the work as simply "schedule project" or should there be more specific tasks such as "develop schedule coding structure," "define schedule specifications," and "resource load schedule"?

The next step is to identify the different roles that will support the project controls activities, such as scheduler and cost engineer. The final step is to define the relationship between roles and responsibilities. The output of this session is typically a document or a matrix depicting the roles and responsibilities for the project controls team.

A common type of matrix is called the responsibility assignment matrix (RAM). This matrix typically lists the activities of work and deliverables down the page in vertical rows and lists the roles horizontally across the top of the page. In the most basic format, the relationship between the role and the work is simply indicated with an "x" in the matrix cell where the role and work intersect.

Regardless of the type of tools used to define and communicate the roles and responsibilities, the key is for all the team members to clearly understand their roles, responsibilities, and levels of authority in order to effectively support the project goals and objectives.

Recommended Practice

A more comprehensive type of RAM is called the RACI (Responsible, Accountable, Consult, and Inform) (PMI, 2008), which clearly defines the type of participation. A basic sample of a RACI for the project controls team is represented in Table 1-1.

Table 1-2 illustrates general definitions for the RACI.

Responsibilities (work, task, deliverable)	Project Manager	Project Controls Manager	Scheduler	Cost Engineer
Define work breakdown structure	C	A	–	–
Develop baseline schedule	I	A	R	–
Create project budget	I	A	–	R
Monthly project report	I	A	C	C

Table 1-1: Project controls team RACI—abbreviated sample

R	Responsible	Performs the work to accomplish project requirements and goals.
A	Accountable	Approves the work of the person who is responsible for performing the work and has the authority to make decisions and assign resources.
C	Consult	Provides recommendations and input to improve work.
I	Inform	Receives information about the status of the work being performed.

Table 1-2: RACI definitions

In the use of RACIs, the role can be defined generally, such as by department or function. The roles can be further defined by job title, such as "scheduler" or by the specific name of the person who will be responsible for the tasks.

In some cases, the role can have responsibility for the work, task, or deliverable and the role can also have accountability. Where this is applicable, select "Accountable" as the participation type. In the "Project Controls Team RACI" example shown in Table 1-2, the project controls manager is both responsible and accountable for defining the Work Breakdown Structure (WBS).

Because there are many different styles and approaches, it is important to provide a legend, similar to Table 1-2, to define the precise meaning of the different participation types in the RACI for each project so there is a clear understanding for everyone.

In using a RACI, it is important to include any roles that require information on the status of the work being performed, or in other words, the "inform" participant type. For example, if the project controls team is required to inform the project manager on certain activities, then the project manager needs to be a role defined on the RACI. In fact, any interactions with roles outside of the project controls team should be included in the RACI.

Advisories

Avoid delaying the definition and communication of the roles and responsibilities for the project controls team. These should be clear before the project controls effort engages.

If creating a RACI responsibility matrix, avoid using multiple participation types (Responsible, Accountable, Consult, or Inform) for any one task/role combination. In other words, each role for each task should have only one participation type defined.

1.1.2 Evaluation of Capabilities

Evaluating the capabilities and competencies is another part of the pre-project planning phase and further supports the selection process for the project controls team.

Guidelines

Definitions

The evaluation of capabilities and competencies is the process of assessing each team member's current knowledge and skill, as well as his or her future potential to successfully perform the responsibilities in project controls.

Capability is the potential for a person to be developed for future opportunities. It is important to understand the capability of prospective members of the project controls team to see how they could be trained and coached to develop into different positions.

Competence is the demonstrated use of knowledge, skill, and ability to consistently perform tasks. It is important to understand the competence of prospective members of the project controls team to evaluate how they can perform current responsibilities required to meet the goals and objectives of the project.

Purpose

The evaluation of capabilities and competencies is a critical step in selecting the project controls team to determine if individuals can effectively and efficiently perform their roles and responsibilities.

Default Condition

A careful review of capabilities and competencies should be performed on every project to ensure the project controls team will have the proper skill-sets and sufficient experience to be successful. Failure to adequately evaluate capabilities and competencies can lead to selecting the wrong team members, which could cause ineffective project controls, higher project risk, and the inability to meet project goals and objectives.

Best Practices

It is important to first define the key capabilities and competencies required for the members of the project controls team. Questions to ask include: What is required to support the roles and responsibilities on this project? More specifically, what are the important skills the scheduler should have to perform their duties and responsibilities on the project? Should the scheduler demonstrate experience in a particular software tool?

After the key capability and competency requirements are defined, potential team members can be evaluated to determine if they meet the needs of the project controls team for a particular project.

There are a variety of methods to evaluate capabilities and competencies, ranging from structured interviews to questionnaires to testing. The evaluations are typically performed by the project manager or project controls manager.

Capabilities are more difficult to assess because the focus is on a person's capacity and potential to develop the specific knowledge and skills required for a project controls position.

The following example, shown in Table 1-3, pertains to a project controls manager's evaluation of whether or not a prospective scheduler should be selected to join the team.

In the example shown in Table 1-3, the project manager is using his or her judgment to determine if this person has the capability to become a scheduler. This is typically a subjective process, unless it is conducted by a professional with proven experience in capability assessments. Nonetheless, project teams perform these kinds of assessments every day, doing their best to determine the capabilities of team members and positioning them for future roles. Evaluating capabilities is critical, not just to the immediate needs of a current project, but more to support the needs of future projects.

Because the need for personnel on projects is typically immediate, most evaluations focus on an individual's competencies. Competencies are easier to evaluate because knowledge, skills, and ability can be

Required Knowledge, Skill, or Ability	Ability to develop a critical-path-method schedule using the latest version of primavera software.
Situation	The project controls manager interviews a person and learns they have hands-on construction field experience, understand the proper sequencing of construction work, and know the typical resource issues on a job site. This person has communicated great interest in scheduling, but has never developed or utilized a critical-path-method schedule.
Evaluation	The project controls manager concludes this person has potential to be a scheduler, but does not have the in-depth knowledge and proven technical skills to be the scheduler for this project. In other words, the project controls manager believes this person has the capability to be a scheduler in the future if given the proper training and development, but he or she does not have the competency to fulfill the scheduler role today on this project.

Table 1-3: Project control manager's evaluation

determined with structured interviews, questionnaires, and tests. It is not about predicting how a person could develop in the future, but about how the person can perform today on a given project.

Recommended Practice

To evaluate competencies, develop a list of the required knowledge, skills, and abilities to support the roles and responsibilities of the project controls team members. To facilitate this process, create a basic table for each role to define the responsibilities and the associated knowledge, skill, and/or ability required. Table 1-4 shows an abbreviated example for a scheduler.

Responsibilities	Required Knowledge, Skills, or Abilities
Develop baseline schedule	• Knowledge of critical-path-method scheduling • Advanced level proficiency in using the latest Primavera software for scheduling
Prepare monthly schedule report	• Ability to work with project team to obtain project updates • Intermediate level proficiency in using Microsoft PowerPoint software • Strong organizational, presentation, and written skills
Facilitate meetings to develop integrated project schedules	• Ability to work with other scheduler professionals in a collaborative manner to plan projects • Knowledge of integrated project scheduling methods and best practices • Advanced level proficiency in using the latest Primavera software for scheduling • Excellent communication skills

Table 1-4: Knowledge, skill, and ability table, scheduler sample

After the required knowledge, skills, and abilities are defined for each role on the project controls team, the evaluation process can begin. Evaluations can be in the form of structured interviews, questionnaires, and tests. There are many different approaches, formats, and variables in designing an effective evaluation process and procedure. It is recommended to research the different options and create one that is acceptable to both the organization and project team.

The common goal, however, is to systematically, accurately, and fairly assess a prospective team member's competency to fill a project controls role and make the selection decision. Table 1-5 shows a simple example of scoring how well an individual meets the competency requirements for a scheduler position.

Table 1-5 starts with the list of required knowledge, skills, and abilities to support the responsibilities of a scheduler. The next step is to assign the level of importance by weighting each knowledge, skill, and capability item, then score how well the potential scheduler meets the requirements through structured

Required Knowledge, Skills, or Abilities	Importance Weighting	Score
Knowledge of critical-path-method scheduling	30%	4
Ability to work with other scheduler professionals in a collaborative manner to plan projects	15%	3
Knowledge of integrated project scheduling methods and best practices	10%	1
Advanced level proficiency in using the latest Primavera software for scheduling	25%	3
Excellent communication skills	20%	2
Overall weighted score	**100%**	**2.9**

Table 1-5: Knowledge, skill, and ability score, scheduler sample

Score	Definition
4	Superior
3	Above acceptable
2	Acceptable
1	Not sufficient

Table 1-6: Knowledge, skill, and ability score legend

interviews, questionnaires, or tests. Finally, the overall weighted score can be calculated for each prospective scheduler evaluated and the person with the highest score can be recommended for selection.

The scoring system shown in Table 1-5 is based on definitions shown in Table 1-6, but can be customized to meet the requirements of the organization and project team.

Advisories

All aspects of evaluating, promoting, and selecting team members must be performed in accordance with the organization's standard policies, processes, and procedures. Do not conduct interviews or implement questionnaires or tests without the participation of and guidance from internal human resource and legal professionals.

All types of evaluations for selecting or promoting human resources must be carefully designed, tested, and implemented to ensure they comply with the governing local, state, and country regulatory requirements.

1.1.3 Team Formation

Team formation is a key step in structuring an effective project controls team. Team formation is part of the pre-project planning phase.

Guidelines

Definitions

Team formation defines the specific positions within and structure of the project controls team.

Purpose

The organization structure also defines how the project controls team is related to the rest of the project team members, defining clear lines of communication and authority.

Default Condition

Consideration should be given to team formation on every project to ensure the proper structure is in place to support the project controls roles and responsibilities.

Best Practices

Team formation utilizes the roles and responsibilities and the evaluation of capabilities and competencies developed in the previous sections to bring the team together. The following are all predecessors to team formation:

- Project goals and objectives
- Defining the project characteristics/criteria
- Roles and responsibilities
- Evaluation of capabilities and competencies

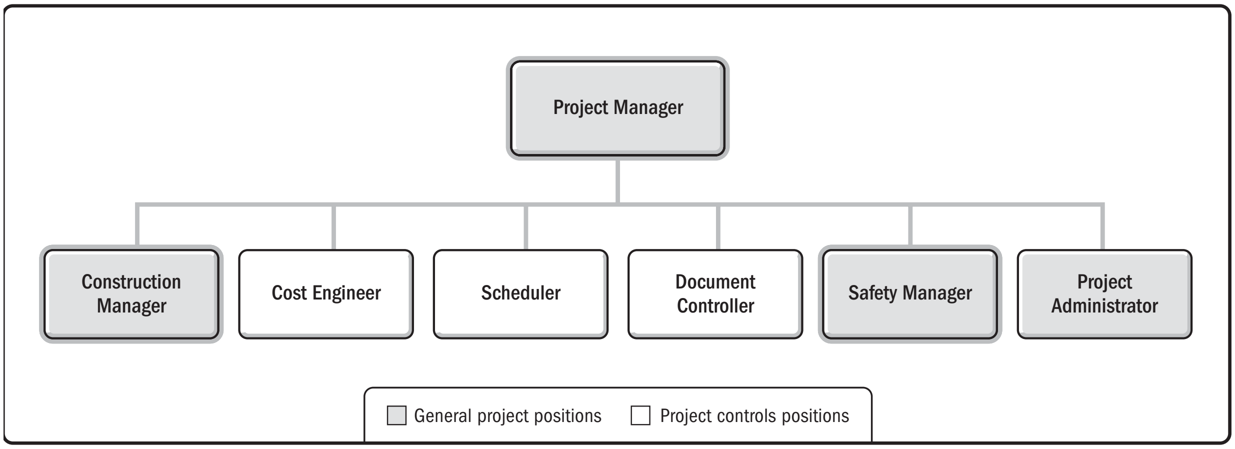

Figure 1-1: Project controls team structure—simple low-risk project

Project controls team structures vary greatly from project to project. Simple, low-risk, and low-dollar value projects could have a basic structure as illustrated in Figure 1-1.

On the other hand, larger projects with significant risks will typically require more project control and result in a more complex team structure, as illustrated in Figure 1-2.

The team structure will define the specific positions and their reporting structure. It will also determine the quantity of each type of position required and eventually assign specific names to each position. The

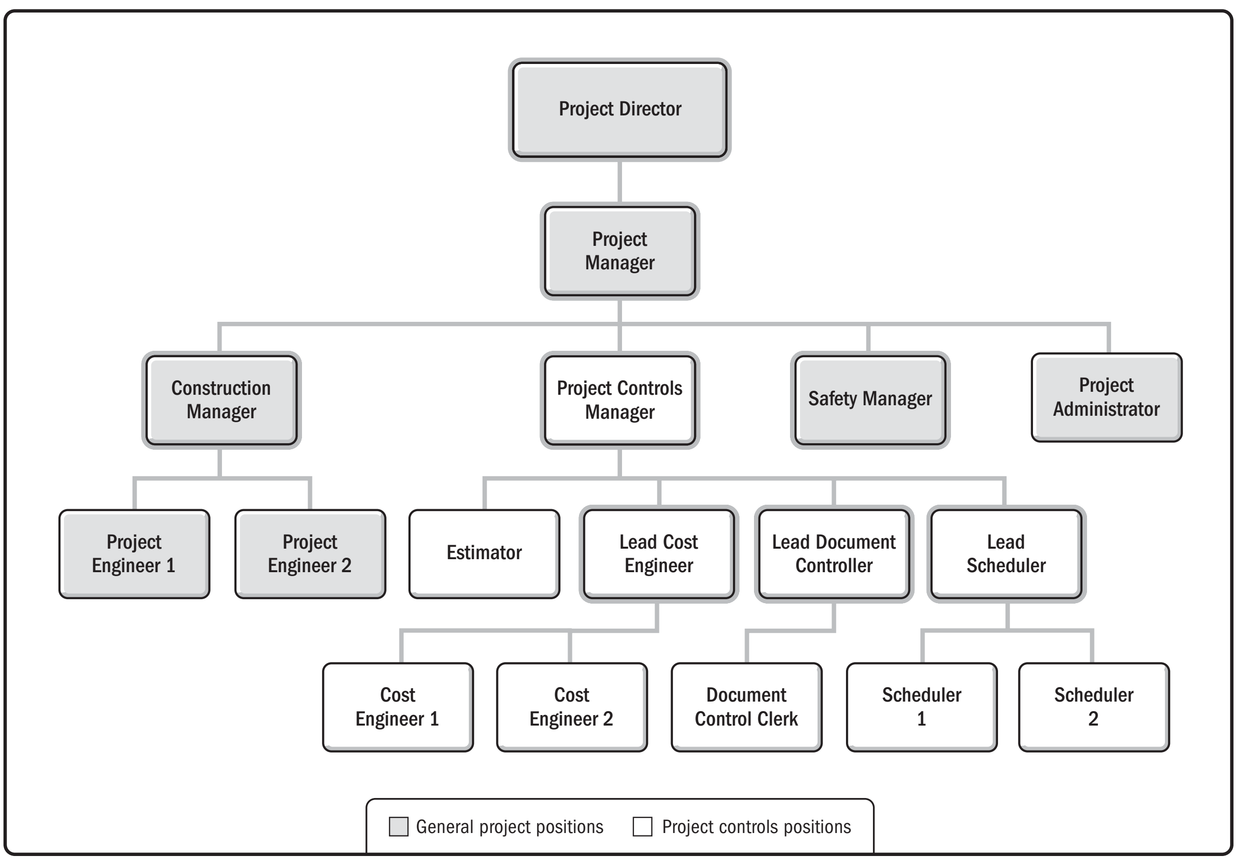

Figure 1-2: Project controls team structure—complex high-risk project

above examples illustrate the specific positions and also identify the project controls positions and how they relate to the rest of the project team.

Recommended Practice

In developing the team structure, it is important to revisit the roles and responsibilities of the project controls team. For example, if the level of control for the project requires a large scheduling effort with a lead scheduler and supporting schedulers, then the roles and responsibilities should be expanded to address both scheduling roles.

During team formation, it is recommended to hold a brainstorming session wherein the members of the project controls team can collaborate on refining the roles and responsibilities. During this session, each of the positions can be reviewed to refine the specific work, tasks, and deliverables. The output of this session is an updated roles and responsibilities matrix for the project controls team. This session will further result in providing a clear understanding of the specific duties of each team member and in engaging a higher level of buy-in and commitment from all members of the team.

Advisories

Ensure the team formation provides the proper level of project control to support the project goals and objectives. The structure of the project controls team must be consistent with the roles and responsibilities matrix.

1.2 Preparing a Pre-Project Planning Outline

Guidelines

Definitions

Pre-project planning is defined as the process of developing sufficient strategic information for owners to address risk and decide to commit resources to maximize the chance for a successful project (Construction Industry Institute, 1995).

Pre-project planning is also referred to as front-end planning, feasibility analysis, scope definition, and business case, to name a few.

Purpose

The purpose of preparing a pre-project planning outline is to ensure some or all of the following:

- The business requirements, and that the project is the correct solution;
- The stakeholders, and the critical stakeholders' views and concerns have been addressed;
- The project team has been created and has the skills to execute the project;
- All options and alternatives have been examined;
- The most appropriate delivery method has been selected;
- The most appropriate technology has been selected;
- The scope, schedule, costs and quality;
- The capacity of suppliers and contractors is understood;
- Risks are understood and managed;
- Legal and statuary requirements are known and understood;
- Project controls including reporting have been defined;
- Funding is available; and
- Sufficient information is available to allow a decision on whether to proceed.

Default Condition

A pre-project planning outline is required for all project owners and this document should be created for every project. The size and complexity of the document should be driven by the requirements of the project.

Best Practices

Pre-project planning starts after the project charter has been approved and the document outline is used to authorize the project. The outline should be used as a baseline for progress reporting and is used to judge the ultimate success of the project delivery and confirming that the benefits of the project have been achieved by the organization.

Pre-project planning should:

- Be driven by the owner and contract;
- Include clearly defined roles and responsibilities;
- Have sufficient time, budget, and resources to be completed effective;
- Include users such as operations and maintenance;
- Be iterative and become a working document that drives the project and is updated throughout the life cycle of a project;
- Start as early as possible; and
- View team building as an important aspect of this process.

Recommended Practice

Organizations should develop processes, procedures, terminology, and checklists for teams to use.

An independent review process should be used at every stage of the development of the document to ensure errors and omissions are picked up early.

Teams should be supported by training and tools as required by the project type.

Advisories

The time spent on pre-project planning has a significant impact on a project's ultimate success, not just on successful project delivery but also on ensuring that the project delivers the expected benefit to the owners of the asset.

All projects must not be considered the same and each project should be individually planned.

Section 2

Schedule Design

Design entails the application of scientific, technical, and practical knowledge to a problem in order to define an acceptable solution. For complex problems, the first step of the design process is problem definition, where the broad outlines of the problem are refined into a definite set of needs. Then design proceeds, and the elements of the design are developed through a process of planning and decision making with the intent to fulfill a definite set of purposes. Whether the design team is one person or many, the best solutions to complex problems are attained through a well-structured design process.

For the execution of a complex scope of work, the benefit of schedule design lays down the foundation for schedule development, maintenance, and usage. As more resources are committed to the project, the benefits of good planning can be as important as good design of the scope itself. That is why the best schedules for the execution of a complex scope of work are planned through a schedule design process. This chapter details the elements of the schedule design process based on the best practices that have been identified by scheduling practitioners.

2.1 Schedule Design Process Overview

Guidelines

Definition

Schedule design is the process of developing the structure and organization for the schedule prior to beginning detailed schedule development. In other words, schedule design is planning for schedule development. It provides a methodical approach to building the schedule, so that when schedule development starts, it will advance logically to the end result, and that end result will be what was envisioned from the beginning. Schedule design provides the guidance needed to make sure that the schedule that is ultimately developed is what the stakeholders need to manage the project.

Purpose

Why design a schedule?

When a significant effort is to be undertaken to plan a project in detail, it makes sense to consider the scope and organization of that effort at the outset—to start with the end in mind. A schedule is a management tool used to plan and coordinate multiple activities and resources on a project. Like any good plan, it must outline the steps to the objective in an organized and understandable manner.

Those requirements imply the need for conscious design—planning with the intent to fulfill a definite set of purposes. PMI's *Practice Standard for Scheduling* – Second Edition states that the schedule model requires planning and design like any other project deliverable and that the project team needs to consider a number of factors to optimize the design of the schedule (PMI, 2007). Practitioners have stated that good schedule design:

- Plans the schedule development effort, which meets the criteria for a "project" in itself;
- Keeps the schedule development process on track;
- Prevents rework due to late understanding of needs;

- Facilitates buy-in from end users early in the planning and scheduling process;
- Makes schedule development sessions more meaningful;
- Provides a methodical approach to schedule development to minimize the chance of oversights;
- Provides opportunity to document the assumptions and intention of the schedule for the end users and for future reference;
- Facilitates the schedule review and approval process;
- Eases transitions due to changes in project controls staffing or project management staffing; and
- Provides an opportunity to incorporate lessons learned from previous projects.

The schedule design process should also include an assessment of the available scheduling techniques, tools and resources—including methodologies, hardware, software, and staff. The project team must decide how to use the selected tools, techniques, and resources for the success of their unique project.

Scope of Design versus Development

In these *Best Practices and Guidelines,* schedule design is distinguished from schedule development in that design is focused on the organization, division, and coding of the schedule's structure, whereas development is focused on the detailed definition of activities and the relationships between those activities. Design is performed before development and typically includes organizing the project into manageable parts for detailed planning purposes.

Design should be coordinated with high-level decisions on how the project will be managed and executed. Will the project be divided into several phases? Will detailed schedule development be undertaken by several separate teams? Will the project schedule be used to generate management metrics, or reports based on subtotals that roll-up to summarize large segments of work?

The answers to these questions are important considerations in the design process. They will lead to decisions as to whether the schedule should incorporate a fixed, hierarchical work breakdown structure (WBS), a more flexible coding structure, or both. If the project scope is likely to change or expand, flexibility and scalability of the schedule structure may be the most important considerations in schedule design. When the project is large and includes many repetitive elements, consistency of descriptions and coding may be the most important considerations in schedule design.

Decisions as to how to structure the schedule call for consideration of the management, reporting, and communication needs that the schedule will meet. There is no one correct way to design a schedule, but some designs will be better suited than others to addressing specific needs. The better the design the more it will ease the schedule development process, meet management needs, communicate the content of the schedule to the end users, and minimize the burden of updating and revising the schedule as the project progresses.

Detailed activity, duration, and logic definitions are reserved for the schedule development process. During that process, the design may be revisited to ensure that development is proceeding consistently. If certain elements of the design are found to be unhelpful, they may be revised.

Good Design Leads to the Development of a Quality Schedule

Proper schedules address project management needs, are coordinated with specifications, and provide accurate forecasts with an appropriate level of detail to function as a flexible yet accurate management tool. Such schedules are not prepared haphazardly; they are intentionally designed. One well-respected practitioner has stated that the omission or inadequate performance of schedule design is the number one way to sabotage a scheduling effort (Woolf, 2007).

Just as projects need to be planned, schedules need to be planned to ensure the right product delivery to the stakeholders. So the purpose of schedule design is to provide the road map necessary to guide schedule development to produce a schedule that will meet project needs.

If the project is part of a larger program, the goal is the same, although there may be additional schedule design considerations due to program-wide schedule coordination needs. When many schedulers are producing schedules on the same program, having a consistent approach to schedule design and some coordination of schedule structure, coding, and techniques will facilitate program-wide management reporting, coordination among related projects, and transition of staff from project to project within the program. Having a consistent schedule structure will provide program staff with a familiarity and level of comfort with reading and using the schedules as they coordinate multiple project or transition from project to project.

A properly designed and developed schedule provides a roadmap for project execution. Development of this roadmap can be seen as a project in itself. It fits the definition for a project—a temporary endeavor undertaken to create a unique product, service, or result (PMI, 2008).

So, if the development of a schedule is a project, what is the plan for this project? What is the plan for schedule development?

Without a plan, the scheduler may simply sit down in front of a computer and begin typing in activities, or members of the project team may attend a schedule development session and identify activities that are posted on the wall. In both cases, schedule development has started without a discussion of the purpose or results needed. Although this approach could be improved, it may be sufficient for a small project schedule. However, this approach is unlikely to be effective on a larger, more complex project schedule. The approach increases the risk that schedule development will be incomplete, with portions of the project insufficiently planned, or that the schedule will not meet the needs of all stakeholders for managing their activities or reporting to their management or clients.

The quality of a schedule may be viewed along a spectrum from poor to excellent. A poor schedule will fail to include portions of the project scope, inaccurately represent relationships between activities, not meet project reporting needs, or produce inaccurate forecasts. In fact, a poor schedule will probably have many of these issues. An excellent schedule will model the entire project scope in a way that facilitates management of that scope. The scope and status of individual activities will be clear to those managing the activities. The relationships between the activities in the schedule will accurately reflect the relationships between the activities in reality. Float values reflected in the schedule will be useful to the end users in understanding the relative criticality of the various paths of activities in the schedule.

While no schedule is perfect, it is clearly desirable to develop one that is as close as possible to the "excellent schedule" end of the spectrum. The users of such a schedule are likely to be satisfied that the planning and scheduling functions have been properly and successfully performed by those who developed the schedule. The purpose of design is to give the planning and scheduling staff the best chance at creating an excellent schedule.

Default Condition

In the default condition, personnel responsible for schedule design have a good understanding of how the project scope will be organized or have access to those who do, so that the organizational structure of the schedule can reflect the organizational structure of the project.

A Guide to the Project Management Body of Knowledge (PMBOK®) – Fifth Edition does not specifically define schedule design or treat it as a separate project management process. It defines the schedule management plan as the document that establishes criteria and the activities for developing and controlling the project schedule (PMI, 2013). According to the *PMBOK® Guide*, the schedule management plan is expected to be part of the overall project management plan. In this case, the criteria for developing the project schedule may be initially developed in the first step of the planning process group.

If schedule design does not begin when the project management plan is developed, it may begin when creating the Work Breakdown Structure (WBS), as schedule design is closely related to creating the WBS and has many of the same inputs outlined in the *PMBOK® Guide*—the project scope statement, requirements documentation, and organizational process assets (PMI, 2013). Regardless of the names or format of the input information, a good understanding of how the project scope will be organized, managed, and reported is the key to good schedule design.

The planning processes that follow creation of the WBS—particularly defining activities, sequencing activities, and estimating resources and durations—fall under the schedule development section of these *Best Practices and Guidelines*. In the default condition, schedule design precedes and establishes the framework for schedule development.

AACE International's *Total Cost Management (TCM) Framework* notes that schedule planning and development are separate but related sub-processes that call for different skills and knowledge emphasis

(AACE, 2006). However, the *TCM Framework* characterizes the division between schedule planning and schedule development somewhat differently than the division between schedule design and schedule development defined in these *Best Practices and Guidelines*.

AACE includes development of activities, sequencing the activities, and estimating the durations of the activities in schedule design. For AACE, schedule development is then focused on iteratively refining the schedule based on the allocation of available resources. The default condition for these *Best Practices and Guidelines* includes detailed development of activities and logic under schedule development, which follows schedule design.

In summary, much of the available literature outlines elements of the schedule design process, but those elements are typically characterized as a subset of project management planning or are indistinct from the schedule development process. These *Best Practices and Guidelines* are based on the expectation that schedule design will be a conscious effort, significant enough to be considered a process unto itself.

Best Practices

While some of the available scheduling and project management literature recommends a high-level planning process prior to schedule development, no detailed references exist on how best to execute schedule design as a distinct process. In the preparation of these *Best Practices and Guidelines,* several experienced practitioners expanded upon the brief recommendations in the available literature and outlined their best practices for schedule design.

The best practices for schedule design have been organized into the following categories:

- Purpose
- Communication
- Organization
- Level of detail
- Methods and tools
- Risk management
- Lessons learned
- Inputs/Outputs
- Staff
- Buy-In

These categories were developed by compiling the various recommendations related to the schedule design process from practitioners and the existing literature and forming them into logical groups. The practices are detailed in the subsections below.

Purpose

The purpose of the schedule design process was described previously, but many practitioners have emphasized that the process should begin with the discussion and definition of the purpose of the schedule itself. Certainly, it is common for the schedule to function as the primary time management tool for the project, but the project team should develop a common understanding of what that means. The schedule will likely have several purposes, including many of the following:

- Manage the overall project for timely completion;
- Determine which activities are critical;
- Communicate to resources the dates on which they should expect to mobilize, perform their work, and demobilize;
- Manage the activity of internal resources;
- Manage and coordinate subcontractors;
- Coordinate with clients, owners, or end users;
- Manage a time-phased budget (support earned value management);
- Predict milestone and completion dates;
- Fulfill specification requirements for providing a schedule;
- Manage change;

- Control time-related costs; and
- Avoid, defend, or document claims.

Listing these various common goals of a CPM schedule highlights the fact that the schedule is often used to achieve many ends on a project. When one tool is required to achieve many goals, there is an increased risk that it will fail to achieve one or more of them, especially when there is a risk that the goals may be at odds with one another.

For example, the goals of coordinating the mobilization of subcontractors and attempting to avoid claims would be at odds with one another in a situation where a prime contractor's precedent work is behind schedule and the subcontract has an escalation clause. If the prime contractor reschedules the subcontractor's work based on a later forecast completion of the precedent work, that action could be taken by the subcontractor as a direction to perform later and may trigger the contract's escalation clause. In this situation, there may be pressure on the project management or project controls staff to maintain the subcontract mobilization date in the schedule by modifying logic or over-estimating progress on the precedent work. If the subcontractor fails to mobilize on time, or elects to delay mobilization of its own accord, it may have a more difficult time putting forth a claim for escalation than if its work had been proactively rescheduled by the prime.

While the example described here raises issues that will be dealt with during project execution, not schedule design, it also raises questions that should be discussed during the schedule design phase. For example, how detailed should subcontract activities be reflected in the prime contractor's schedule? Will the subcontractors be developing their own logic and providing complete CPM schedules that will be integrated into the prime contractor's schedule, or will the subcontractors simply provide lists of activities and durations with the logic to be developed by the prime contractor? Will all subcontractors attend schedule development meetings, or will only key subcontractors attend? Who are the key subcontractors? Should mobilization and demobilization activities be included in the schedule? Should they be constrained based on terms in the subcontracts even though the work may not be critical in terms of the overall project schedule?

The list of questions could go on almost endlessly, and there must be a time to transition from schedule design to development, and ultimately to execution. Still, establishing a common understanding of how these issues will be handled will lead to a more effective schedule development process and a better schedule. This is especially true in the case where multiple schedulers will be developing portions of the same schedule and there is a desire to create consistency in the treatment of issues. If the project team members have a common understanding of which schedule purposes should be emphasized more or less, the quality of the schedule will be improved, and those relying on the schedule for information will benefit from their common understanding of its purpose throughout the project.

When budget management is a primary purpose of the schedule, the stress of achieving multiple goals with one tool will be felt even more acutely. If project payment applications are prepared based on reports from the schedule—often termed a "cost-loaded" or "value-loaded" schedule—the pressure to manage cash flow is likely to have an influence on progress reporting at some point in the project.

In addition, using the schedule as a budget management tool raises more questions that should be discussed and addressed as much as possible through the schedule design process. How will the cost accounts be structured? Will the schedule be loaded with internal cost forecasts excluding overhead and profit or will the budget in the schedule be matched to the contract value? Will procurement activities be cost-loaded? Do the project specifications have specific requirements that must be maintained to meet owner or client goals to minimize "front-end loading"? The answers to these questions will guide the format and organization of the cost accounts and budgets that will be incorporated into the schedule, and the decisions made in this phase will greatly affect the ease of preparing any time-phased cost reports that may be required over the course of the project.

Sometimes the purpose of the schedule is simply to fulfill a specification requirement. Perhaps the schedule is for a building project, the superintendent has built 50 buildings exactly like this one, and he believes the schedule will just get in his way. If this is the case, there is no reason to spend an inordinate amount of time in developing a schedule that will not be used, and the update process will be a burden and frustration to all. Instead, a simplified approach to the schedule might be taken to provide just enough to protect the company's interest and fulfill the specification requirements while minimizing the burden on those managing the work.

In summary, establishing the needs of stakeholders, the requirements of contracts and specifications, and the resources to be managed with the schedule will provide valuable insight that will guide the format and structure of the schedule. Decisions will be made regarding the content of the schedule, level of detail, resources and cost accounts to be incorporated, and parties to be involved in schedule development. These decisions will guide the team's schedule development and leave a lasting common impression of how the schedule will be used to manage the project. Development of this common understanding early in the project will ease communications that relate to time management and interpretation of the schedule for the duration of the project. The purpose of the schedule—or the multiple purposes of the schedule—will be understood by all stakeholders.

Communication

Develop a common lexicon and understanding of terms related to the scope of work and the scheduling techniques to be used. Most projects are awash in abbreviations and technical jargon. The terminology is likely familiar to most project team members, but that may serve to prevent those who have questions from asking them. Over the course of a project, almost every project team member is likely to pause trying to recollect the meaning of at least one term.

Leaving room for confusion and uncertainty does not serve anyone. Developing common understanding, especially among those who will be involved in schedule development, will reduce the chance for confusion. The schedule planning effort may include the development of a glossary of terms that will be used in the development process so that everyone uses them consistently and with the same understanding.

Perhaps highest among the terms that should be discussed during the planning process is "critical path." As scheduling techniques have developed, the understanding of what is critical has diverged from the single meaning of a path of activities through the CPM network that could be identified by having zero total float. Members of the project team who have not worked together before may well have different understandings of how to apply the term, however. For example, will only the longest path be called critical, or will all paths with negative total float be called critical? Regardless of the school of thought applied, a common understanding of what is critical is key when trying to focus efforts on critical activities.

Discussions of project and scheduling terminology can be a good way to establish common understanding among team members and open lines of communication to address future issues. A thorough understanding of how the team is applying terms and concepts will help with project communications. After all, what is a schedule if not a communications tool?

Organization

If schedule design fails to create organization for the pursuant schedule development process then it has failed. Develop an organized approach to the schedule structure. The initial WBS, activity coding, calendars, resources, and cost accounts should be defined during the schedule design process, allowing for some iterative feedback from the schedule development process that follows.

WBS

As stated previously, the process of schedule design is closely related to the process of WBS development, which has been described in more detail in the available literature. PMI's *Practice Standard for Work Breakdown Structures* – Second Edition states that WBS is used to define the project's scope in terms of deliverables and decompose those deliverables into their components. WBS also provides the project management team with a framework for status reporting and facilitates communication among stakeholders (PMI, 2006). PMI's standard further states that a well-designed WBS "presents information at the appropriate level of detail and in formats and structures meaningful to those performing the work" (PMI, 2006, p. 6).

The use of a WBS for organizing project scope has become more common recently, particularly as more government projects have required it for the implementation of earned value management (EVM). However, even if a WBS is not required or used on a project, some coding structures are typically used to organize the project scope and schedule. The design of these coding structures will be part of schedule design regardless of whether a formal WBS is developed.

In any case, a complete framework for schedule development will go beyond WBS development and may include more detailed items that must be coordinated among all team members that will be involved in the schedule development process. These more detailed items could include:

- Key activities to monitor based on past experience or team expertise
- Intermediate milestones and a summary path to achieving them
- Long lead items
- Site constraints
- Work packages descriptions (such as in a WBS dictionary)
- Influences of other contracts or third-party activities

The schedule design process is the time to rectify any ambiguity in milestone requirements or sequencing that may exist. Recognizing site access and storage constraints and procurement lead times can be helpful in further refining sequencing. The WBS structure speaks to a full and complete understanding of the scope of work, and identifying all work packages and their sequencing will ensure that the schedule provides direction for all elements of procurement and installation. With this information in hand, and a well-thought-out design, development of the schedule can take place quickly and accurately.

Activity Coding

Organizational structures can also be established during the schedule design process using activity codes in addition to, or in place of, a WBS. In the past, alpha-numeric coding was incorporated directly into the unique activity identifiers themselves. Now scheduling software allows for a wide variety of activity codes to accommodate the ability to isolate and manipulate schedule data to match analysis and reporting needs, and they are also more flexible than the rigid hierarchy of a WBS. For example, work can be organized by area then trade to provide an overview of the work in one area of the project. Alternatively, work can be organized by trade and then area to provide an overview to a craft superintendent who is supervising one trade throughout the project. Activity codes are used in this way to allow quick and effective monitoring and to provide targeted reports and printouts for project management. Example activity codes include:

- Work phase
- Structure
- Area
- Floor or station
- Location
- Responsibility
- Work shift
- Reference specification
- Change order

One of the primary schedule design decisions to be made related to the organization of the project schedule is whether the schedule will incorporate the rigid hierarchy of a WBS structure, the less structured and more flexible activity code dictionary, or both. Rigid structures can benefit project management in that they create a consistency of structure that may carry through schedule, cost, and change management functions. On the other hand, flexibility has its advantages, especially when the schedule must generate reports for various needs, as described in the previous example. On many complex projects, both structures are used.

Calendars

Calendar definition is another organizational tool available to schedule designers. Work may proceed in multiple shifts on some activities. Contractors may work four, five, or six days per week. Work outside may be affected by weather, while administrative, design, procurement, and other interior work can proceed without impact.

Particularly in the construction industry, planning for adverse weather is an important element of schedule design. There are several different approaches to planning for weather. Some practitioners advocate the allocation of a weather contingency at the end of the project, while others advocate a monthly weather contingency activity. Many address weather planning through the use of calendars. Regardless of the approach, the method for weather planning should be understood by all those who will be involved in the schedule development process. The project scheduling specifications should also be reviewed, when applicable, as they may require that weather be addressed in a certain way. Agreed-upon holidays and other nonwork periods should also be addressed in a way that is clear to all developers.

Resources

If the schedule is to be resource-loaded, another set of considerations must be made as to how to organize the schedule. Resource quantities in terms of labor and equipment hours often come from a project estimate, which is typically well detailed prior to the schedule development process. When this is the case, reviewing the project estimate and assessing its organizational structure can assist in designing the schedule in a manner that will make it easier to load resources.

Not every line item in the estimate will necessarily have a corresponding activity in the schedule. Similarly, there will be activities in the schedule that do not have corresponding line items in the estimate. Decisions will be made regarding how to align the resources in the schedule with those in the estimate during the schedule development process. However, coordination between the organization of the estimate and the organization of the schedule can facilitate later resource loading. Like the other elements incorporated into the schedule, considerations should be made as to what types of reports will be generated from the resource loading.

Cost Accounts

Similar considerations should be made for any requirement to cost-load the schedule. Coordination of the input information from the estimate or from the budget and coordination of the output information with any required or desired reports is best done during the schedule design process. In the event that the schedule will be used to support contract payments, it is important to understand whether the schedule must be closely aligned or exactly aligned with payment applications. Some contracts require that the earned value in the schedule match the amount of the payment application exactly. If there is not an exact alignment between the line items in the payment application and the activities in the schedule, there must be a method to account for any adjustments made.

Some practitioners accommodate differences in schedule progress and agreed-upon progress for the purposes of a payment application by separating or "unlinking" the schedule progress and the physical progress of the activities—essentially reporting two different values for the progress of the activity. One of those values is typically reported as progress in workdays for the purpose of the schedule, and the other as a percentage complete for the purposes of payment.

Still some adjustments to budgeted values may need to be made if there are changes in the scope of work that adjust the contract price. Contracts that have elements that are paid on a time-and-materials basis or a unit-price basis can also complicate the process of balancing the earned value in the schedule with the amount of a payment application. Review of the scheduling specifications and consideration of the payment application requirements during the schedule design phase will guide the cost loading that will take place during schedule development.

Level of Detail

The level of detail of a schedule is an important determinant of its usefulness for those who will be reading the schedule itself to manage their work, those who will be updating all of the activities in the schedule, and those who will be reading reports that are generated by the schedule. The level of detail must be sufficient to manage the work and provide required reports, but not so detailed that managing the schedule becomes time-consuming and more of a burden than an aid to project management.

The level of detail determined during schedule design depends on the nature, size, and complexity of the project. The schedule needs enough activities to reflect intricacies and interdependencies. Too few activities will require greater use of start-to-start and finish-to-finish relationships with long lags. This summary-level schedule will be less useful for the management of specific activities and harder to analyze and isolate impacts to individual activities if work proceeds differently than planned. On the other hand, too great a level of detail will make updates more time-consuming and schedules and reports lengthier, but may make analysis easier and more accurate.

The creation of the detailed schedule activities will take place during schedule development, but approaching the design of the level of detail is important to create a schedule that has a consistent and appropriate level of detail through all phases and areas, and for the entire project duration. Factors that drive the determination of the level of detail include:

- Schedule purpose
- Needs of the end users
- Frequency of updates
- Sequencing plan
- Quantity and nature of intermediate milestones
- Nature of key activities being tracked
- Effect of long-lead procurements
- Ability to track responsibility for work and impacts to work
- Interfaces with other data systems
- Ability to monitor separate trades
- Need for coordination with other contracts
- Need for detailed resource tracking
- Approach to change management
- Need to document potential claims or delays
- Reports required
- How innovative or typical the tasks are
- History of conflict or cooperation between parties
- Level of risk on the project and approach to risk management
- Specification requirements
- Desire to maximize finish-to-start relationships among activities

Considering these factors is one way to arrive at an appropriate level of detail. There are also broader approaches, such as considering the level of detail that will make it possible to truly understand the resources required at the activity level to complete each work package within the WBS. Another approach is to establish a level of detail that is consistent with how those responsible for performing the work will actually manage it. Do managers or superintendents need additional detail in order to direct their crews weekly, daily, or hourly? If not, then adding that detail and updating it may be an undue burden with little benefit to those who are using the schedule.

Establishing a common understanding of what the level of detail in the schedule should be will create a greater chance for consistency through the schedule development process. While the detail will be created during schedule development, the decisions regarding the appropriate level of detail can be made during schedule design, with an allowance for feedback from the schedule development process.

Methods and Tools

There are numerous scheduling techniques available for time management, and many incorporate varying degrees of resource management, production management, or financial management. Narrative plans, bar charts, and linear or "line-of-balance" schedules, all continue to be used to plan projects. However, most complex projects now implement some type of network analysis system. These *Best Practices and Guidelines* focus on network analysis scheduling techniques, which have some significant variations in approach. The variety of network scheduling techniques includes:

- Critical Path Method (CPM)
  - Arrow Diagramming Method (ADM) or Activity on Arrow
  - Precedence Diagramming Method (PDM) or Activity on Node
  - Relationship Diagramming Method (RDM)
- Project Evaluation and Review Technique (PERT)
- Graphical Evaluation and Review Technique (GERT)

- Graphical Path Method (GPM) and Logic Diagramming Method (LDM)
- Critical Chain Project Management (CCPM)

Each of these techniques has strengths and weaknesses that have been discussed by their proponents and detractors. ADM has the benefit of clear logic diagrams, but some users feel limited by the use of only finish-to-start relationships and burdened by the need to include "dummy" activities to fully link the network. PDM typically provides four types of relationships, which add flexibility but blur the black-and-white relationships between activities offered by using only finish-to-start relationships. RDM provides the ability to add significantly more coding (and analysis ability) by differentiating between physical relationships and resource relationships, for example (Plotnick, 2008). However, the additional coding is only helpful if used properly. Coding relationships also add another level of effort to the preparation and modification of the schedule.

PERT emphasizes the probabilistic nature of scheduling by having the user estimate three durations for the time between each network node. These durations are commonly referred to as the optimistic, most likely, and pessimistic durations (Galway, 2004). GERT is employed for stochastic networks and allows for Boolean nodes—AND, OR, XOR—and randomly variable times between the network nodes (Pritsker, 1966). Either of these techniques may be more appropriate for the planning of a research-and-development project or for a project that is based on the implementation of innovative technologies or construction techniques. Selection of one of these techniques as opposed to one of the techniques that is based on deterministic duration estimates will have a significant effect on how the schedule is developed. This selection must certainly be made early in the schedule design process. Both PERT and GERT see only limited application currently. The more common technique for addressing the probabilistic nature of forecasting is a Monte Carlo analysis of a properly structured CPM schedule (Galway, 2004). That technique and the software that supports it have many features that were not available in the original PERT technique, but they may lack features that support the looping and Boolean logic that are available in the GERT technique.

The graphical path method and logic diagramming method are techniques that are used in conjunction and focus on collaborative planning and visualization of the project schedule (Ponce de Leon, 2008). The GPM technique focuses on joint planning sessions by project stakeholders to develop the project schedule. The algorithm differs from the typical CPM algorithm in that there is no backward pass. Instead, GPM calculates the "gap" on non-driving relationships in the project schedule, which denotes the amount of leeway between activities that are scheduled on user-defined dates. This differs from traditional CPM schedules, which typically display activities as scheduled on the calculated early dates and display the amount of float available between the early and late dates.

CCPM applies the theory of constraints from operations management to project management (Goldratt, 1997). A key concept of CCPM and the key issue that it seeks to address is the padding (overestimation) of activity duration estimates by those responsible for performing the work. According to CCPM theory, those responsible for tasks pad durations to give themselves a better chance of completing their particular tasks within the allowed time. Proponents of critical chain argue that the padding of task durations undermines the effectiveness of CPM networks in managing for timely completion. Critical chain focuses on identifying the controlling resource (bottleneck) on the project, providing a buffer to keep the controlling resource busy at all times. Like CPM, critical chain theory has proponents and detractors. Its applicability to a particular project must be determined by the project team.

Methods and tools for processes that are closely related to scheduling or supplemental to scheduling should also be selected during the schedule design process. If EVM processes are to be implemented, they will be highly reliant on the structure of the schedule, which must be developed to support required EVM reports. If Building Information Management (BIM) is to be implemented, it is likely and advisable that interfaces between project controls personnel and the design team will be greatly expanded. Software interface requirements will also increase greatly, and compatibility between the BIM techniques and software and the scheduling techniques and software may drive selection of the scheduling tool.

The selection of the primary planning technique will have a profound effect on the schedule design and development. CPM design and development sessions will proceed differently than PERT, GPM, or critical chain sessions. The nature of the project and the experience of the project team with a particular technique will be the primary determinants in technique selection. Software selection will follow technique selection and will be influenced by team preferences and experience, IT infrastructure, and cost.

Existing scheduling techniques and software are continuing to evolve, and new techniques and software are constantly being introduced. Multiple techniques can be evaluated for application to any project, but the selected technique and any software implemented should be well understood by the project team. In addition, the requirements for information technology (IT) infrastructure should be considered in the application of any software package, including software, hardware, communications, internal IT staff, and external support requirements.

Risk Management

All projects are subject to both opportunities and threats, which are considered a risk to schedule, cost, and performance. As noted in the previous section, evaluation of the project's schedule through a Monte Carlo analysis has become the primary quantitative method of analyzing schedule risk. If a formal risk analysis is to be undertaken, it should be identified during the schedule design process so that the structure of the schedule supports the analysis. The quality of the risk analysis will be reliant upon the quality of the schedule on which it is based.

Determining how risk management will be incorporated into the schedule development process by identifying what formal or informal risk management activities will be undertaken will also be important for the timely completion of schedule development. After all, the project must proceed at some point. Understanding the steps that will be undertaken will be important to timely completion of the schedule development process, especially if the schedule is to be adjusted to mitigate risks identified from the risk analysis. Developing the original plan, identifying the known problems, brainstorming the predicted or possible problems, determining the potential impacts, and establishing time contingencies and the method of carrying these contingencies will improve the chance of delivering the project on time. During schedule design, this entire process can be discussed, formalized, and explained so that it will be incorporated into the baseline schedule development process.

Lessons Learned

There is no better time than schedule design to discuss what has worked well in the past and what has not. The immediate project management team as well as other professionals in the organizations can all provide historical data, which will be helpful in the development of the schedule. Incorporate lessons learned from prior schedule design and development efforts and from the execution of previous projects. If the schedule update process was burdensome, discuss ways in which it could be simplified while still providing value. If accurate cost reports were difficult to generate due to budget or contract changes that had to be incorporated into the schedule, find a way to improve that process. If the client or team members were not satisfied with the schedule reports, contact them to determine what reports might be more useful. If project execution is to improve from project to project, the lessons learned from past projects should be incorporated prior to full schedule development in order to have the best chance of correcting the issue.

Inputs/Outputs

No matter how organized the schedule, the quality of the plan is only as good as the information on which it is based: garbage in, garbage out. The schedule design process should include identification of the input data required for schedule development and the output that will be produced, including report content, frequency, and format requirements. With the inputs and outputs identified, the schedule design team can best design the schedule that will convert inputs to outputs over the course of the project.

A detailed understanding of the project scope of work, contractual requirements, and project deliverables can be obtained by reviewing project scope documents and consulting with project stakeholders. The terminology used for scope documents varies by industry, but typical documents include:

- Contract or agreement
- Plans or drawings
- Standard, special, and supplementary provisions

- Specifications, specifically including those related to:
  - Scheduling
  - Liquidated damages
  - Sequencing or phasing
- Award, release, notice to proceed (NTP), or other contractual notice letters
- Scope of work description or summary
- Owner-produced master schedule
- Area designation plan
- Estimate and quantity surveys
- Resource availability table
- Bills of materials

This list of documents can be transmitted as a request to the project management team, and used as a checklist to ensure that the team is really ready to start the design process. In Jim O'Brien and Fred Plotnick's instructional text *CPM in Construction Management* (2010), they note that it is imperative that the person responsible for the execution of the work be involved in the entire data collection phase.

Understanding the outputs that will be required from the schedule design process, from schedule development and from the schedule itself, is as important to design as understanding the inputs. Outputs from the design process can include a written description of the schedule or schedules to be generated, their structure, coding, and other features determined from the design process. Outputs from schedule development include the baseline schedule, resource and cost loading, if applicable, and a written narrative of the execution plan.

Description of Schedules

Identifying and describing all schedules that will be provided or needed during the schedule design process will provide clarity to the schedule development process and provide a reference and checklist for that process. If there are separate contractors who will be providing schedules that need to be integrated into a master project schedule, or if there will be a need to "check-out" a portion of the schedule for remote updates, these issues should be discussed during design. Identifying these types of needs later in the project adds cost and burden and makes it that much harder to maintain a schedule that fits the project.

Narrative

Most practitioners recommend that schedules include written narratives that discuss the intent, assumptions, and constraints on the schedule. The narrative can be used to document the basis for the scope of work that has been modeled, the resources planned, and the costs. Having a clear narrative for the baseline schedule should greatly reduce the time and effort spent in the periodic narrative writing for updates. As the original intent will be clear, update narratives can focus on project variances. Design of the written narrative includes a statement of the purpose and a good description of the contents. With a good checklist in place, and modified during this design process, the development of the narrative during baseline schedule and schedule updates can be reasonably fast while still being professional and thorough.

Schedules

The ultimate work products generated from the schedule design and development processes are the schedules themselves. The intent of all this effort is to generate a tool that is as useful as possible for the project team and stakeholders. For the best work product, apply best practices in design, establish good communications, and rely on feedback from the end users of the schedule in order to improve it continually. Development of schedules is discussed in detail in the Schedule Development chapter of these *Best Practices and Guidelines.*

Update Cycle

One of the primary outputs of the schedule will be the schedule updates prepared over the course of the projects to give the stakeholders a current view of the project status and forecast for completion. The updates likely will be compared to the baseline schedule to determine if the project is ahead of schedule, on schedule, or behind schedule. They will be compared to the previous updates to determine whether any variance is improving or worsening.

How often should the schedule be reviewed with the project team? How often should it be updated with progress? How often should the logic be evaluated or even modified to conform to actual execution conditions? The answers to these questions cannot all be known in advance. However, knowing the requirements for completion of the project and any intermediate milestones, knowing the desire of the stakeholders for status reports, and knowing the potential for risks to materialize into issues, the update cycle can be planned.

The Project Management Institute's *Practice Standard for Scheduling* – Second Edition notes that an understanding of the types of reports that will be generated from the schedule model for each instance of the project schedule will provide guidance on optimizing the coding in the model. The standard also notes that the selection of the frequency of control processes is influenced by the rate of change on the project and the level of detail of the schedule (PMI, 2011b).

Reports

The final baseline and update schedules have to be able to produce the reports that will be required, so it makes sense to have an idea of all required reports while designing the schedule. This means that the organization of the schedule can be set up in the schedule activity codes, filters, layouts, and page formats in a way that supports the required reports. Knowing the reporting requirements up front will allow design of a schedule that best supports those requirements.

Staff

Identify the resources to be used in the schedule development process, and identify the resources that will be responsible for updating and revising the schedule and producing status reports. These are the people whose roles will impact how the schedule is to be used and what information is both needed and available. Another consideration is who will review the schedules. This is the time to work out the process for schedule submission and approval, including any lessons learned about issues that the reviewer will bring to the table.

The change management process should be discussed as it relates to the schedule. When will additional work be added to the schedule, and what will the review requirements be for the additional activities? Some contracts require that activities be submitted as fragnets and accepted prior to incorporation into the project schedule. This review cycle can make it difficult to keep the schedule up-to-date with project process. If this is the case, discuss how to best expedite the process so that contract requirements can be fulfilled, while still maintaining the usefulness of the schedule as a management tool, as opposed to having it become just a documentation tool.

Knowing when the reviewer wants and is able to review the schedule, and what formats are used all help contribute to a smoother process. If the reviewer is loaded down with schedules from other projects on the first of every month it is naïve to think that adding another schedule to review might not be a problem. The time frames for review and approval and the issue of providing an initial project schedule for the first 120 days while the detailed project schedule is developed is a very good discussion to have at this early stage.

On the contractor side, understanding who will provide the update progress data is important, especially recognizing their availability and knowledge of the project. The scheduler may need to validate the data independently or review out-of-sequence progress. The schedule reviewer may allow or even require minor adjustments to logic as part of the update process, or may want full approval for all changes to the schedule. Understanding these issues at the outset will make the project updates run more smoothly and with less contention between the parties. Creation of a responsibility assignment matrix (RAM) for the schedule development and update processes can clarify the roles of the staff that will be involved and ensure that they are aware of their responsibilities.

Buy-In

Buy-in is very important part of the process, as the schedule needs to be the entire project team's schedule, not just the schedulers'. Involve key stakeholders as much as possible and as early as possible in the schedule planning process. If project leadership is involved in the decisions made during schedule design, they are most likely to endorse the use of the schedule to manage the project, and carry expectations that progress reports and metrics will be consistent with the schedule.

Even if key stakeholders have not been extensively involved in schedule planning, an effort should be made to obtain their buy-in to the results of the schedule planning process. Even if it is based on minimal involvement, the endorsement of project leadership will assist in getting the maximum value from the schedule by encouraging the support of all project team members. Similarly, the more team members responsible for executing the work are involved in the schedule design process, the more likely they are to take ownership of the schedule, and provide quality updates and constructive comments to address deviations from the plan.

Recommended Practice

The recommended practice for schedule design consolidates the best practices of the practitioners from the previous section into a concise set of guidelines. In the case of schedule design, the recommended practice represents the minimum set of recommendations that are applicable to almost all projects. Schedulers should review all of the best practices in the previous section and—to the extent time and resource constraints allow—they should incorporate all of those practices that they believe will benefit their project. Recognizing that the time and resources for planning are limited, start with the following:

- Design the schedule before beginning development;
- Involve project leadership and obtain their buy-in;
- Involve project stakeholders and staff to determine their needs;
- Establish the purposes for which the schedule will be used;
- Define a structure for the schedule to help organize the project scope;
- Establish a level of detail that fits how end users manage their activities;
- Select scheduling techniques and software that can support your needs;
- Solicit input and communicate openly to generate common understanding;
- Incorporate lessons learned and build on what has worked in the past; and
- Make a plan for how risk will be incorporated into the schedule.

This list consolidates some of the most significant best practices identified in the previous section. However, recall that no one set of recommendations will be appropriate for every project. Once the intended steps of the process are established for a particular project, it is helpful to create a checklist to ensure that all of them are executed. As the process has been executed on additional projects, it can be continually improved by incorporating the experiences from schedule design, development, and execution into the lessons learned and risk management aspects of subsequent schedule designs. Continuing to hold schedule design sessions for each project, separately and prior to development of the schedule, will provide the best opportunity to maximize the effectiveness of the practices applied to each individual project.

Advisories

Often no plan exists for schedule development, and poorly planned schedules result. Unfortunately, literature in the scheduling industry rarely addresses planning for development of a schedule. The *PMBOK® Guide* establishes scheduling planning as part of project planning, and not as a separate process. Therefore, schedule design has a relatively low profile in comparison to the explicit project management processes and can be overlooked or treated in summary fashion.

Too often, schedulers jump right into development without a plan. In the construction industry, contractor project management personnel are often overworked and may focus management attention only on those activities considered crises. The schedule development deadline is driven by the contract and project progress, but the impetus to start the schedule development is not driven by these same issues. Rather, it is driven by the availability of the project management team to participate in the development of the schedule.

All too often, schedules are not designed, but rather developed immediately without thought for the end result. Schedulers focus on the mechanics of schedule development while the reason for the schedule in the first place is ignored. Decisions regarding available input, level of detail, reporting needs, and end-user needs are not made explicitly. Consequently, they are often made with little thought, and there is a lack of consistency in the approach of the project team.

Schedule development is started without the planning necessary to proceed efficiently and thoroughly. This is a significant risk, and constant efforts must be made to encourage the project team to take the time to perform schedule design. Then schedule development can start and proceed in an orderly, efficient, and complete manner.

The haphazard definition of activity codes provides a good example of problematic schedule development. If schedule development starts without design, activity codes are often defined without thinking out what the final results need to look like, or who the target audiences are that will read the schedule. The schedule and its reports are organized in a clumsy manner, with multiple levels of repeated codes and users hunting from page to page to find activities.

In summary, the greatest advisory regarding schedule design is to not overlook it or give it too little attention. The ability to impact the usefulness of the schedule is greatest before development proceeds, and the opportunity for that influence should not be wasted. In-depth planning, including discussion of project stakeholder needs, and continuing with coordination of these needs with the contract requirements, is far more likely to develop a highly useful tool for monitoring progress and forecasting critical deliverables.

2.2 Analytical Tools

Guidelines

Definitions

Section 6 of the *PMBOK® Guide* – Fifth Edition (PMI, 2013) defines schedule control as a process which is concerned with:

- Determining the current status of the project schedule;
- Influencing the factors that create schedule changes;
- Determining that the project schedule has changed; and
- Managing the actual changes as they occur.

Another definition put forward in AACE's *Recommended Practice No. 53R-06*, "Schedule Update Review—As Applied in Engineering, Procurement, and Construction," (Winter, 2008) is as follows:

> A schedule update review is performed by observing the changes made to the schedule since the last updated schedule update (or the baseline schedule if no previous updates have been submitted and accepted) and evaluating the appropriateness and impacts of the changes.

A project schedule is an important tool for communicating with all the parties involved in the development of the project. The tools used to identify the information mentioned in the above definitions are the analytical tools. Earned value technique, critical path analysis, time performance ratio, Gantt charts, and reports generated from software systems like Digger and Schedule Analyzer are some of the typical tools used for schedule analysis.

Purpose

The *PMBOK® Guide* – Fifth Edition (PMI, 2013) defines a schedule baseline as the approved version of a schedule model that can be changed only through formal change control procedures and is used as a basis for comparison to actual results. A schedule is a dynamic entity and will be impacted and adjusted a number of times during the project life cycle, and comparing the current schedule to the baseline provides indications of performance against the original plan. It is important to keep track of changes to the planned work though formal change controls. Any deviation is likely to introduce additional cost or risk to the project, so changes to the schedule must be analyzed to determine if there is any impact to the time and cost associated with the work. Any time or cost impacts observed as an outcome of schedule analysis must be documented and provided to the project management team. Appropriate stakeholders must be notified about any significant modifications to the project schedule as they occur.

Best Practices

Some of the most commonly used analysis tools are:

Earned Value—The *PMBOK® Guide* – Fifth Edition (PMI, 2013) explains earned value as a performance measurement technique which compares the value of budgeted cost for work performed (earned) at the original allocated budget amount to both the budgeted cost for work scheduled (planned) and to the actual cost for work performed (actual). This technique is useful for cost control, resource management, and production. With the knowledge of earned value (EV), planned value (PV), and actual cost (AC), certain performance indicators can be calculated, which provides information on the current status of the project. These indicators are:

- Schedule Performance indicator: SPI = EV/PV
- Cost Performance indicator: CPI = EV/AC
- Schedule Variance: SV = EV – PV
- Cost Variance: CV = EV – AC

These indicators are helpful in understanding how the project is doing as of the current data date. SPI greater than 1 and a positive SV indicate that more work has been completed than planned. However, SPI greater than 1 does not necessarily suggest that the project is ahead of schedule since more work could be accomplished by working on the activities on a non-critical path. Study of project float will be useful to determine whether the project is ahead of schedule. Similarly, a CPI less than 1 and a negative CV indicates that the project cost performance is below the plan (Lukas, 2008). It also means that more money is spent in performing the work than planned for the same amount of work.

Critical Path Analysis—This determines the duration of the project, as it drives the project completion based on logical relationships and durations of the scheduled activities. It is the longest path through the schedule, but other activities or sequence of activities can become critical if imposed date constraints are assigned to activities. A delay in any of the activities on the critical path will create a delay in the project end date.

Analysis of a critical path for each update period is important as it highlights the high priority activities that must be completed in order to meet the project deliverables. It is a valuable project planning and management tool for (a) time management, (b) monitoring ongoing progress of activities that can delay a project, and (c) for providing project information for early problem detection and decision making.

Time Performance Ratio (TPR)—This is the measure of actual time spent on an activity by the contractor as compared to the originally planned duration. It is a ratio of actual duration to original duration, and it is a performance indicator and is used to identify the affected area, the contractor responsible, and the type of work being affected. It is an effective way to narrow down to the problem area so that further detailed investigation can be carried out. A TPR value of less than 1 indicates that work is accomplished in less time than originally planned.

Gantt Charts—This is graphical representation of schedule information providing the start date and finish date for an activity or group of activities. The data should be selected in such a way that it is easily banded and does not have too many vertical linkages, which can make it unreadable. This is the easy and quick way of analyzing the workflow and conveying the idea of how the project work will be executed. This becomes meaningful when displayed with a timeline that has an easy-to-comprehend timescale.

Gantt charts are useful when different project areas are involved. The work sequence can be easily compared by targeting the previous update and using color coding for distinguishing the two schedule bars. Similarly, Gantt charts can be used to compare the critical path or longest path between any two schedule updates. By adjusting the timescale and sight lines, day-to-day work logic and resources for a small number of activities can be checked.

Analysis by Using Software—A few software systems in the market can be used as excellent tools for analyzing schedule updates. Digger, Schedule Analyzer, and Microsoft Excel are some of the commonly used software systems. These tools can generate reports which provide all the changes made between any two updates. Any information added, deleted, or modified related to any component of the schedule (for example: activities, WBS, dates, calendars, relationships, floats, cost, resources, logs, activity codes/IDs, lags, and many more) can be obtained quickly.

Recommended Practice

It should be noted that analytical tools are the catalyst in the analysis process throughout the project's duration for understanding project status more clearly, and for identifying the problems and making decisions early on. In order to use these tools correctly and obtain accurate results, the schedule needs to be developed using best practices with a sufficient level of details, and a correct work sequence. The schedule also needs to be updated frequently and accurately to represent the actual work.

A well-established schedule management plan, as a part of project management plan, should be in place that discusses how to manage and control the schedule throughout the project's duration.

An approved project schedule known as the schedule baseline should be in place to provide the basis for measuring and reporting progress.

Integrated change control is necessary for continuously managing, approving, or rejecting changes and incorporating the approved changes in to the schedule. An approved change affects the scope, cost, budget, schedule, and quality requirements.

Moreover, the output of an analysis will greatly rely on the inputs provided to the schedule. Therefore, it is important to capture the progress and actual cost correctly.

Advisories

Along with several uses of performance indicators in the earned value technique, there are several limitations. As can be seen from the formulations, earned value (EV) and planned value (PV) conclude at budget at completion (BAC), the planned cost for the project. Therefore, the value of PV does not change if the project is delayed and it causes the schedule indicators to provide false information related to performance. This is observed when the project crosses the 65% to 70% completion mark and therefore should not be the sole measure for tracking a project.

When using a critical path as an analytical tool, it is advisable to minimize the use of multiple milestones and constraints. All activities must have at least one predecessor except the project start, and at least one successor except the project finish milestone, so as to obtain more accurate results.

It should be noted that Gantt charts are not a planning tool and used merely for presentation purposes. Therefore, if the schedule is a complex one with large number of relationships, it does not serve as a useful tool to show logic between activities.

While calculating the time performance ratio for a schedule, the activities should consist of task-dependent activities so as to obtain a rational number. In progress activities, milestones and hammock activities should be avoided in order to obtain more acute performance results.

2.3 Schedule Buy-In

Guidelines

Definitions

Buy-in is a theoretical state where the primary, secondary, direct, and indirect stakeholders of a project commit and demonstrate a willingness to contribute to and reach equitable consensus for the development and execution of the project schedule.

Purpose

Achieving buy-in from the project team can foster an atmosphere of cooperation, thereby facilitating a team effort toward a successful, collaborative endeavor.

Best Practices

First and most important is to identify the project stakeholders. These are people, agencies, owners, etc., that will have direct or indirect influence on the project schedule development and execution.

Once the stakeholders have been identified they should be categorized. To categorize the stakeholders, consider the following:

- What will their influence on the project be?
- Will they be an active participant in the project or a monitoring agency?

- Do they have investment in the project?
- Will they use the product produced from the project?
- Are they for or against the project?

Once you have categorized the stakeholders, prioritize them with regard to their importance and influence on the project. Not all stakeholders need to buy-in or even be involved in the schedule development and execution. Understanding the role a stakeholder plays in the project and addressing each stakeholder correctly will help promote the buy-in process.

Recommended Practice

Establish the need for buy-in at the very beginning of the schedule planning and development process. Reinforce that point throughout the process.

Get formal acknowledgement and buy-in for all important stakeholders at predetermined milestones in the schedule development process. Do not work through the entire schedule development process and then ask for formal buy-in only at the end. If a stakeholder's cooperation and or buy-in is "lost" along the way and not discovered quickly, irreparable damage could be done to the schedule development process and the schedule.

If during the schedule planning or development stage buy-in from important stakeholders is lost, stop the process. Retrace the development/execution steps back to a point when all of the important stakeholders were in agreement. Having found that point, analyze what took place thereafter to create discord, disagreement, and loss of buy-in.

Once the cause of the discord and disagreement has been exposed, work as a facilitator to get the parties back in harmony. Remember, the schedule is a tool for the entire project team to embrace and use. It does not belong to any single member of the project team.

There will be differences of opinion between stakeholders. The influence of special interests and hidden agendas can be devastating to the development and execution of a project schedule. Expect them, and when they become apparent, work as a facilitator/mediator to mitigate their effect.

When possible, collect a stakeholder's needs, suggestions, and requirements in writing. This will provide easy access for future reference.

Advisories

Buy-in is very important to the schedule development and execution process. The stakeholders are more likely to be involved in and support the schedule if they have bought into the process. To proceed without buy-in from the project team and important stakeholders could be very disruptive to the schedule development and execution processes.

2.4 Specification Requirements

Guidelines

Definitions

All projects have a set of documents that define it—the contract, a set of plans, and the specifications. There are others, but these are the main three. The contract speaks for itself and may include some of the specifications. The plans define how the project will be built, what it will look like when completed, and includes all of the necessary dimensions and information on how to complete it. The specifications take that one step further. They define the materials, engineering, equipment, colors, appliances, lighting, finishes, furniture, and every physical thing that will go into the building or the project. They also include specifications on how the project will be managed, responsibilities, reports, scheduling, estimating, and everything necessary to start and complete the project for eventual turnover and occupancy by the owner. In this section we are concerned about the specifications as they relate to the schedule of the project. The specifications are usually created by the owner/design/architectural/structural engineering team, as they are the ones who develop the plans and specifications at the behest of the owner in a design/bid/build construction scenario. If the project is design/build, the contractor may have some say in the plan and specifications development.

Purpose

The construction of a project schedule is not much different from the construction of the project itself. There are certain and specific steps, stages, and logic to building the project as there are in building the schedule that is the plan for building that particular project. The purpose of specification requirements is to ensure uniformity, accuracy, proper accounting for progress, sufficient detailing of the scope of work, the ways to communicate the schedule to the stakeholders, and the ability to account for change and impacts to the project to the satisfaction of all parties concerned.

Default Condition

Specification requirements with the specifications in the project contract and scheduling *Best Practices and Guidelines* from a multitude of sources must be adhered to in any and all schedules.

Best Practices

The aim here is not to provide an example of a schedule specification, but rather to give you an idea of what a schedule specification should include. Both the contract specs and industry standards to build a project schedule need to be followed because, in many cases, the degree of detail in specifications can vary greatly. In all cases the industry standards should be followed, as adherence to them will create a properly built project schedule no matter what the owner specifies. Owner-generated contract specifications can include the same standards as the industry standards, but in some cases they won't or can't, depending on what the owner's demands are for schedule development and report out, or on his knowledge of what a proper scheduling specification should be in the first place. Generally, it can be said that construction industry standards are detailed and cover all the bases. Owner specifications can be very simple and straight forward; they can mirror or mimic industry standards; or they can go way overboard and be very detailed and controlling.

Recommended Schedule Specification Content

- Purpose of the schedule
  - Planning and coordination of the work—plan the work/work the plan
  - Monitor progress
  - Impact and change analysis
- Related specification
  - Notes other spec sections that contain information pertinent to schedule requirements
  - Need to read/review all noted spec sections
  - Related Division 1 sections include the following—taken from master format:
    - "Summary of Multiple Contract," for preparing a combined contractor's construction schedule
    - "Payment Procedures," for submitting the schedule of values
    - "Project Management and Coordination," for submitting and distributing meeting and conference minutes
    - "Submittal Procedures," for submitting schedules and reports
    - "Photographic Documentation," for submitting construction photographs
- Software requirements
  - Notes what scheduling software must be used for schedule submissions
  - May only state what the owner is using, but data must be compatible
  - Sometimes called a relational database
- Data exchange requirements
  - Standard data exchange format
  - Allows database exchange between Primavera and other systems
- Master dictionaries and reports
  - Dictionaries for activity codes, activity IDs, work breakdown structures, resources and cost accounts, and report formats

    - The schedule will and should be rejected if these dictionaries are not utilized in the submittal schedule
- Preconstruction meeting
    - Preparation for the meeting
        - Need of a sequencing plan
        - Need understanding of contractor resources
            - What work is done in-house/self-performed
            - Crew availability
            - Trade issues—buyout and availability
        - Contractor needs for mobilization
        - Need understanding of completion time and all milestones
- Qualifications of the scheduler
    - Software certifications
    - Years of experience
    - Specific project experience
    - Industry certification
    - Scheduler resume submitted needs to show compliance with specs
- Required submittal contents
    - Electronic
    - Paper
        - Report sizes
        - Report formats
        - Required information
        - Copies
        - Distribution
- Owner-mandated milestone treatment
    - Need clear definition
    - Identify all predecessor activities
    - Identify all successor activities
    - Identify any outside influences on completion
    - Decide how to incorporate the milestones in the schedule
    - Determine use of constraints and the type of constraint
- Float ownership
  Float is not for exclusive use or benefit of either the owner or contractor but is a resource available to both parties.
- How is weather contingency being handled?
    - Normal weather
    - Abnormal weather
- Prohibitions on manipulation of a schedule
    - Use of float suppression techniques such as preferential sequencing or logic, special lead/lag logic restraints, and extended activity times or durations are prohibited.
    - Use of any network technique solely for the purpose of suppressing float will be cause for rejection of schedule submittal.
    - Need to have a rationale for any time contingencies incorporated in the schedule
    - Eliminate or define all lags to eliminate concern about float sequestering.
        - Remember, a lag is essentially an undefined activity.
    - Check all start-to-start (SS) and finish-to-start (FS) relationships with lags for possible sequestering.
- Planning units and calendar requirements
    - May specify smallest planning unit
    - May also specify other total project shutdowns—for example, a Department of Transportation (DOT) winter paving halt
- Coding of activities
    - Allows for the filtering out of specific information from the schedule

- CPM network requirements
  - Ensure the spec calls for CPM
  - Normally Precedence Scheduling required
- Duration definitions and restrictions (level of detail)
  - Limitations on size of duration
    - Tied to update period size
    - Tied to project length
    - Tied to project complexity
    - Could be just a limitation such as maximum 20-work-day duration
    - A good rule of thumb is no duration longer than the reporting period, except for long-lead procurement activities.
- Scope definitions
  - Level of detail sufficient to track progress
    - This also ties in with duration.
  - As a general rule, try to eliminate in any activity description the scope of work to be performed by multiple subcontractors. For example, in the activity "Form/Rebar/Pour Spread Footings in Zone 1" there are at minimum three different subcontractors involved in performing that activity—the formwork sub, the rebar sub, and the concrete placement and finish sub. There could also be at least three more if electrical, mechanical, or plumbing trades are needed to perform their scope of work in the embedded concrete.
- Initial Project Schedule (IPS) submission
  - First 90 to 120 days of project
  - Highly detailed for this period
  - Conceptual for balance of work
  - Allows monitoring and management of initial work period
  - Usually details procurement process and permitting
  - Must incorporate all milestones and completion
- Detailed project schedule (DPS, or baseline) submission
  - Use IPS so there is only one schedule
  - Fully detailed with all scope of work on project
  - Must incorporate all scope of work
  - Must incorporate correct milestones and completion time
  - The DPS/baseline is also called the ICPM—initial critical path method schedule
- Schedule updates
  - Usually dictates strict requirements
    - Field verification meeting
    - List of people involved
  - Spec dictates time and process for updates
  - Formal reporting typical
  - Narrative requirement common
  - Checklist of submittal reports required
- Delays and time extensions
  - Details process necessary to prove delay earning time extension
  - Time Impact Analysis requirement
  - Notification requirement
    - Important process to follow
    - Usually tied to discovery of delay event
    - Can be two-part: notice of delay event and the submittal of analysis that will result in a request for time extension
- Recovery schedules
  - If the project encounters the need for a major revision of the schedule due to a change order or a major delay, a rework of the schedule is needed to create a new baseline schedule.

- Early completion schedules
  - Spec may be silent, i.e., no language about submission of a schedule showing early completion.
  - Early completion schedule contains total float, so planned project completion is earlier than contract requirement.
  - Sometimes there is no benefit to the owner for early completion.
  - Sometimes spec requires a change order to advance contract completion to planned completion.
- Final as-built submittal
  - Usually requires one final submittal with all activities progressed to 100%
  - Needs verification of accuracy
  - Spec may require additional activities showing change orders or impact events.
- Short interim schedules (look-aheads)
  - Sometimes called "rolling wave scheduling"
  - Can be produced from full baseline schedule or developed weekly by superintendent
  - Contains more detail, allowing day-to-day management of project
  - If created in another database or software package other than the baseline, the detailed activities in the look-ahead MUST match the overall less detailed/summary activities in the baseline in terms of overall duration, especially as it pertains to the critical path.
- Cost and resource loading
  - Cost loading
    - Commonly done to produce invoices based on schedule progress
    - If required, should unlink percent complete from remaining duration in software
    - Check to see how general conditions are handled. (General conditions are the project's time-based costs; trailer, staff, project utilities, etc.)
      - General conditions may be loaded in hammock or level of effort activities.
  - Resource loading
    - Resources can be manpower, specific equipment, or materials.
    - Units can be hours, days, equipment-hours (running hours), crews, cubic yards, linear feet, tons, etc.
    - Used to enable earned value management
    - Good data in the case of a delay, so planned equipment use can be compared to actual.
- Narrative requirements
  - Spec may have a specific list. For example:
    - Work performed and/or completed this period
    - Work to be performed in the next period
    - The critical path
    - Areas of concern/impact to project
  - Initial project schedule narrative should identify sequence and workflow.
  - Update schedule narratives should identify ALL changes to the planned workflow.
  - The narrative must "Tell the truth, the whole truth, and nothing but the truth."

Recommended Practice

The preferred practice is that there is a schedule specification for all projects. There are many sources available to create your own schedule specification (see list below). The origination of contract schedule specification is dependent on the project delivery system. If the project is design/bid/build, the schedule specifications (and all the other specifications) are usually created by the owner and/or one of his representatives (the architect, construction manager [CM] etc.). It is rare that a general contractor (GC) will create the specification because by the time the GC sees the bid documents (drawings and the project documentation, specs, etc.) they are already created. It doesn't mean that they are etched in stone, however. In most cases, all specifications are negotiable, including the scheduling specs. In a design/build project delivery system the creation of all of the specifications could be a joint effort by all parties. Sources for schedule specifications include:

- AACE
- PMI's *Practice Standard for Scheduling* – Second Edition (2011b)

- *CPM in Construction Management* (6th Edition), by James J. O'Brien and Fredric L. Plotnick
- *Construction Specification Institutes Master Format System,* (CSI 2014 Edition), Section 01.32.16
- U.S. Army Corps of Engineers
- U.S. Department of Energy

Advisories

A project schedule that doesn't adhere to any schedule specifications or to the schedule specifications dictated by the contract and scheduling best practices and guidelines in general will:

- More than likely not be an approved project schedule by the owner
- Be a grave error on the general contractor's part for non-compliance of the contract
- Place the general contractor heavily at risk for using a flawed schedule that may or may not work at all in depicting the scope of work of the project or be able to track and progress that scope of work. Remember, the whole idea behind a project schedule is to tell "the truth" as the project team experiences it throughout the life of the project.

2.5 Critical Path Method

Guidelines

The critical path method (CPM) of scheduling is the most common format used worldwide in the construction industry.

Definitions

Network Techniques

The importance of accurate network construction cannot be overemphasized, for it is the foundation upon which the whole structure of the network depends. A network must logically express the sequence and pattern of workflow as well as the relationships and restraints implicit in the intended plan of operations. Before commencing to construct the network, it is preferable if a written brief or specification is prepared for the project, clearly defining all the objectives to be accomplished. Since networks can be drawn for different levels of management, i.e. with greater or lesser detail, it is important to establish the nature and amount of detail to be included for the level of indenture concerned. Accurate network construction can often be achieved more readily as a team effort by key personnel having specific knowledge of the activities and processes involved. The leader of the team should be fully conversant with the rules and conventions applicable to network logic.

Network Diagrams

A network can be represented by one of two techniques, arrow diagrams or precedence diagrams. The basic element of each is the activity, which represents a task to be performed. Each activity is given a duration, which defines the time required to complete the task.

Networks can be subdivided into smaller units called sub-networks. Each sub-network must be logically complete. Sub-networks are the smallest unit that can be processed, but they can be linked together to form larger networks.

Arrow Diagrams

The two elements of an arrow diagram are directional lines (or arrows) each representing one activity, and circles representing events. Events represent the points at which activities start and finish.

In Figure 2-1, Build Section 1 and Make Up Component 2 finish at event E4, is a name given to an event and is known as the identifier by the preceding event and succeeding event identifiers. Therefore, in Figure 2-1, the first activity is identified as E1-E2; its description is Prepare Site and it has a duration of four

(4) time periods. Events may also be given descriptive data. For example, event E1 can be described as Start Of Net1. However, as previously stated, an event cannot have a duration.

An event is achieved when its preceding activities are completed. For example, in Figure 2-1, event E4 (Component 2) and E2-E4 (Build Section 1) are complete.

Accurate representation of the project by the network is very important, since the data that defines the network is the basis on which analysis is performed. The activities must be placed in logical work sequence, showing which may be worked at the same time. In Figure 2-1, Manufacture Part A, Build Section 1 and Build Section 2 can be worked at the same time, but cannot start until Prepare Site has finished.

Activities may have properties that affect the way in which the network is processed. Such activities are described using the following activity types:

Dummy Activity—This is an activity that represents not an actual task, but a logical link between network paths.

Ladder Activity—Ladder activities are a special group of activities that are used to present progressive feed tasks; for example, in the manufacture of parts that are used to assemble components that are in turn used to make up finished products.

Hammock Activity—If summaries are required or information is needed about a particular phase of a network, a hammock activity can be defined. It can be used to span a number of activities within a network. Similarly, events may have properties that affect the way in which the network is processed. Such events are described using the following event types:

Start Event—This represents the logical start of a network path.

End Event—This represents the logical end of a network path.

Interface Event—Networks can be subdivided into smaller processing units, called sub-networks. Interface events denote points in time at which activities in different sub-networks are dependent on each other.

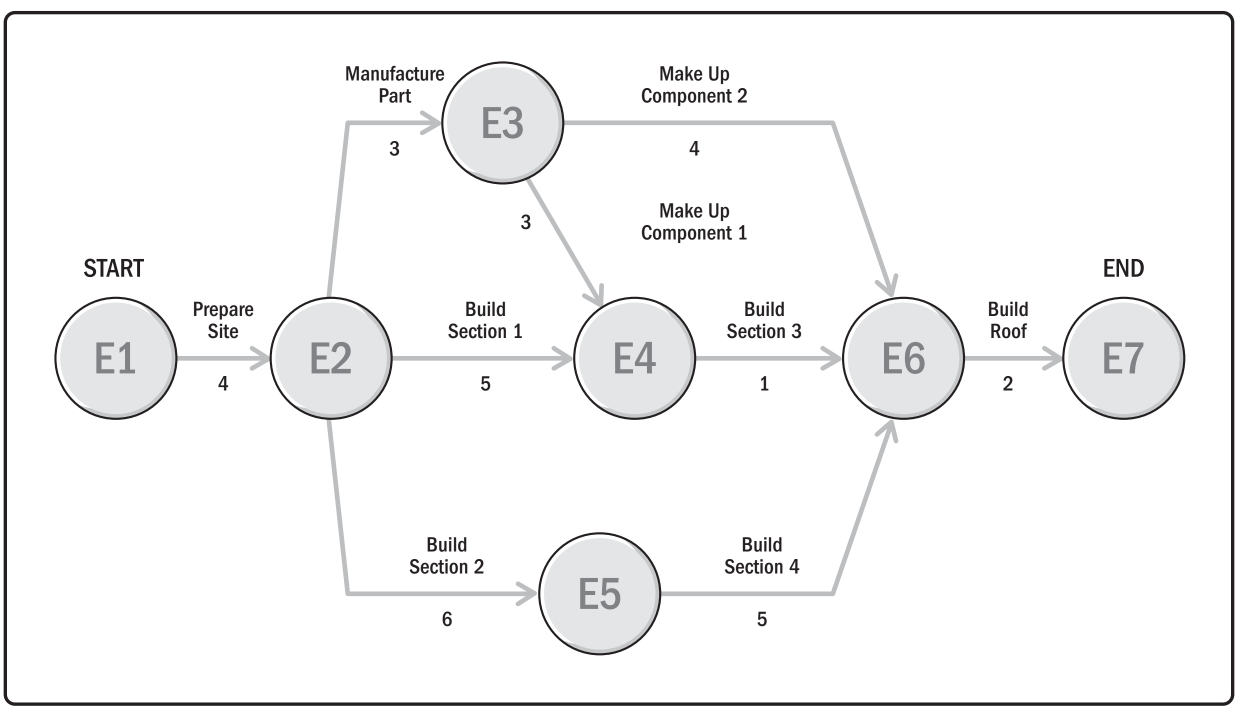

Figure 2-1: Example arrow network of net 1

Precedence Diagrams

Precedence diagrams use boxes to represent the basic network elements, or the activity. The other element of precedence networks is the dependency, which defines the logical link between activities. A dependency is shown in a precedence network diagram as a line.

In Figure 2-2, the dependencies show that Build Section 4 is logically after Build Section 2, and that Manufacture Part A, Build Section 1, and Build Section 2, can all be worked at the same time but cannot start until Prepare Site is complete.

In precedence networks, activities are identified by an activity identifier; for example, A1, A2, A3, etc., as shown in Figure 2-3. Activities have durations giving the period of time required to perform the task, and may have descriptive data attached to them.

Dependencies in precedence networks are more flexible than events in arrow networks. These are four dependency types, as shown in Figure 2-3.

- Finish-to-start
- Finish-to-finish
- Start-to-start
- Start-to-finish

In addition, dependencies may have durations. For example, a finish-to-start dependency with a duration of four time periods between activities A1 and A2 implies that A2 cannot start until four time periods have elapsed since the completion of A1.

Dependencies are identified by their preceding activity sub-network and activity identifier and their succeeding activity sub-network and activity identifier. Dependencies are therefore uniquely identified not only within sub-networks but also within the whole network. This unique identification means that no special action is required to specify the interfaces in networks with interdependent sub-networks.

- As with the arrow diagrams, accurate representation of the project by the network is important.
- Dependencies must be set up to ensure that activities are placed in correct logical sequence.

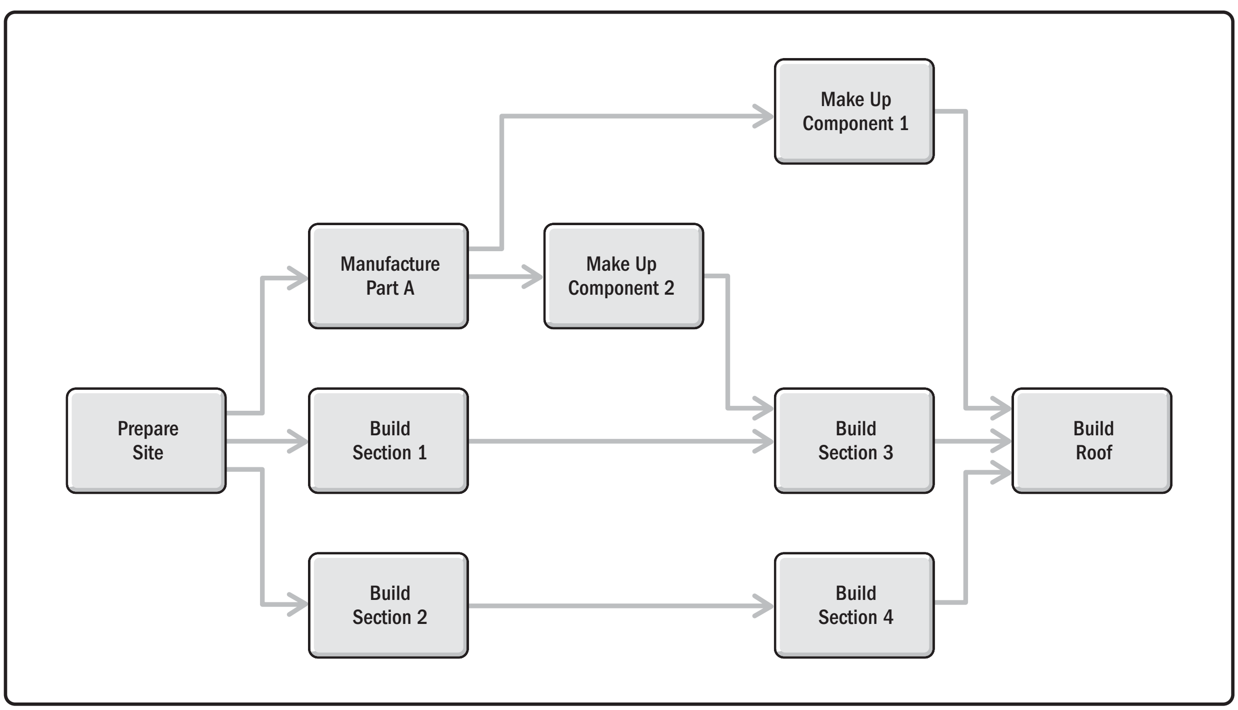

Figure 2-2: Example precedence diagram of network 1

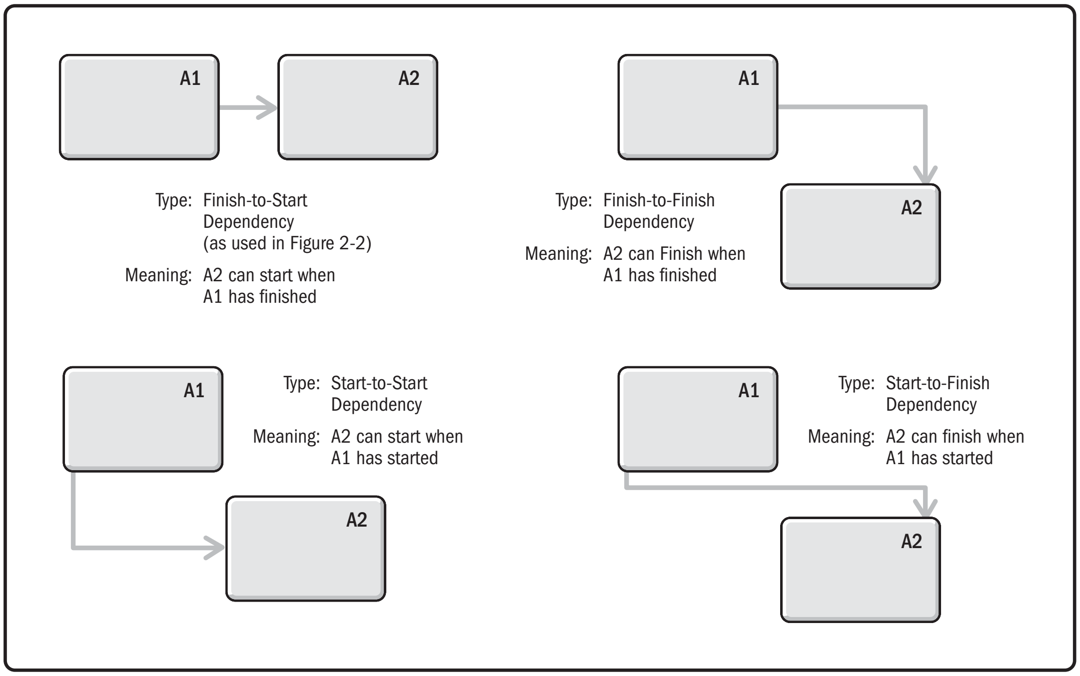

Figure 2-3: Activity and event types

Activity and Event Types

As described in the previous section, activities and events can be given properties that indicate the logic of the network and the way in which it is processed. These properties, usually called "types," are applied according to whether the network is represented by an arrow or a precedence diagram. Common to arrow and precedence networks are:

- Dummy activities
- Hammock activities
- For arrow networks only:
  - Ladder activities
  - All event types
- For precedence networks only:
  - Start activities
  - End activities

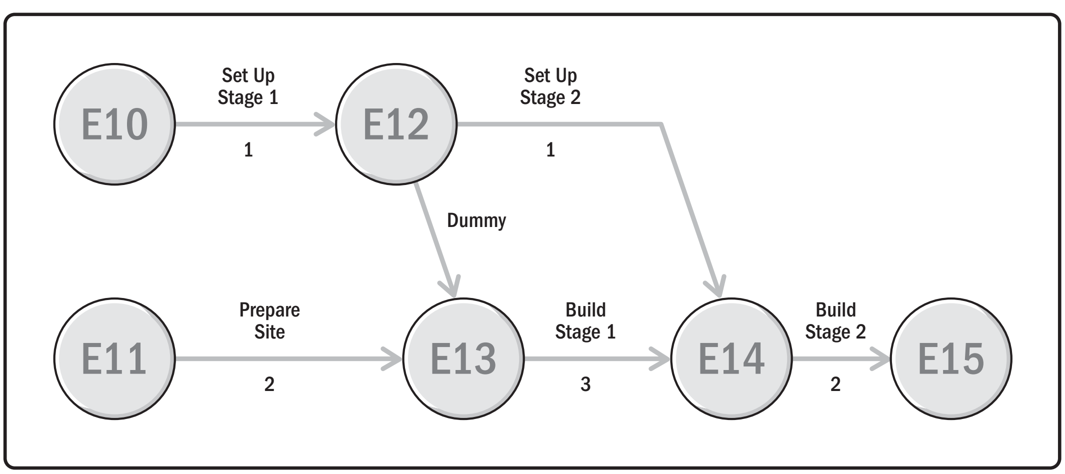

Figure 2-4: Dummy activities

Dummy Activities

A dummy activity is one that represents a logical link between network paths rather than an actual task to be performed.

In arrow network diagrams, dummy activities are normally indicated by a broken line.

In precedence network diagrams, the box of a dummy activity is drawn with a broken line. Dummies can be used in precedence networks to reduce the number of dependencies that must be defined when a number of successor activities are each dependent on a number of predecessors. A dummy activity can also be used to provide a common start or end point in a precedence network that has several start or end activities.

Dummy activities normally have a zero duration because they are being used simply to indicate a logical link. However, some dummy activities do not conform to this pattern. For example, in a building project a wait may be necessary while concrete cures. No actual work is being done and the use of a dummy activity may make the network logically correct. However, the time taken for the concrete to cure is obviously important and a duration should be given to this activity. Such activities are called real time dummies.

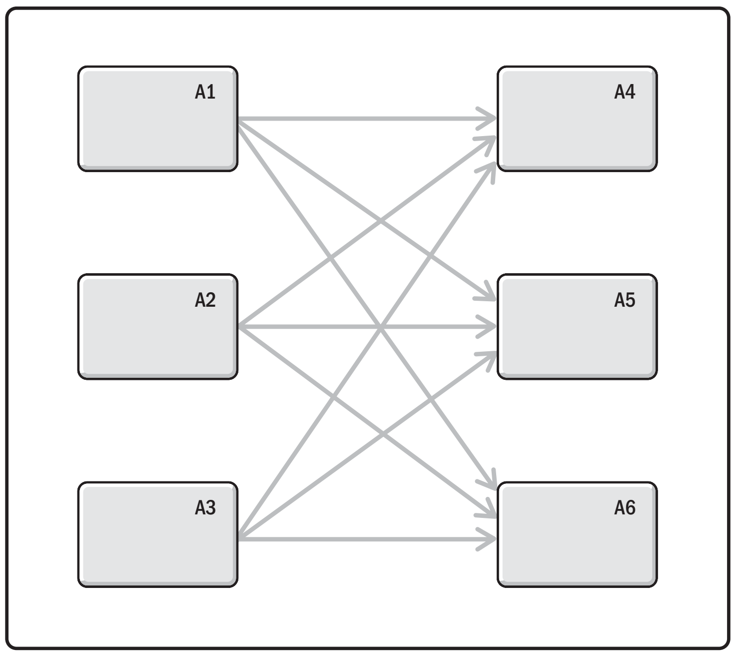

Figure 2-5: Network section using dependencies

Ladder

Ladder activities are a special group of activities used to represent progressive feed tasks. They are relevant only to arrow networks; in precedence networks similar results may be obtained by the normal use of dependencies.

An example of a progressive feed task occurs in the manufacture of a number of identical components, each component having to go through several manufacturing processes. To represent these processes on the network in the normal way would require one activity for the manufacture of the components, another to assemble the unit, probably another for inspection, etc. The same sequence of activities would have to be repeated for each unit required. The resulting network could be extremely complex as shown in Figure 2-7.

Before the second task in such a progressive feed process can start, the first task must have been in progress for a given time to ensure a supply of components for the second task. The time that must elapse before the second task starts is called lead time. Similarly, there is a lag time after the completion of the first task before the second task can be completed. This situation is represented diagrammatically as shown in Figure 2-7:

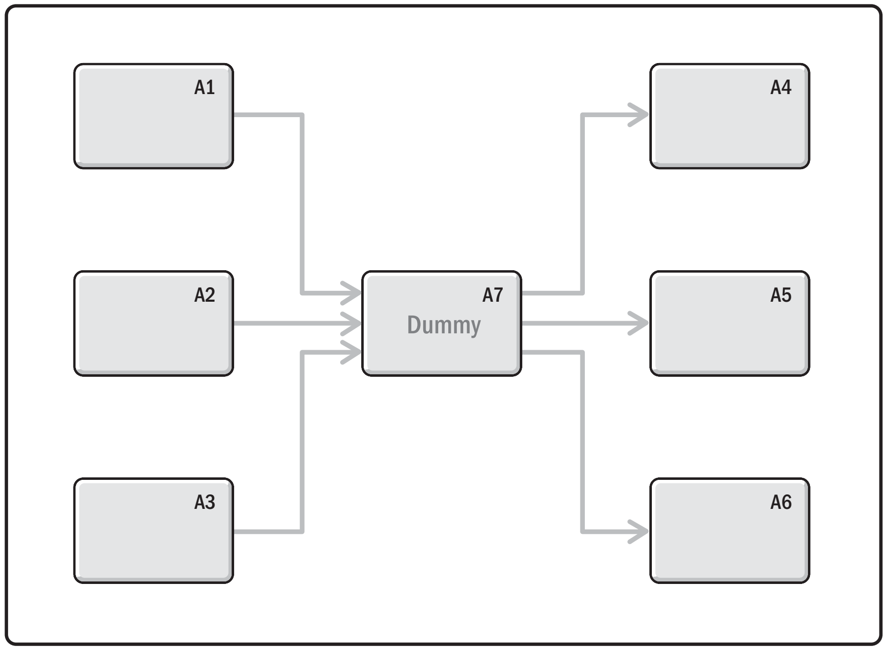

Figure 2-6: Network section using a dummy

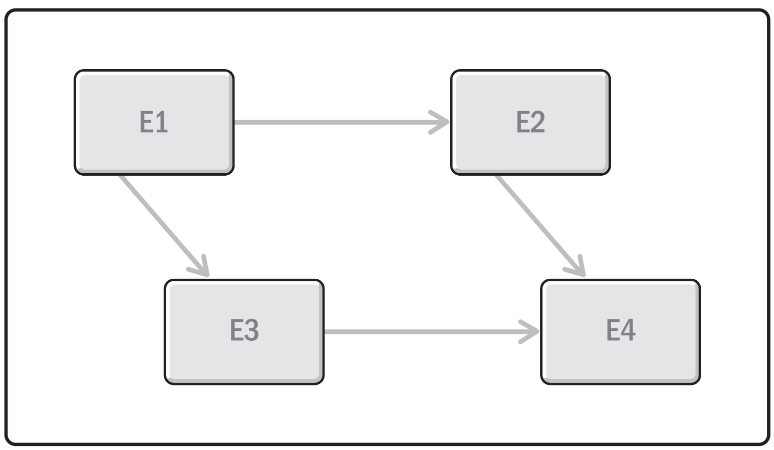

Figure 2-7: Lag time example

Activity E1-E2 represents the first task and E3-E4 the second. In the diagram, they are drawn horizontally and are known as the rungs of the ladder. Therefore the rung activities represent the progressive feed tasks.

Activity E1-E3 is a lead activity, and its duration is equal to the lead time that must elapse between the start time of the preceding and succeeding rungs. The duration of the lead determines the amount of the preceding rung that must have been worked before the succeeding rung can be started.

Activity E2-E4 is a lag activity, and its duration is equal to the lag time that must elapse between rungs. The duration of the lag determines the concluding amount of the succeeding rung that cannot be worked until the preceding rung has been completed.

Figure 2-9 uses a ladder to represent the same progressive feed chain as Figure 2-8, but in a much simpler form. The ladder represents the following logic:

Make Components, Assemble Units, and Inspect Units can all be worked in parallel, but Assemble Units cannot start until five time periods have been worked on Make Components and cannot finish until

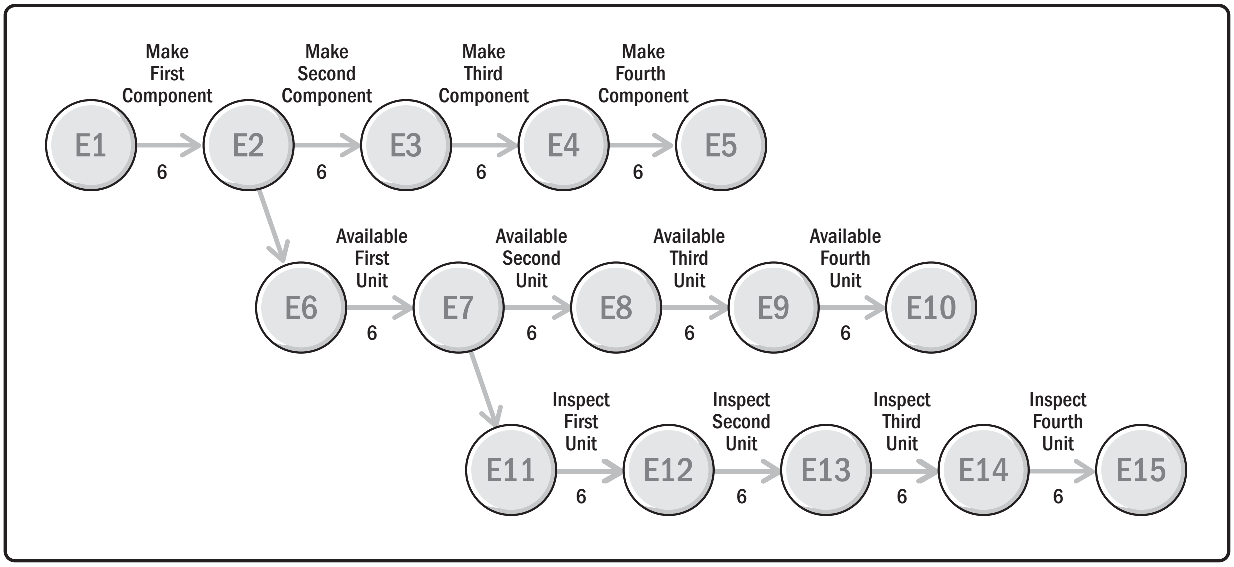

Figure 2-8: Progressive feed without ladders

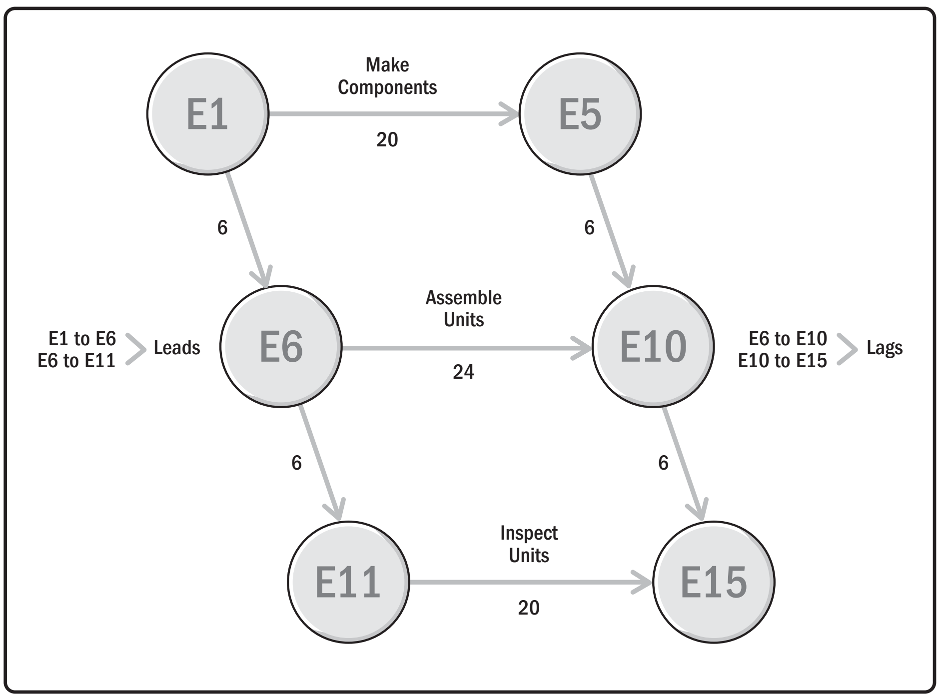

Figure 2-9: Progressive feed with ladders

six time periods after Make Components has finished. Inspect Units cannot start until six time periods have been worked on Assemble Units and cannot finish until five time periods after Assemble Units has finished.

Rung activities are normal activities, given the rung activity type. However, leads and lags are special activities not directly created by the user. The only data supplied by the user about a lead or a lag is its duration, and this is specified with reference to the run activity from which the lead or lag originates.

Therefore, in the simple example given above, the durations for lead E1-E3 and lag E2-E4 would be associated with the rung activity E1-E2.

Complex ladder structures can be created. A ladder can extend to many levels of rungs and branches may occur in the structure. Therefore, a rung may own several pairs of leads and lags, and may be the successor to many pairs of leads and lags. Simple examples of such structures are illustrated in Figures 2-10, 2-11, and 2-12.

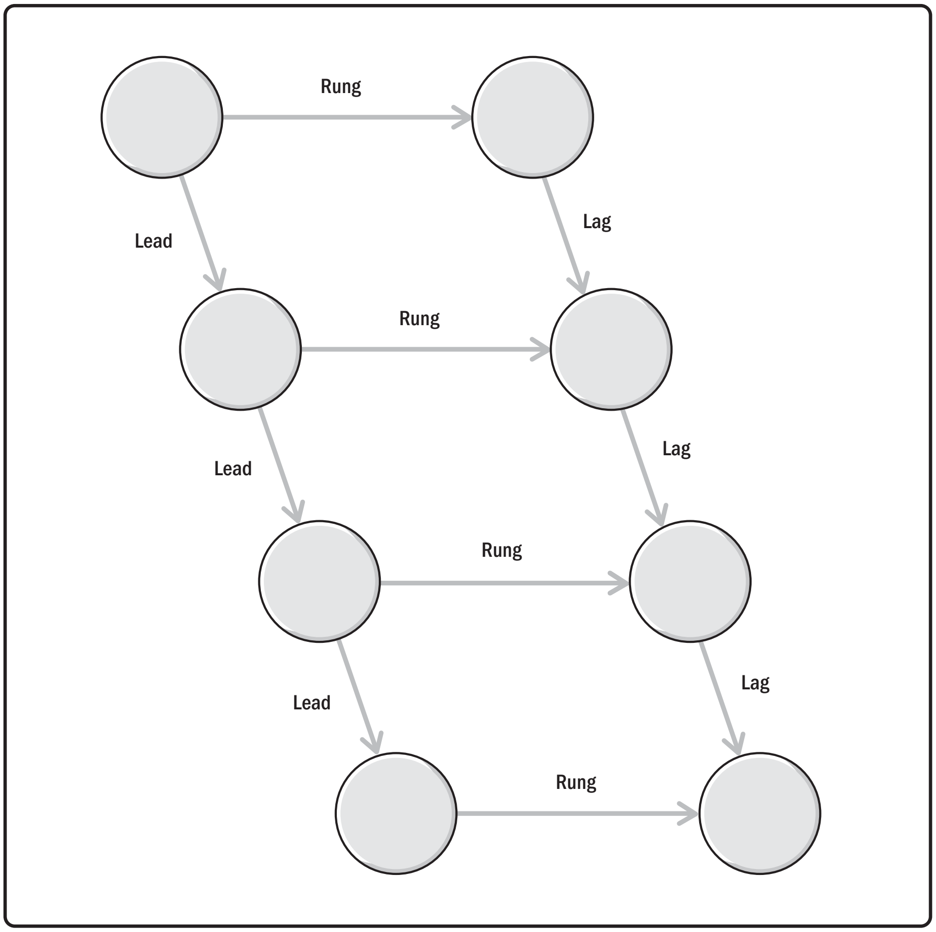

Figure 2-10: A four rung ladder

Hammock

A hammock activity can be used to span a number of activities within a network. The duration of a hammock is not specified by the user; it is calculated by time analysis. Hammock activities can be used in various ways, the two most usual applications being as follows:

Producing Summary Reports

If a project has, for example, 12 major phases—each phase consisting of between 100 and 200 activities on the network—hammocks can be used to produce a high-level report.

A hammock activity could span each phase of the network, and a report selecting hammocks only would give the start and end time and duration of each phase.

Showing Overheads

Consider the example of a project that requires specialist equipment to be hired for part of its duration. If a hammock activity is specified from the preceding event of the first activity that requires the equipment to the succeeding event of the last activity that requires it, the duration of the hammock will give the duration of hire.

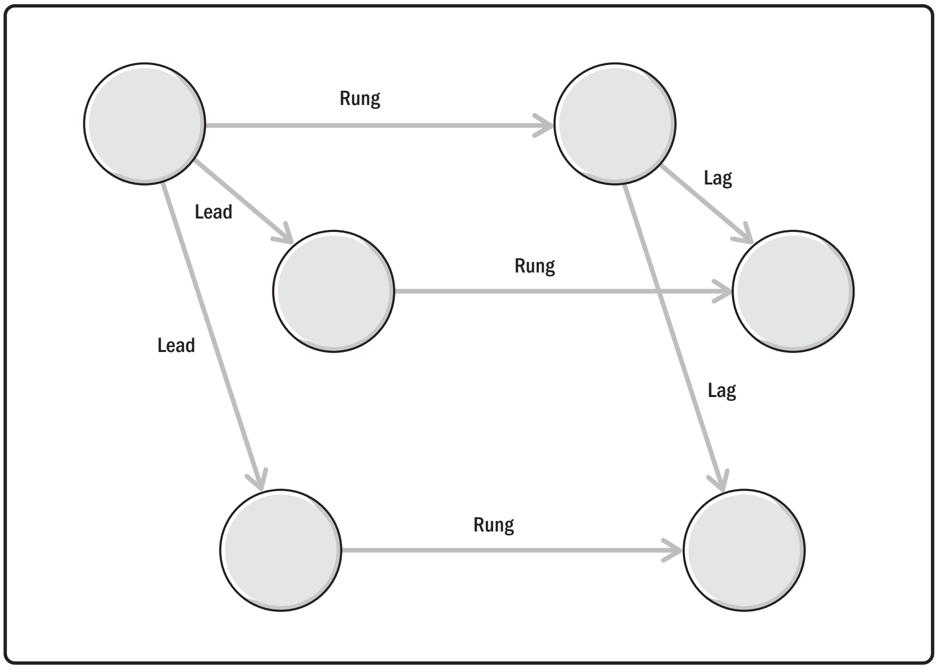

Figure 2-11: A rung owning more than one lead-lag pair

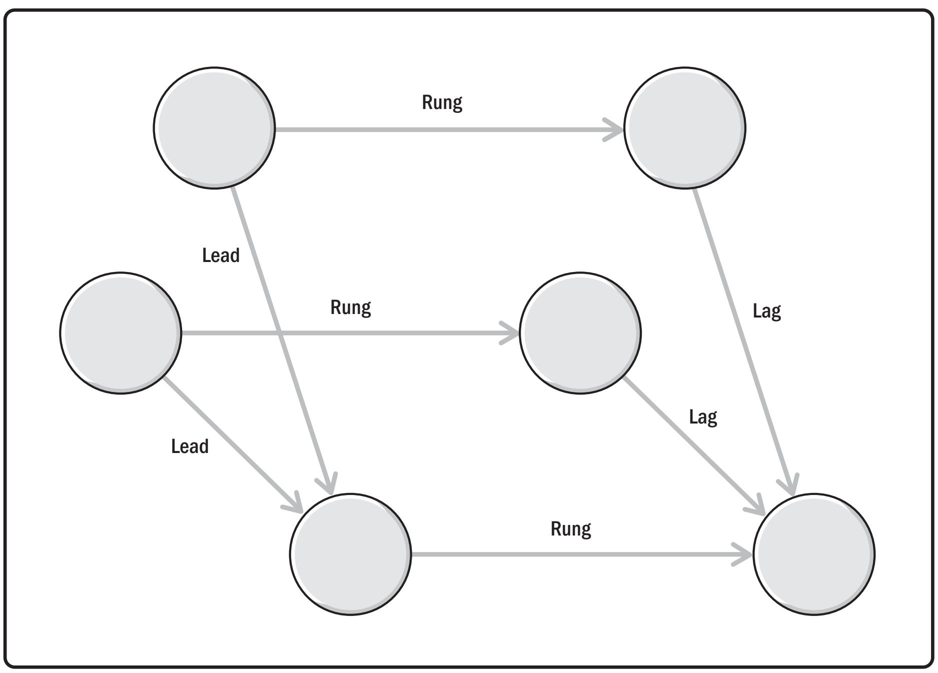

Figure 2-12: A rung with more than one preceding rung

In an arrow network, the preceding event of a hammock must have a non-hammock activity emanating from it. The succeeding event of a hammock must have a non-hammock activity entering it. See Figure 2-13.

Starts, Ends, and Dangles

Events in arrow networks and activities in precedence networks can be given the type start or end. A start event has no preceding activities and a start activity has no incoming dependencies; an end event has no succeeding activities and an end activity has no outgoing dependencies.

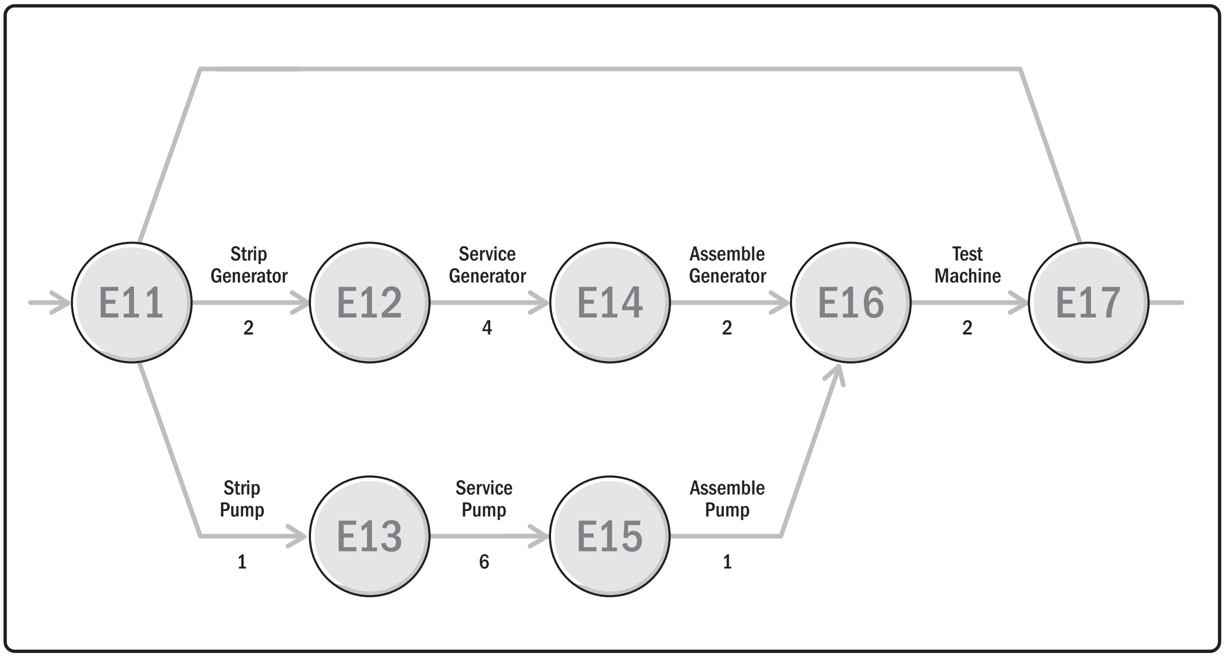

Figure 2-13: Example section from arrow network showing a hammock

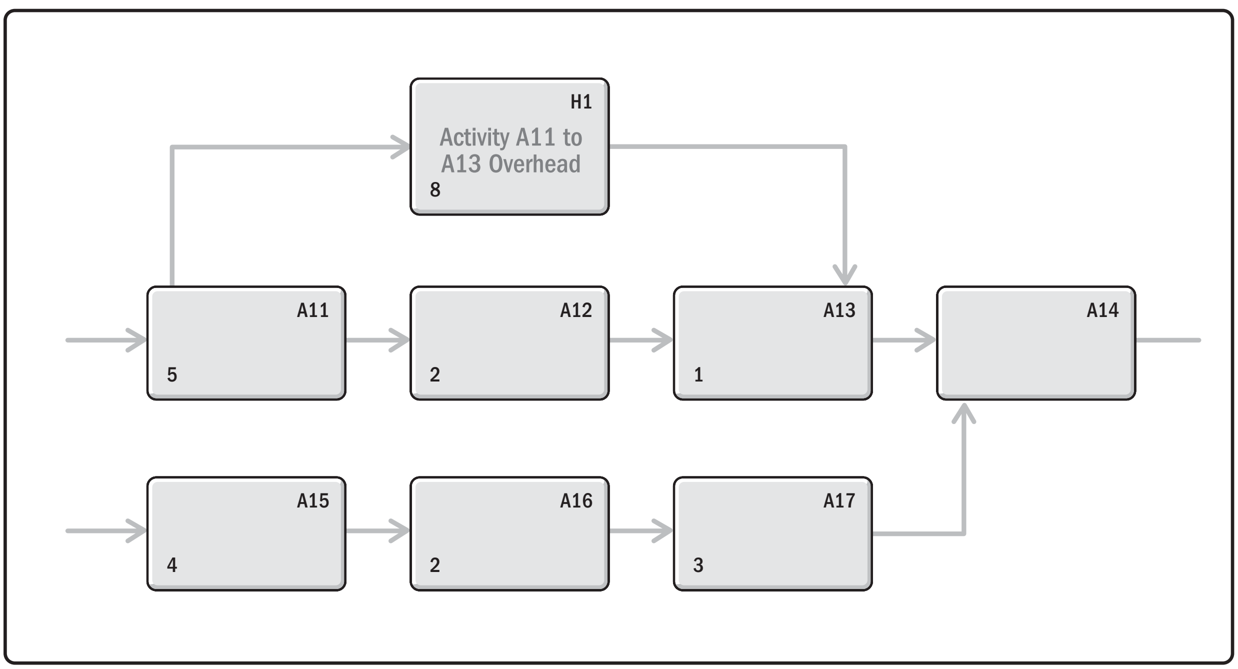

Figure 2-14: Example section from precedence network showing hammock

Networks can have several start and end events or activities.

A dangle is a start or end event or activity that has not been specified as such by the user.

Although networks with dangles can be processed, the user should check that all start and end dangles detected were intended to be start or end events/activities. Time analysis will assume that dangles are logical starts or ends for its calculations and if this is not the case the resulting schedule will be meaningless.

Loops

Occasionally when a network is being constructed an activity is inadvertently inserted such that it causes a section of the network to form a closed loop. This is an illogical condition. When such a condition is found during the analysis of a network, processing must stop since valid results cannot be produced.

2.5.1 Gantt Charts

Guidelines

Definitions

PMI's *Practice Standard for Scheduling* – Second Edition (PMI, 2011) defines a bar chart or Gantt chart as:

> a graphic display of schedule-related information. In the typical bar chart, schedule activities or work breakdown structure components are listed down the left side of the chart, dates are shown across the top, and activity durations are shown as date-placed horizontal bars.

Gantt charts are "static" representations of how the schedule work will be achieved over a specific duration. Gantt charts contain some common features:

- The activities depicted are logic driven but they do not have to display the logic or activity relationships.
- The project activities are shown as horizontal bars against a predefined timescale (or calendar).
- The start and finish dates of the tasks or activities are reflected on the chart.
- Hammock or summary activities are also reflected on the charts.
- Activity dependencies or relationships between the various tasks/activities can be displayed.
- The chart always reflects a "time now" or "data date" to indicate the latest project status reporting date.
- The charts may also reflect extra bars that represent the project baseline for visual comparisons.

Many times in a project schedule, especially in the IT and services sectors, the bars are drawn in graphical or spreadsheet software in absolute terms and are determined by calculated start and finish dates.

Purpose

The Gantt chart was originally developed as a production control tool in 1917 by Henry L. Gantt, an American engineer and social scientist. It is commonly used in project management and provides a graphical or visual illustration of a schedule that helps to plan, coordinate, and track specific tasks or activities that comprise a project. The basic purpose of a Gantt chart is to communicate to the audience a variety of schedule-related information. Examples of information that may be displayed are: activities on the project's critical path, the actual dates of completed tasks or activities, and early start and finish dates for planned tasks.

Default Condition

A Gantt chart could be used in any type of project of any size or complexity. It does not lose its ability to efficiently convey project information to the various users, regardless of project size or complexity. The level of detail reflected on the Gantt chart should be based on logic and manageable by the project scheduler. Whenever possible, avoid activities with durations longer than a reporting period. This allows recording progress of activities and project performance to be more manageable and realistic.

Best Practices

The following are some of the best practices identified with using Gantt charts:

- A Gantt chart is a powerful visual aid to display critical path. However, many of the enhancement features typically exploit color coding. Care must be taken to select colors appropriately. In cases where grayscale copies are made, patterns may be a better alternative.
- Gantt charts can be used to show variances from previously issued schedules. These are usually the baseline and/or a previous update and any schedule variations, both good and bad, and the impact of these variances should be visually displayed.
- The data to be shown in a Gantt chart should be selected in such a way that it is easily banded.

- When showing logic, care must be taken to ensure that there are not too many vertical linkage lines, as this will make the Gantt chart unreadable.
- Set the timescale so that daily work shows up, with a vertical sight line set solid for weekly and dotted for daily, then look at the day-to-day work, along with the relationship lines.
- "Neck" the bars to show non-workdays. This will provide a quick view of the required work and can be used to show a superintendent or carpentry foreman their areas of focus.
- There should be a distinct bar that will depict the percent complete of physical progress since the beginning of the activity or bar.
- It is advisable to show the planned bar or target on top of the current bar, to visually show slippages against the target.

Recommended Practice

Gantt charts should be generated from scheduling software which calculates activity dates and generates the charts based on logic, sequencing, and algorithms specific to the project. It is possible to develop these types of charts manually or in stand-alone graphics software, but it is not recommended.

On large projects that encompass both design and implementation during the conceptual phase of the project, the Gantt charts tend to be based on benchmarks, not detailed logic, which often does not exist yet. In such cases, project management needs to acknowledge the preliminary nature of the early Gantt charts and define a point in the project life cycle when more detailed, and thus representative, Gantt charts will be produced. This is often accomplished following the approval of detail design, when project scope is best understood.

Advisories

Milestones should be reflected on the Gantt charts. Unfortunately, not all tools follow this convention.

A Gantt chart, by definition, does not have to display logic. It is no different than a simple bar chart, except that the dates reflected are driven by logic and sequencing. Activities displayed on a Gantt chart should always reflect the activity description, duration, and start and finish dates.

While allowed, Gantt charts are not the correct tool to use to show logic or relationships. Reflecting this data on a Gantt chart generally makes it too complex to understand.

The Gantt charts should be developed in accordance with the requirements of the target audience/readership and will factor in their likes and dislikes. The use of well-constructed code fields and other tools can be very helpful in the creation of well-received and constructed Gantt charts.

The milestones and summary bars are powerful tools and should be used with discretion. Overuse can overwhelm the user.

Detailed activities in Gantt charts should be assignable to a certain entity in the responsibility assignment matrix. For instance, having an activity called "MEP—first floor" is a bad practice, since there will be a number of trades involved with this. Instead, it is better to break this down into mechanical, electric, and plumbing activities so that the individual activities are assignable to different trades or managers.

Gantt charts should be derived using an acceptable algorithm—one that creates forward and backward passes—and not done manually.

2.5.2 CPM Organization Methods

Guidelines

Definitions

CPM organization is a concept for determining the basic minimal schedule layouts, views, and other conventions to facilitate the use of the CPM schedule by the stakeholders.

Purpose

Activity descriptions, start dates, and finish dates are basic sets of information that are needed in a schedule. Gantt chart provides a time-phased organization of data and is a more powerful communication tool than a simple table containing activity descriptions and dates. Depending on what the audience is interested in, information on variance, float, and responsibility can also be shown on the Gantt chart.

Organizing the schedule so that people can easily read it without getting lost is very important. Grouping activities together, and separating phases and areas, allows everyone to follow the progress of the project and know what should be happening next. The use of filters for creating a critical path or look-ahead schedule can also be useful.

Recommended Practice

Do not micromanage the plan. Organizational tools encourage inexperienced users to keep decomposing tasks into minutiae.

Some schedules are overloaded with milestones, which defeats the purpose of milestones. That purpose should be to reflect the end or beginning of something important to the project. It could be required by contract. or because the project team wants to focus particular attention upon it. Professional discretion is necessary, as the suitable level of milestones depends on the project/program.

2.5.3 Arrow Diagram and Precedence Diagram Schedules

A network is the pictorial representation of the project plan, which shows the interrelationships and interdependencies of the component tasks. It is sometimes known as a "logic diagram" or "precedence diagram"; however, the term "critical path network" is more commonly used throughout industry and will be used in this text.

Critical Path Network Techniques

A network must logically express the sequence and pattern of workflow, as well as the relationships and restraints implicit in the intended plan of operations. Since networks can be drawn for different levels of management, i.e., with greater or lesser detail, it is important to establish the nature and amount of detail to be included. Accurate network construction can often be achieved more readily as a team effort by key personnel having specific knowledge of the tasks and processes involved. The leader of the team should be fully conversant with the rules and conventions applicable to network logic.

Critical Path Network Diagrams

A network can be represented by one of two techniques—arrow diagrams or precedence diagrams. However, the general construction industry standard is to use the precedence diagram, the basic element of which is the task, that represents an amount of work to be performed. Each task is given a duration, which defines the time required to complete the task as well as the resources required to carry out the task.

Networks can be subdivided into smaller units called sub-projects. Each sub-project must be logically complete. Sub-projects are the smallest units that can be processed, but they can be linked together to form larger networks.

Arrow Diagrams

The two elements of an arrow diagram are directional lines (or arrows), each representing one activity, and circles representing events. Events represent the points at which activities start and finish.

In Figure 2-15, Build Section 1 and Make Up Component 2 finish at event E4, is a name given to an event and is known as the identifier by their preceding event and succeeding event identifiers. Therefore, in Figure 2-15 the first activity is identified as E1-E2, its description is Prepare Site, and it has a duration of four (4) time periods. Events may also be given descriptive data. For example, event E1 can be described as Start Of Net 1. However, as previously stated, an event cannot have duration.

An event is achieved when its preceding activities are completed. For example, in Figure 2-15, event E4 (Component 2) and E2-E4 (Build Section 1) are complete.

Accurate representation of the project by the network is very important, since the data that defines the network is the basis on which analysis is performed. The activities must be placed in logical work sequence, showing which may be worked at the same time. In Figure 2-15, Manufacture Part A, Build Section 1 and Build Section 2 can be worked at the same time, but cannot start until Prepare Site has finished.

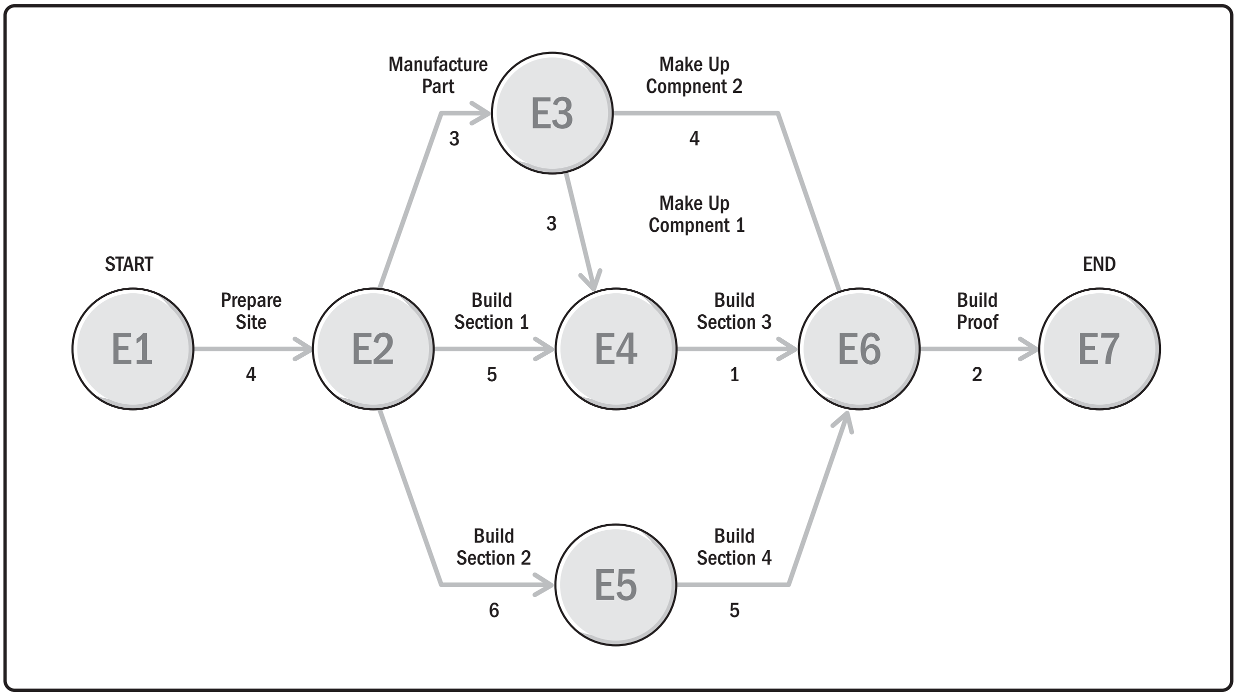

Figure 2-15: Example arrow network of Net 1

Activities may have properties that affect the way in which the network is processed. Such activities are described using the following activity types:

Activity Type

Dummy Activity—This is an activity that represents not an actual task, but a logical link between network paths.

Ladder Activity—Ladder activities are a special group of activities used to represent progressive feed tasks; for example, in the manufacture of parts that are used to assemble components that are in turn used to make up finished products.

Precedence Diagrams

Precedence diagrams use boxes to represent the basic network elements, or the tasks. The other element of precedence networks is the dependency, which defines the logical link between tasks. A dependency is shown in a precedence network diagram as a line.

In the precedence diagram (Figure 2-16), the dependencies show that Build Section 4 is logically after Build Section 2, and that Manufacture Part A, Build Section 1 and Build Section 2, can all be worked at the same time, but cannot start until Prepare Site is complete.

In precedence networks, tasks are identified by a task identifier; for example, ABC21001, ABC21002, ABC21003, etc., as shown in Figure 2-17. Tasks have durations giving the period of time required to perform the task, and may have descriptive data attached to them. Links or dependencies in precedence networks are more flexible than events in arrow networks.

2.6 Schedule Design And Management Plan

Guidelines

Definitions

Schedule design is the process of determining the structure of the schedule based on project and contract requirements. This design is for the project schedule from notice to proceed or any other contractual or project start milestone.

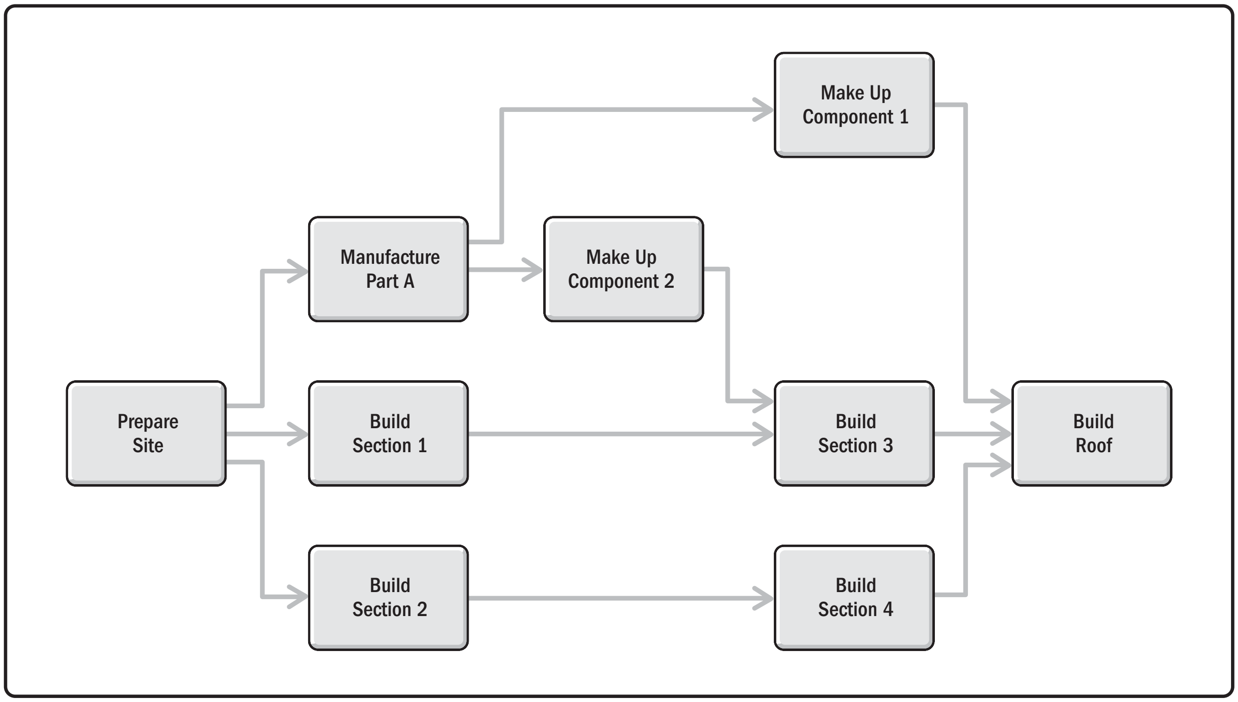

Figure 2-16: Precedence diagram

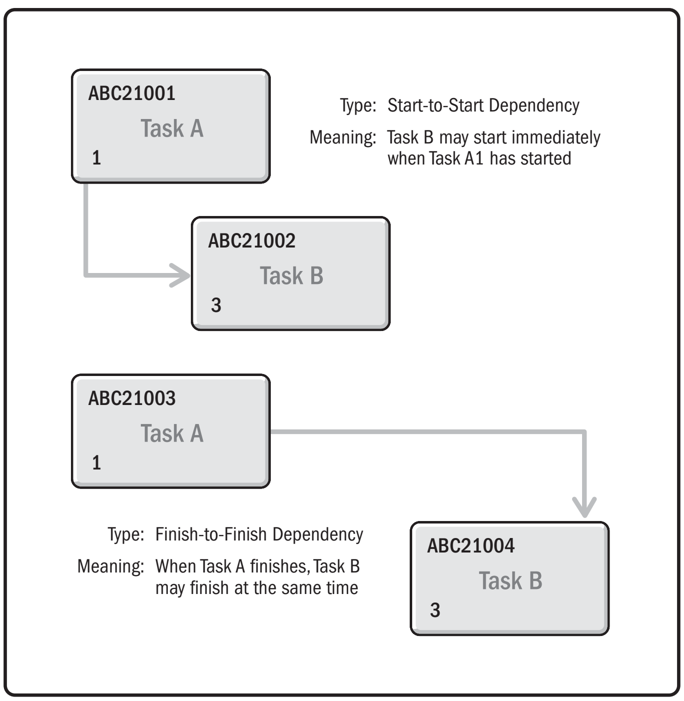

Figure 2-17: Precedence network

Purpose

The purpose of schedule design is to make sure that the structure of the schedule (activity code dictionary, WBS, calendars) is correct before investing time in schedule development. The output of schedule design is a narrative describing the "skeleton" or architecture of the schedule to be used in schedule development.

Default Condition

The schedule design process should occur prior to the development of the initial baseline schedule. Sometimes this process may occur at the same time as bid/proposal schedule development.

Best Practices

Generally, the schedule design requirements will be outlined in the contract documents provided by the owner. The contractor may have their own internal schedule design template, which can be refined as needed to meet the specific needs and requirements of the project. These requirements typically include, but are not limited to:

- Responsibility for schedule development
- Maintenance and approval
- Time frames for schedule submittals
- Updates and approvals
- Level of detail required (durations and activities by trade or responsibility)
- Work restrictions and other constraints
- Work stages/phases
- Area separations
- Milestones
- Cost and/or resource loading requirements
- Contract modification procedures (updates/revisions)
- Types of reports required and format for these reports
- Computer software
- Coding structures to be used

Whether or not the requirements are defined up front, design must happen before development. Time and effort needs to be spent with all major parties (stakeholders) planning out the project requirements.

The output of this schedule design process should be included in the Schedule Basis Documentation.

Recommended Practice

Schedule design should occur prior to schedule development. It is recommended that the structure be defined based on project requirements prior to developing the schedule. During this schedule design process, it is important to identify and determine the following:

- Use/purpose of the schedule
- Stakeholders
- Level of management use
- End user of the schedule
- Necessary inputs
- How often the schedule is to be updated (length of update period)
- Owner requirements versus user/contractor requirements
- Who will update the schedule
- Level of detail required (detailed 90 days)
- Maximum duration of any activity
- Calendar/work hours (workdays/non-workdays)
- Types of reports required
- Activity code structure
- Work breakdown structure, including phases of work
- Milestones
- Resource breakdown structure (if required)
- Cost account structure (if required)
- Earned value rules (if required)
- Assumptions (access, resources, etc.)
- Decision gates
- Schedule integration
- Integrated change control process

Advisories

If little thought and time are put into the schedule design prior to the schedule development, the development process could take longer and likely will not be as useful or efficient.

The owner should ensure that scheduling requirements are defined in request for proposal and project documents.

The contractor should fully review and comply with scheduling requirements and specifications.

The contractor may have their own internal schedule design template, but this template should be refined as needed to meet the specific needs and requirements of the project.

There should be full justification and explanation of different calendars and what activities they apply to. For example, a 7-day procurement calendar involving import from another country may have different holidays/non-workdays than construction activity on a 5-day calendar.

2.6.1 Design of Baselines

Guidelines

There are certain key components necessary for successfully defining a project. These include the scope of work to be performed, the schedule for accomplishing the work, the organization tasked for doing the work, and a budget for the work. These various considerations become the basis of the plan for accomplishing the project. This plan can be documented in a "baseline" or "as-planned" schedule. In complex projects, or projects where there is limited time to develop the schedule, there may be a need to use a two-step process with a separate initial baseline for accomplishing the early work, while a formal detailed baseline is developed for the full project. See Section 3.2.1, "Initial Baseline Development," and 3.2.2, "Detailed Baseline Development," for information.

Definition

The baseline or as-planned schedule is the official project plan for accomplishing a project scope within an authorized budget and within a specified period of time. The fully developed baseline is the detailed work plan for the total project and should include all elements of work at a level of detail to adequately manage and monitor the project.

Purpose

The primary purpose of establishing a baseline schedule is to model the plan for accomplishing the project by its required completion date. It is impossible to know if the project is proceeding according to plan if there is no plan. The baseline establishes a benchmark against which progress reporting can be compared to allow identification of schedule variances, their impact, and corrective action to be initiated. It is essential that all affected parties agree to the project schedule baseline so that it can be used as the common measuring stick for progress, status, and analysis of delays.

This is not to say that the plan for accomplishing the project work will never change. As a project progresses, circumstances may change, and even the project scope may change. As changes occur, it may be necessary to adjust the plan, but the baseline is always available for comparison back to the original plan.

There should only be one baseline schedule. This is the schedule created by the contractor and approved by the owner at the beginning of the project. Later revisions are updates which model the contemporaneous plan for construction, and may incorporate changed conditions that have been approved.

Timing of the Baseline Preparation

The ideal conditions are that the baseline would be ready at the pre-construction meeting, well before construction starts. This is an important goal, though many times not achieved. This is often not unreasonable, however, and should be done whenever possible.

However, when the owner chooses the contract award date and the notice to proceed (NTP) date such that there is minimal time between the two dates for planning, there is a risk that the contractor cannot develop a good schedule in that time frame. The contractor is commonly still contracting parts of the project immediately after contract award and may not have major subcontractors identified yet, so it becomes very difficult to get quality and relevant input for all trades. Clearly, involvement by the entire project management team, including subcontractors and suppliers, is vital for development of a good schedule, and to promote the necessary buy-in by the stakeholders, so without the stakeholders in place during schedule development, the schedule will likely not be as useful as possible.

When a schedule is resource- and/or cost-loaded, this creates additional complexities and risks. The level and type of detail that a subcontractor provides for a resource-loaded schedule is entirely different from one that is not resource-loaded, so this automatically adds time to the information flow. Some organizations use a two-tier approach, completing the full-time schedule without loading, and then later loading costs into the completed time schedule. However, this can cause revisions as the subcontractors start compiling their costs and resources. The time allowed for schedule development should be commensurate with the complexity of the project, the type of project delivery method, the contract, and the length of the project.

The worst scenario is when the notice to proceed is issued immediately upon contract award, and everyone is ready to start work. Under such circumstances, it is nearly impossible to get the contractor to focus on planning, since implementation has already begun and there is pressure to generate invoices. There should be a planning period from notice to proceed until mobilization, and this period should include purchasing, start of the submittal process, permit acquisition, and schedule development. It is reasonable for a contractor to require two months to design and develop a good baseline schedule for an 18-month job.

The goal is to have the schedule submitted as soon as possible. In order to facilitate that, the recommended practice is that schedule requirements be spelled out specifically in the bid documents. This includes the need for a two-stage baseline schedule development process. It can be useful for a progress payment to be tied to submittal of the baseline by the contractor. This will help motivate and expedite the preparation of the baseline.

Best Practice

There is a logical, sequential approach that can and should be used when developing the overall project schedule baseline. The major steps in developing the official project schedule baseline include the following:

1. Define the total project scope.
2. Identify the organization structure for performing the project.
3. Identify the general contracting strategy, so that interfaces between contractors can be adequately represented in the schedule.

These first three steps relate to definition of the project before it is actually scheduled. This early definition enhances understanding of the project and allows schedule development to proceed more effectively. The next steps relate to actual schedule development.

4. Develop a summary schedule with major contractual milestones.

The major milestones are typically dictated by the owner of the project. At this time, it is critically important to insert another step that can make or break the entire baseline development effort.

5. Conduct a schedule planning meeting, or baseline development meeting. No matter what it is called, it serves the purpose of bringing everyone associated with the implementation of the project together in one place to promote mutual understanding and ensure that all parties' needs are satisfied.

On some projects, a single contractor, project manager, or scheduler largely develops the schedule in isolation. This is not the best practice. The problem with this approach is that it does not adequately represent the abilities, resource limitations, or work strategy of all the key project participants. All stakeholders must be represented if project participants on both the owner's side and the contractor's side are later going to accept the plan as their own. Typically, this includes the project management team, with plans in hand, and their knowledge of the project, ready to discuss in detail the required sequencing of the project. If they have not discussed the project sequence with the major subcontractors, the major subcontractors should also be present. This means the general contractor and subcontractors such as concrete, grading, steel, and electrical, should be represented in the effort of developing a cohesive project baseline. This includes superintendents, project managers, schedulers, and the estimators who developed the project budget. Allowing all affected parties input to the official baseline by creating the network schedule is the best approach.

The schedule development meeting generates a number of things outside of the planned sequencing and identification of means and methods. It yields requests for missing information from the plans, a list of issues for the superintendent and project manager to research, risk identification, and much more knowledge about the project than the project management team would normally have at this point. This is the best way to "jump-start" the project plan and project implementation.

This allows the parties involved to buy off on the schedule from the beginning, instead of it being arbitrarily dictated. This has the added advantage that, since the superintendent and project manager were involved in the initial planning, there is a better chance that the field management team will follow the schedule instead of constantly changing the logic because of a need to assert control over the process, or because they did not engage with the planning until a later time.

6. Identify the detailed activities necessary to support the summary schedule.
7. Assign responsibility for each activity.
8. Develop the detailed critical path network logic.
9. Determine initial activity durations.
10. Use scheduling software to perform critical path calculations.
11. Revise the schedule if necessary to ensure consistency.
12. Build a resource table of all resources needed for the project.
13. Load the resources for each activity.
14. Compare the dates developed from the "bottom-up" approach in Step 13 with the "top-down" approach used in Steps 4 and 5.

The detailed baseline must consider the availability of resources so that activity durations are realistic. This may result in adjustments to the initial activity durations established in Step 7.

15. Specify available resources and compare them with those required by the resource-loaded CPM schedule.
16. Resource level the schedule. This is generally done manually by the scheduler and the project team to define priorities.
17. Have the project team conduct a detailed schedule review, ensuring that all work scope is included, resources are reasonable, schedule logic is accurate, and required milestone dates are met.
18. Revise the schedule as needed.

This is important enough to merit some additional discussion. Before the schedule is formally accepted, there needs to be a quality control checkpoint. At this juncture, the schedule should be evaluated by a QC Checklist to make sure that best practices are followed. This includes running some basic metrics on the project, along with analytical reports like a Late Start Sort, in order to see if the worst-case project planning (because the logic shown by the backward pass may very well become the project plan) is even possible. This view may show that there is clearly logic missing that would distort planning of the work.

In fact, this is also an appropriate time to verify that the schedule logic is accurate. Are there activities with no successor? If so, that suggests that the activity does not even need to be performed for the project to be completed. Does the logic reflect real requirements or "nice-to-have" wishes? While those responsible for the work may want to have every bit of information available before beginning their assigned task, it is unlikely in a project environment that such logic will support required milestone and completion dates. Activities may need to be done in parallel rather than in series in order to support the schedule objectives of the project. Once there is confidence that the planned baseline is accurate and can be supported by the various parties, it is time for the final steps.

19. Submit the baseline for approval.
20. Review the baseline schedule and approve if appropriate. This approval should only occur after all major parties agree to the schedule. This includes the owner, owner's engineer, and the construction contractor as a minimum. Once approved, the detailed baseline should be "frozen" for future comparison against the current working plan as schedule status is incorporated. This will allow schedule analysis to be performed and schedule performance to be measured. There are potential concerns about approving the project schedule and administering the approved schedule. These will be discussed in the "Advisories" section.

    While this is a lot of effort, the development of a realistic project plan that allows progress measurement and the visibility of problems early enough to allow effective corrective action is essential to a successful project.

Baseline Challenges

Under-Developed Baselines—In the low-dollar, hard-bid construction industry we all too often see the contractor only willing to perform the minimum scheduling requirements contained in the contract. This leads to under-developed baseline schedules. At bid time, contractors often do not fully review the schedule requirements or adequately budget for the schedule development or management. This equates directly to the level of detail in the submitted schedules and their later usefulness as management and monitoring tools.

This is not a one-sided contractor problem. There is often the problem of the owner not following through on the scheduling requirements, or not knowing what their requirements are. Far too often the project starts without a baseline, and the owner does not put the baseline requirement in the forefront until the project is in trouble.

By allowing the contractor to proceed without a preliminary or baseline schedule being submitted, the owner encourages the same practice on future projects, and then contractors will ignore future requests for establishing a schedule baseline.

A similar problem is sometimes encountered when contractors are negotiating their work. They feel they have an established relationship with the owner, so they don't want to make it look like they are documenting a claim or don't need the planning capabilities.

Specifications that have a minimum number of activities support this problem with under-developed baselines. The contractor will develop a schedule with 501 activities because the specification calls for a 500-activity schedule. This is not the way to design a schedule. The level of detail in the schedule is a function of many other factors such as the end users, the level of management use, the complexity of the project, and the length of the update period.

These important considerations make it essential to define very specific schedule requirements in the initial request for proposal, without trying to tell the contractor *how* to prepare the schedule. Progress payments should be defined and identified specifically related to schedule deliverables, such as submittal of the initial project schedule and proposed schedule baseline, and approval of the schedule baseline by the owner. In addition, company management has to be willing to eliminate a bidder from consideration if the bidder does not comply with the submittal and reporting requirements. In the absence of these conditions, it is difficult if not impossible to get a useful schedule from a contractor.

Compounded Activities—In the development of the initial draft and baseline schedules, we often see the scheduler incorporating compounded activities. For example, the schedule may have a single activity incorporating mechanical, electrical, and plumbing. This is often done for expediency, or to keep the schedule simple. The problem is that these are three separate trades, and typically represented by at least two, but more often three separate subcontractors. Each should have their own separate activities. Further, by compounding activities, the scheduler eliminates the ability to fully manage the resources of the project.

Say a compounded mechanical/electrical/plumbing activity is slipping, and let's assume it is due to the electrical subcontractor not having sufficient manpower. How can the project manager or schedule reviewer fully analyze the situation? Compounded activities also preclude the staggering of these different trades. The mechanical/electrical/plumbing example is used here, but the same scenario also applies to concrete work. An example would be activity descriptions such as Form/Rebar/Pour Foundation XYZ. This practice should be avoided.

It is useful to insist on having separate activities for each resource, as well as for every point in the project where there is a change in responsibility. When multiple tasks are combined in a single activity, it is difficult or impossible to establish who or what is delaying the schedule. Likewise, if any interface points are missing, such as the receipt of vendor drawings for system design, it is possible that the critical path is inaccurate.

Another area to avoid is compounding several areas within a phase into single activities. One example would be a recovery schedule for a school. There may be several buildings in each phase, and let's say the activities are combined for all of the buildings within the phase. This makes it impossible to track, since there may be delays in some buildings while the others could continue. Any recovery schedule would need to separate each of the buildings so that it would be possible to better track progress. Field personnel may still complain because it takes longer to update each week, but why bother even using a schedule that cannot serve its intended function?

In the fully detailed baseline, it is important to divide the project into areas within which progress is relatively uniform. An example is the corridors in a building. These areas usually have mechanicals running in the ceiling, are also delayed from completion by traffic and the potential for traffic damage, and will never progress at the same rate as adjacent rooms. If the corridors are included in the adjacent room activities, either there will be activities that are progressed to 90% and left stagnant until the corridors are ready for finishing, or there will be corridor work that is no longer monitored because activities covering this work are advanced to completion with the adjacent offices. During proper schedule design, it is recommended that areas be clustered with similar areas with expected rates of progress so that the update process will be reasonable.

Advisories

Details of Submittals in Schedule Baseline—There needs to be discussion among the project parties involved about how much detail to provide regarding submittals of information to the owner. Opinions on this subject may be sharply divided between contractors and owners.

Construction contractors like to group submittals into a single activity or a few activities (e.g., concrete, asphalt, electrical, submittals, etc.), unless there is a specific piece of equipment or material that is going to take a long lead time to arrive on-site. Architect-engineering firms will not want to schedule submittal of each specification and drawing. There are some projects where the owner wants to have all of the submittals to help schedule his/her own activities, such as review and approval of each of those submittals. This may result in more submittal activities than actual work. Contractors argue that having so many submittal activities in the schedule creates confusion, and they will filter them out in order to focus on the work activities. They may argue that an excessive number of submittals are not really required for that project.

Owners will argue in response that there cannot be too many submittals in a detailed baseline. Further, the specifications are part of the project contract and, therefore, if a submittal is called out in the specifications, it is required for the project. They will state that the criticality or near-criticality of a particular submittal cannot be determined until it is included in the schedule and properly tied to the physical work activity that is dependent on the submittal being made, reviewed, and then procured in a timely manner. They will state that the criticality of any submittal is a function of the building systems employed, site conditions and geometry, and operational conditions/restrictions. While an experienced person can guess what submittals may be driving the project and if they are critical or near-critical, no one can know for certain until they are included in the schedule. In unusual cases, there have been instances where the miscellaneous steel or rock anchor submittals were driving the critical path due to the phasing and geometry of the site.

As a best practice, we believe in including all potentially driving submittals in the initial baseline, and all submittals in the detailed baseline. Experience has shown that often submittals really are driving the critical path, but project management may not believe that non-work activities should be critical. In addition, it is good practice to place several buyout activities in the schedule so that discussion about how far along the buyout (awarding of all subcontracts and purchase orders) is can be forced at each update. Very often, the failure to either draft or execute a subcontract will prevent the superintendent from starting critical work. This may cause some to say, "We can't see the building in the schedule because of the administrative paperwork." However, that may actually be the case if the failure to pursue administrative work (permits, procurement, etc.) has allowed these items to completely take over the critical path and obscure any work.

Another important point on submittals is that it is critical for the general contractor to confirm with his subcontractors the number of submittals to be made for a particular system. For example, on a recent project the baseline reflected a singular submittal for HVAC. This submittal was on the critical path, and it was actually submitted in five different packages over a period of months. Further, the first of these submittal packages was submitted a few days late. As the initial submittal package was a few days late, this would have been a contractor's delay and it should have been possible to recover. However, as the total submittal package was actually broken down to five different packages, the overall delay impact was much greater. This confusion could have been avoided if the general contractor would have communicated the actual detail with his subcontractor and then incorporated it into the detailed baseline.

The initial draft schedule should include all required early submittal and procurement activities. All too often, projects get off to a bad start by only including submittals that one party believes are important or "critical" to them. We have seen situations where the construction manager for a community college district was only interested in the submittals that had to be reviewed by the department of the state architect (the building authority, in this case), while the contractor's project manager only wanted to include submittals that he felt were critical. His judgment of what was critical was based upon his experience. In reality, no one fully knows what submittals are going to be critical or near-critical until all are included in the schedule and logically tied into the network. Personal judgments of importance or criticality do not take into account the design, site, phasing, or appropriate logic of the schedules. It is the scheduler's responsibility to educate non-schedulers to these issues and resist not fully developing this portion of the schedule to satisfy the desires of non-schedulers. "You won't know what is critical or near-critical until it is in the schedule."

Another benefit of all the submittal processes is that, if done correctly, the schedule will automatically provide the priorities for reviewing and approving submittals. This is of great benefit for a project manager who is overworked, and has multiple submittals in the inbox. This may include items that will prevent the project manager from either starting with the earliest submittal to come in, or worse, from focusing on the simplest submittal (a judgment call) thinking that it can be done quickly. This is often a poor decision because it can take up too much time while critical submittals are ignored.

Approval of Baseline by Owner—All too often, once the initial baseline schedule is created, some parties tend to hold the schedule as an absolute and unforgiving picture of events. The detailed baseline, along with the updates, must be viewed as a living flow of events that can be measured against the initial baseline schedule to confirm or deny viability of progress or delays. Any project activity can be made a variable against the baseline schedule as long as the intent of that schedule remains the same and the accepted completion date is not compromised.

Some hold the opinion that any "approval" by the owner is a risky enterprise and should be clarified further (timing, conditions, forms, etc.) The review and checking of the schedule by the owner, in order to satisfy himself of the viability of the contractor's proposed sequence, poses no problems, but an "approval" of a baseline schedule could potentially open the gates to a flood of claims for a variety of reasons by the contractor if any baseline activities/sequences are disturbed during the works. Any departure from the approved baseline document represents a potential ground for future disputes.

While the baseline schedule commits the project team to the plan they made before the project started, there are always changes in plans once the project is underway. If the owner puts too many restrictions on making changes in logic, or forbids adding additional activities for delays or newly defined work, the schedule no longer represents the project. It then becomes a document nobody follows, but is mostly used as a tool against the contractor for not following the original plan.

There should only be one baseline schedule. This is the schedule created by the contractor and approved by the owner at the beginning of the project. Anything else is either a change order or recovery schedule, and should be noted as such instead of confusing everyone by referring to several versions of the schedule as the "baseline."

However, we need to keep in mind that the schedule should represent an agreement, or meeting of the minds, as to the work plan and the commitments that all project stakeholders are making. While revisions to the schedule may be necessary to accurately reflect the changing conditions of the project, that circumstance does not grant the right for unilateral revisions. Unilateral revisions violate this meeting of the minds. Typically, the owner should restrict the contractor from making unilateral revisions. If a revision to the schedule is necessary, a formal revision request should be submitted by the contractor to the owner for approval. The contractor would accompany this request with the "before" and "after" conditions of the schedule change request, so that the impact is clearly identified. This will avoid later confusion and provide documentation at the end of the project for any schedule delay claims. All proposed changes to the original baseline schedule should be accompanied by adequate justification for each change. This revised schedule is then reviewed and either agreed to, or corrective actions are taken to achieve agreement to a revised schedule.

Some confusion has resulted in the industry because certain scheduling software vendors have loosely used the terminology for "baselines." The baseline is a formally reviewed and approved schedule retained as a starting point for the life of the project. Later approved changes to this plan are documented in "target schedules," which should not be confused with the original baseline plan. There is only one original baseline schedule. In some cases, the project may change so much that an official revised baseline may need to be created at some point, but every change in circumstances and every schedule slip should NOT be declared as a new baseline. Useful schedule analysis requires comparison of the current working schedule against the originally approved baseline schedule, as well as comparison to any "target schedules" that reflect later approved changes to project scope or schedule.

Calendars—A potentially confusing factor when the baseline schedule is developed is the use of multiple calendars. Care must be taken so that realistic project conditions are reflected and the true critical path is not obscured by careless calendar definition. There have been instances of confusion related to project duration, due to misunderstandings between schedulers and non-schedulers regarding activity durations. Does a one-week activity mean 40 working hours, five working days, six working days, or seven working days, possibly around the clock? If different calendars are unavoidable in the establishment of a baseline, a careful review of the calendars becomes part of the overall schedule baseline review at the beginning of the project. Full justification and explanation of different calendars used for the baseline should be provided as part of the submission of the baseline schedule. This is especially valid for procurement activities (usually required on a 7-day calendar) which may involve imports from countries with different statutory holidays than those considered for the construction activities.

The development of both the initial and the detailed baseline is necessary in order to define the initial plan for a project. In the absence of a defined baseline, progress is measured against constantly moving targets which provide little (if any) useful information about schedule progress and performance. Both the initial and detailed baselines must include all contractually required milestone dates. The only reason not to have a defined baseline would be if there are no schedule requirements and the end date is of no concern.

In order to be successfully applied, both the initial baseline and the detailed baseline need input from the contractor and the owner. The contractor's input is necessary so that the schedule reflects the way the work is to be performed. The owner's review and approval is required so there is a confirmation that the contractor's schedule plan will satisfy the schedule need dates of the owner.

2.6.1.1 Initial Baseline Design

Guidelines

Definitions

Initial baseline design is the process of determining the structure of the schedule based on project requirements.

Purpose

The purpose of the initial baseline design is to make sure that the structure of the schedule (activity code dictionary, WBS, calendars, etc.) is correct before investing time in initial baseline development.

Default Condition

The initial baseline design should occur prior to the development of the initial baseline.

Best Practices

Ideally, the schedule design requirements will be outlined in the project bid documents. These requirements should include, but are not limited to, the following:

- Responsibility for schedule development, maintenance, and approval time frames for schedule submittals, updates, and approvals;
- Level of detail required (durations and activities by trade or responsibility);
- Work restrictions and other constraints;
- Work stages/phases;
- Area separations;
- Milestones;
- Cost and/or resource loading requirements;
- Contract modification procedures (updates/revisions);
- Types of reports required and format for these reports; and
- Computer software to be used.

Time and effort needs to be spent with all major parties (stakeholders) to plan out the project from beginning to end.

Recommended Practice

Initial baseline design should occur prior to initial baseline development. It is recommended that the structure be defined based on project requirements prior to developing the schedule. During design, it is important to identify and determine the following:

- Use/purpose of the schedule
- Stakeholders
- Level of management use
- End user of the schedule
- Necessary inputs
- How often the schedule is to be updated (length of update period)
- Who will update the schedule
- Level of detail required
- Calendar/work hours
- Types of reports required
- Activity code structure
- WBS, including phases of work and milestones
- Resource breakdown structure (if required)
- Cost account structure (if required)

Advisories

If little thought and time is put into the initial baseline design prior to the initial baseline development, the development process could take longer to complete.

The owner should ensure that scheduling requirements are defined in the request for proposal and project documents.

The contractor should fully review and comply with scheduling requirements and specifications.

There needs to be full justification and explanation of different calendars and what activities they apply to. For example, a procurement activity that involves equipment or materials coming from a different country on a 7-day calendar that accounts for that country's holidays and non-workdays would require a different calendar than a construction activity such as the curing of concrete that is also on a 7-day calendar where holidays and non-workdays have no influence on the curing of concrete.

2.6.1.2 Detailed Baseline Design

Guidelines

Definitions

Detailed baseline design is the process of determining the structure of the schedule based on project requirements. The detailed baseline design is a refinement of the initial baseline design.

Purpose

The purpose of the detailed baseline design is to make sure that the structure of the schedule (activity code dictionary, WBS, calendars, etc.) is correct before investing time in detailed baseline development.

Default Condition

The detailed baseline design should occur prior to the development of the detailed baseline.

Best Practices

Ideally, the schedule design requirements will be outlined in the project bid documents. These requirements should include, but are not limited to, the following:

- Use/purpose of the schedule
- Stakeholders
- Level of management use
- End user of the schedule
- Necessary inputs

- How often the schedule is to be updated (length of update period)
- Who will update the schedule
- Level of detail required
- Calendar/work hours
- Types of reports required
- Activity code structure
- WBS, including phases of work and milestones
- Resource breakdown structure (if required)
- Cost account structure (if required)

Time and effort needs to be spent with all major parties (stakeholders) planning out the project from beginning to end.

Recommended Practice

Detailed baseline design should occur prior to detailed baseline development. It is recommended that the structure be defined based on project requirements prior to developing the schedule. During design, it is important to identify and determine the following:

- Use/purpose of the schedule
- Stakeholders
- Level of management use
- End user of the schedule
- Necessary inputs
- How often the schedule is to be updated (length of update period)
- Who will update the schedule
- Level of detail required
- Calendar/work hours
- Types of reports required
- Activity code structure
- WBS, including phases of work, milestones
- Resource breakdown structure (if required)
- Cost account structure (if required)

Advisories

If little thought and time is put into the detailed baseline design prior to detailed baseline development, the development process could take longer to complete.

The owner should ensure that scheduling requirements are defined in the request for proposal and project documents.

The contractor should fully review and comply with scheduling requirements and specifications.

There needs to be full justification and explanation of different calendars and what activities they apply to. For example, a procurement activity that involves equipment or materials coming from a different country on a 7-day calendar that accounts for that country's holidays and non-workday would require a different calendar than a construction activity such as the curing of concrete that is also on a 7-day calendar where holidays and non-workdays have no influence on the curing of concrete.

2.6.1.3 Level of Detail

Projects require a schedule as part of the project management process. While there is agreement regarding the need for a schedule, it can be challenging to determine the appropriate level of detail. A number of factors impact the level of detail necessary, and these will be discussed in this section.

Guidelines

Definitions

The simplest definition for schedule detail would be the act of decomposing a scope of work down to the lowest necessary level so that the schedule can be used to achieve its intended purpose.

The level of detail is determined by the amount of information needed by those who will be using the schedule. If using a preliminary or summary level schedule, the amount of detail will be limited to a broad brush scope of work that outlines a general plan of how a project will come together. If using a baseline schedule, then it will be most useful to present the scope of work performed by all parties to a level of detail such that the scope of work can be easily tracked for progress throughout the life of the project. Formal planning of the project before initiation is needed to assess the appropriate level of detail. Development of the project plan for a new project is discussed in Section 3.4 of the *PMBOK® Guide* – Fifth Edition (PMI, 2013).

Purpose

Simply stated, the purpose of schedule detail is to disseminate easily understandable expectations, requirements, and targets to the project team. This will then make it easy for persons involved in a project to understand what they are expected to do and when they are expected to do it. It is intended to adequately illustrate and document the intended plan. Complex problems and systems may, and usually do, require more detail than simple ones. Projects with a large contingent of human resources or subcontractors will require more detail than projects with few resources.

The level of detail is also dependent on what the output from the schedule needs to be, both in data and in accuracy of data. The level of detail depends on the information needed at that stage in the project life cycle. For example, if cost and manpower estimates are expected to have an accuracy of +/- 10%, then a lot of underpinning detail will be needed in the schedule. On the other hand, if it is early in the project life cycle—such as at the stage gate between initiating and planning the project—cost and manpower estimates of +/- 30% would be acceptable. This would require much less detail than in later project stages.

Level of detail is also dependent on the planning unit need. If resources need to be monitored on a daily basis, there must be a much greater level of detail so that out-of-sequence activity work will not artificially distort resource reporting. This is especially true if resources are shared in order to perform out-of-sequence activities, a fairly common problem.

Default Condition

The level of detail is decided based on a number of factors:

- Update frequency
- Uniqueness, size, and complexity of the project
- Risks inherent in the project
- Expertise and availability of project controls staff
- Knowledge and expertise of project management staff
- Management need of visibility on the project
- Stakeholder needs
- Number of contractors and interface points
- Specifications of the project

The amount of detail available for a project schedule depends on the completeness of project scope definition. Very early in a project, when scope is still being defined, it is only possible to produce a summary-level schedule. As the scope is defined more completely, it is possible to increase the amount of detail. This does not mean that the complexity must be increased, just that it can be increased as more information becomes available. Likewise, in a large, multi-year project, it may only be possible to define near-term activities (possibly the first six or nine months' worth of activities) in great detail, while future activities are maintained at a more summary level. As the timeline progresses, these future activities can be expanded into more detail. Nevertheless, there should be a plan very early in the project planning phase concerning the intended use of the schedule and the ultimate reporting requirements. This will greatly influence the amount of detail needed for later project scheduling activities.

Best Practices

The level of detail in a schedule should be determined during the schedule design, well before activities are created during schedule development. This is one of the decisions that have to be made based on a number of factors such as end-user needs, who will manage the schedule, who will read the schedule, how often the schedule will be updated, and what the purpose of the schedule is.

The first rule of thumb is that the schedule should be detailed enough to catch the entire scope of the project, in order to be tracked effectively.

Another rule of thumb used in planning is that no activity can be longer than a specified number of days (such as 20 days) without specific approval. There will be exceptions for certain types of activities, such as shutdowns, research, and long-lead procurement items. This forces more thought by the project team members regarding the logic and detail required to get the work completed and communicated for action and controls.

Alternatively, another rule of thumb states that the activity duration should be no longer than the update cycle, not counting procurement durations with naturally occurring long durations. This link to the update cycle also helps solidify the project decisions concerning how often an update will be performed.

Level of detail is also very dependent on whether the work to be scheduled is going to be performed by the contractor building the schedule. If this schedule is to be used to manage workers on a weekly/daily basis, the detail needs to be much more developed, and updates would normally be expected weekly or every two weeks, with durations limited to one or two weeks.

If most work is subcontracted, there is less need for a weekly/daily management tool and more need for a less detailed schedule in an overview posture. Warning: Subcontractors tend to add wiggle room in their durations when they develop their own schedules, so care must be taken to ensure that their durations and scope of work are detailed enough for tracking.

Still, if the schedule is to be a management tool, used by the staff on-site, the two update period duration is too long. If the schedule is more of an overview with little detail, a two update cycle is probably acceptable. Another recommendation is that interrupted tasks should be broken down into separate tasks instead of in one hammock-type activity.

Absolute requirements in a schedule specification that limit an activity detail based on either a dollar amount or duration may be unreasonable to enforce. When used as an initial guide, this is acceptable. However, absolute requirements may force contractors to break activities into detail that may not make sense. One good example is the ordering of long-lead time material. The manufacturing time for a large valve may easily exceed 20 to 30 weeks, during which there is no detailed activity for the contractor or owner to track. While the valve manufacturer may have a detailed schedule, this would rarely if ever be included in the overall project schedule.

Recommended Practice

The *PMBOK® Guide* – Fifth Edition (PMI, 2013) provides guidance on this topic. A schedule management plan needs to be developed and documented so that project team members are using a consistent set of guidelines. The schedule management plan is defined in the *PMBOK® Guide* as:

> The document that establishes criteria and the activities for developing and controlling the project schedule. It is contained in, or is a subsidiary plan of, the project management plan. The schedule management plan may be formal or informal, highly detailed or broadly framed, based on the needs of the project. (PMI, 2013, p. 558)

Further guidance relating to schedule development and level of detail is provided in Section 6.2.3.1 "Activity List" of the *PMBOK® Guide,* as follows:

> The activity list, WBS, and WBS dictionary can be developed either sequentially or concurrently, with the WBS and WBS dictionary being the basis for development of the final activity list. Each work package within the WBS is decomposed into the schedule activities required to produce the work package deliverables. This activity definition is often performed by the project team members responsible for the work package. (PMI,2013, p. 152)

The question of summary planning versus detailed planning is also addressed by "rolling wave planning," as described in Section 6.2.2.2 of the *PMBOK® Guide.* Rolling wave planning is defined there as:

> a form of progressive elaboration planning where the work to be accomplished in the near term is planned in detail at a low level of the WBS, while work far in the future is planned for WBS components that are at a relatively high level of the WBS. (PMI, 2013, p. 152)

The *PMBOK® Guide* further states that work to be performed within the next one or two reporting periods must be planned in detail.

The level of detail required for an effective schedule will vary from project to project. However, there are certain considerations that should enter into the decision regarding the level of detail to be used. The major considerations include size of project, complexity, duration, and associated risk. Less detail is required for small projects, simple projects, short duration projects, and low-risk projects. As any of these variables increase, the need for larger, more complex schedules arises. The combination of a long duration, complex, risky, and large project will certainly require the greatest amount of detail and schedule complexity. This discussion assumes that the level of schedule detail is to be determined by the scheduler in concert with users. However, these recommendations can be overruled by the owner's direction. If reporting is only required at a summary level and/or schedule is not as critical as cost, then summary schedule tracking and reporting may be adequate.

One obvious rule of thumb is that the schedule cannot be so large and complex that it takes all of the scheduling staff's time to maintain it, with no time left for detailed analysis. A schedule network is too large when nearly all of the scheduling staff's efforts are directed at producing the next report, with little regard for analysis or follow-up.

An important question is, "Who is responsible for setting the level of detail of a project schedule?" The client ultimately defines the required level of schedule detail for reporting. However, the contractor may need a greater level of detail in order to manage daily activities. The project scheduler, or possibly the project controls manager, needs to provide some guidance concerning the schedule development or an unusable schedule may result. Leaving out critical interface points between organizations may result in an erroneous critical path. This must be balanced against the danger of too much detail in the schedule, since that means more time and resources will be required in the development of the initial schedule and maintenance of it throughout the life of the project.

Unfortunately, not all users understand scheduling, so their requirements may not be appropriate. A good suggestion is to have a "meeting of the minds" between the users and a scheduling "consultant" who can make useful recommendations. The project scheduler should facilitate (but also guide) the schedule development process. At the end of the day, it has to be the project team's schedule, and they should own it. The project scheduler should not come up with a schedule independently without consultation with the project team. A caveat to this statement is if the project scheduler is also a planner—meaning that he or she has many years of construction experience. Planners can and do create and build an entire project schedule without input from others as a first pass to schedule development. Once the first pass is built, it is then reviewed and tweaked by the team. This is a real timesaver if a planner is a part of the project team. All the more reason why a schedule management plan is necessary for a collaborative environment.

The above statement reinforces the importance of the first and major step, schedule design, and that in design, all the reasons for the level of detail are discussed. This includes explaining the benefits of more highly detailed schedules, as well as the accompanying disadvantages, and a similar approach for the use of more summary schedules. The team needs to understand both the benefits and disadvantages of the level of detail chosen in the design phase. This decision has to be made and agreed upon by the schedule development team before the first activity is drawn in the network or the first computer is engaged. At the end of the day, the project scheduler is primarily a facilitator, formatting the team's plan into a cohesive, organized document. Schedulers prepare the project schedule for the project team's use, not their own. This suggests that the scheduler must provide what the client (team) wants, even if the scheduler thinks she/he knows better.

Advisories

Use of Templates and "Boiler Plate" Schedules

A standard activity list from a previous project may serve as a useful template for creating a new project schedule. This has the advantage of saving time and using a schedule that was previously "debugged." The caution regarding this is that a project schedule should not be a boiler plate. Each project has unique requirements, risks, and interfaces that must be addressed on a project-specific basis. While a template can be a great timesaving option for the initial creation of a new schedule, it should not stand as is without being adjusted for the current project's specific scope and requirements.

Too Much Detail

Never require more detail than is requested or needed. Excessive detail in a schedule causes friction with the users and can render the schedule useless if the user cannot manage and understand it.

Too Little Detail

Too little detail may result in an erroneous schedule. Specifically, elimination of essential interfaces or certain work scope can easily result in an erroneous critical path. The concern is that the problems with having too little detail typically do not show up until either the project starts slipping and the schedule is of little help, or the project encounters a claims situation.

Compounded Activities

If a schedule is to be used for resource planning, compounded activities should be avoided. For example, the schedule may have a single activity incorporating mechanical, electrical, and plumbing. This is often done for expediency or to keep the schedule simple. The problem is that these are three separate trades, and typically represented by at least two, but more often three separate subcontractors. Each should have their own separate activities or resource planning will be confused.

It is useful to insist on having separate activities for each resource, as well as for every point in the project where there is a change in responsibility. When multiple tasks are combined in a single activity, it is difficult or impossible to establish who or what is delaying the schedule. Likewise, if any interface points are missing, such as the receipt of vendor drawings for system design, it is possible that the critical path is inaccurate.

Avoid Duplications and Redundant Entries

During initial creation of a schedule, it may appear that the list of phases or tasks might have similar descriptions. Each phase should be evaluated independently on its own merit of task duration/value/relationships. If tasks are in an exact and identical pattern for sequenced turnovers, field values or relationships can vary slightly to produce different results. If schedule sequence is modified for any reason, the true values assigned to each task must reflect what is anticipated or expected to occur for that specific activity in the field. This is another way of saying that boiler plate schedules must not be used.

2.6.2 Documentation of Schedule Assumptions

Guidelines

The effort of developing and maintaining a project schedule is an iterative one. It involves many individuals and is comprised of many discussions, assumptions, and actions. Documenting these activities only makes sense. Once captured, these issues provide the guidance needed during the development phase. It allows the scheduler to refer back to notes that assist them in the development process, providing details for complex logic strings that were discussed earlier between various parties and establishing requirements for milestones that were agreed to by the various stakeholders.

Once complete, the project schedule also provides the rationale for why it was constructed the way it was. And over time, as the schedule changes, it will help the scheduler document why changes occur and the rationale for them. This section will discuss the various methods that can be utilized to document schedule assumptions and other pertinent data.

Definitions

During the initial process of creating a project schedule, the entire scope of work may not be completely spelled out or even known, but the builder of the schedule knows that the scope of work is there and needs to be accounted for. Therefore, assumptions are made and documented about that unknown scope of work and they act as placeholders in the schedule that, once they are known, can be fully detailed.

Purpose

As the project scheduler, you have to start gathering information on what you are building and how it is going to be built. Some of that information will be known immediately; however, as the scheduler, you will have to make assumptions about what is not known. Those assumptions and the schedule activities that they represent need to be documented as to how and why you made them and then adjusted at some later date as more information is known.

Default Condition

The project development processes should describe how project documentation is accomplished, as well as establish suggested guidelines for the practice. Project assumptions and other information deemed important to the project should be captured and maintained within the various project components. Once these items are captured they can be referred to again and again to ensure continued compliance with the original concepts or in order to modify them to reflect the new requirements. They can also be used to explain the schedule content to outside parties and others not involved with the original development.

Best Practices

During the development of estimates, schedule milestones, activities, schedule logic, durations, and assignments of resources—to mention just a few events—we make a multitude of assumptions. In addition, we often work out logical activity sequences that become the basis for our schedule logic and requirements to meet project milestones. All of these events take place as we develop the project schedule and are generally specific or unique to a particular project. Documentation of these events through meeting minutes and other narrative reports to the files are examples of how this information can be captured and used at a later date.

Another means of documenting schedule issues is the utilization of log records or other code fields contained within most modern scheduling tools. These tools allow one to capture explanations and narratives that explain what has occurred and why. It has the advantage of linking that narrative directly to the activity that is most affected by the assumed cause of the change. Finally, it is maintained in the schedule database and requires no special effort to save and maintain it.

Recommended Practice

It is recommended that—during the development of estimates, schedule milestones, activities, schedule logic, durations and assignments of resources, and any other schedule development activity—the practitioner utilize some method to capture the events that occurred during the development effort. This includes capturing such things as assumptions, logic, and the basis for durations and resources, to mention a few.

This can be accomplished using meeting minutes, narrative reports, and letters to the files, as well as log records or code fields within various project scheduling tools. It is also possible to use more than one method.

The important thing is to capture and document any assumption or information that will help explain how the schedule was developed and will assist others in understanding what was done and why.

Advisories

We should not only document assumptions but also complicated logic flows (often with fragnets), rationale for major decisions, and other project events that may assist us at a later date.

2.6.3 Use of Multiple Schedules

Guidelines

Definition

Projects require a schedule as part of the project management process. This is defined in Section 6 of the *PMBOK® Guide* – Fifth Edition, "Project Time Management" (PMI, 2013). In addition, the requirement to have a project schedule is also often defined by project contractual and scope documents. In fact, many modern project requirements call for a baseline and other target schedules to be utilized during the life of the project. These various special schedules are in essence copies of the approved project schedule and used mostly in the oversight of project performance.

Competing schedules or multiple versions of the project schedule are not desired and should be avoided. Only one schedule should exist on a given project. There may be copies to be used for historic purposes and for tracking performance, but they should all have been derived from the original single schedule. This section will discuss the various types of acceptable schedules for a project.

Purpose

The purpose of this section is to define what type of schedules will be used on any given project. There can be multiple schedules derived from the master schedule but there cannot be multiple project master schedules.

We will also discuss the unacceptable practice of having multiple project schedules that exist outside of the approved project schedule. These are often utilized by organizations outside of the project management team and will generally result in adverse project performance issues. If found, copies should be eliminated. With today's modern project management tools, containing multiple code fields and interface options, no organization or group should feel the need to create and maintain an isolated schedule.

An isolated schedule would be one created by any number of project participants to paint a different picture of a project schedule other than the master project schedule. Remember that the scheduler is the messenger and often, project participants do not necessarily like the information the master schedule is reporting. For example, the owner, contractor, or subcontractors do not want to hear that the project is going to come in late. So folks have been known to get creative and have two schedules—the real one that tells the true story and another schedule that paints a rosier picture as a cover for what is really happening. The practice is highly unethical and can result in a lot of trouble for those that use it if the practice becomes known.

Default Condition

A typical project maintains a current active schedule, contains an approved baseline schedule, and contains copies of various schedules made after updates or progress were reported. These copies are referred to as "target schedules," and each is numbered uniquely and stored for future comparisons.

A well-constructed schedule contains multiple code fields and other means for sorting and organizing in a number of ways. These methods allow a single schedule to accomplish the needs of all the organizations involved on the project.

An entity that is part of the project might be allowed to possess and maintain its own schedule separate from the master project schedule; however, it must be required to automatically link to and update the integrated project schedule on some defined periodic basis. This ensures that the entity in question remains an integral part of the project team, project schedule, and the impacts from or to any project effort it is responsible for will be automatically released by the entire project. This process can be abused and should be monitored closely.

Best Practices

Most projects have one approved integrated master schedule (IMS), regardless of the project size. The schedule contains code fields and other means of sorting, selecting, and organizing the schedule data to create reports, graphs, and other project data that fully meets the needs of all project team organizations and stakeholders. In addition, the IMS can be summarized to a variety of levels, which provides appropriate levels of project schedule detail to a variety of individuals. Finally, the IMS is properly maintained on a pre-established cycle of updates and reporting progress, so it remains current and accurately reflects the approved project completion plans.

In addition to the IMS, most projects maintain an official baseline schedule (a special target type schedule) which was created from the IMS at the point in time when it was initially approved by the project stakeholders as correctly representing the project plan. Once created, this baseline schedule is maintained and utilized for comparisons and in earned value management (EVM) throughout the project life cycle.

In addition to a baseline, many projects also employ other target schedules. These target schedules are copies of the IMS usually made after an update period. They are used to track performance and project progress from one period to the next. The key is that it is a separate and static copy of the IMS created at a specific point in time and is not statused in any way.

Some projects also allow subcontractor team members to maintain a separate schedule of the project that represents ONLY their activities. In these cases, great care is taken to ensure that the various schedules have and maintain proper linkages. Often the subcontractor is required to number their activities in the same way the IMS is developed, and with identical activity numbers where interface points exist. During the update process, the schedules are electronically linked and the update is obtained in that manner. This close linkage is difficult to maintain, but ensures that any adjustment in the subcontractor's schedule will be transmitted to the IMS which controls the project. In a similar manner, if others cause movements in the subcontractor's activities within the IMS, the subcontractor will see the result of this movement. As you can see, the concept of having and maintaining multiple schedules can be difficult and is strongly discouraged. However, if they are present, they must be linked to the IMS in such a manner that any movement in the separately maintained schedule will be reflected in the IMS at the appropriate level of detail or interface.

Recommended Practice

It is recommended that all projects have one approved IMS, regardless of the project size. The schedule contents should include code fields and other means of sorting and organizing the schedule data to meet the needs of all project team members and stakeholders. These needs can be met at multiple levels of schedule detail. This IMS will be the official project schedule file and will be kept current through an established update process.

In addition to the IMS, the project should maintain an official baseline schedule and may also have and maintain various target schedules. All of these additional schedules including the baseline file will be derived from the IMS at some instance in time and MUST be copies of the IMS at the time they were created.

Additional project schedules maintained separately by any organization are strongly discouraged. However, if they are present they must be linked to the IMS in such a manner that any movement in the separately maintained schedule will be reflected in the IMS at the appropriate level of detail or interface.

Advisories

Projects should have a single current project schedule.

Projects should have an official approved baseline.

Projects should employ a pre-established update cycle.

If projects have separately maintained schedules they should be hard linked at an appropriate level of detail.

There can only be one project schedule on any project once the baseline schedule is built and approved by all stakeholders. Any and all schedules after the baseline schedule has been approved are iterations, or updates, of that baseline schedule. As mentioned, there can be filters of the baseline or the subsequent updates that are presented to the subcontractors and other stakeholders and those parties can alter and add to those schedules on their own as long as they are derivatives of the IMS. The only other schedule that can be used on a project is the look-ahead schedule. This schedule is usually called the three-week-look-ahead schedule and is used on a daily basis by project superintendents to drive the work. This schedule can be more detailed than the IMS but must be a derivative of it and be linked to it.

If a project ends up in arbitration or litigation, due to a claim by any party, and it is determined that there is more than one IMS on the project, precedence says that that claim will be thrown out immediately due to the fact that there is more than one IMS. In the very recent past, it was standard practice for a general contractor to have two schedules—one for the owner and one for the subcontractors. The one for the owner would show the late start and finish dates and paint a rosy picture that all was well, while the one for the subcontractors would show the early start and finish dates in order to drive them to the earliest possible start and finish of any given scope of work. The bottom line is that any project with more than one IMS is at great risk.

2.6.4 Early Completion Schedules

Guidelines

Most projects and contracts, including construction contracts, stipulate a specific time of performance, or have a specified completion date. The date is usually chosen by the owner and takes into account the time frame when the project's deliverable is needed or reasonably determines how long the project would take under normal conditions.

In this section, we will discuss the benefits and risks on both the contractor's and the owner's sides, in order to come up with best practices for dealing with the situation when the contractor needs to finish early and the owner wants to protect their rights to make non-critical path changes without paying extended field overhead.

Definitions

An early completion schedule is defined as a baseline schedule which deliberately anticipates completion of all work (or fragments) prior to the completion date (or dates) established by the contract documents.

An early completion schedule is a schedule which indicates the earliest time at which a project can be completed, based on a forward pass computation of the schedule.

An early finish schedule is related to the early finish date, which is defined in the ***P**MBOK® Guide* – Fifth Edition Glossary as follows:

> In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can finish based on the schedule network logic, the data date, and any schedule constraints. (PMI, 2013, p. 538)

Purpose

In some cases, a project could be completed early if all parties agree. Care should be taken to address penalty clauses, etc., when finding consensus for an early finish schedule.

A risk related to early completion schedules is that when the contractor submits an early completion schedule, they are counting on getting off the job early, and thus spending less field overhead. Conversely, the owner may not have the same need, or even care.

The concern is that, in the contractor's mind, the total float left in the baseline submission becomes his or her owned float and not available to the owner without cost to the owner.

Recommended Practice

The contract documents should clearly state that the contractor has a right to finish early. However, they should also include language that addresses the submission of an early completion schedule. This can be language that simply states that, although the contractor has this right, the contract completion date is that so stated by the contract documents, and any period of time between the early completion date and the contract completion date shall be considered project float. Another way of dealing with this situation is to clearly state that if the contractor submits a schedule that indicates an early completion and upon review it is deemed solely at the discretion of the owner that the plan is realistic, then a change order will be executed revising the contract completion date to the date reflected in the early completion schedule and any liquidated damages will be calculated from this revised contract completion date.

The acceptance of an early completion schedule breaks down into two different subjects:

1. Reasonableness of the submitted early completion schedule. Once the submittal is analyzed and it is determined that it is not reasonable, it needs to be rejected on that basis, regardless of the fact that the completion prediction matched the contract requirements.
2. Ability of the owner to accept possession early. If the owner will accrue additional costs to accept early, it needs to be rejected on that basis, regardless of the reasonableness of that schedule.

The best course of action is to analyze the schedule in detail and communicate to the contractor the reservations about the reasonability of the submitted early completion schedule (if such exist on the owner's side).

In addition, it should be communicated that the owner, upon accommodations to accept the early completion schedule, will suffer damages should the early completion date not be met.

Advisories

For contractors:

1. Avoid presenting an early finish schedule during the development stage.
2. Most likely, all of the scope has not been sufficiently detailed in the schedule during the initial process.
3. Don't overstate anticipated project performance unless you are sure it can be delivered.

For owners:

1. In many cases, an early completion schedule may be an indication that the contractor intends to set up a foundation for claims later on in the project, especially if the schedule includes little float.

2. Courts have long held that, where the owner causes a contractor's performance to extend beyond the contractor's planned completion date, the owner may be liable to the contractor for damages, even though the contract may be completed before the contractually specified completion date. The damage the contractor suffers is the loss of the benefit gained by completing the project prior to the scheduled completion. These damages are measured by defining the contractor's per diem costs in awarding the contractor delay damages equivalent to the time performance was extended beyond the early completion date.
3. Accepting an early completion schedule may force the owner to release assets needed for project financing so that progress payments, which will be greater than initially anticipated, can be made.
4. The owner may not be in a position to accept the facility earlier (e.g., limited resources for oversight, additional possession cost, additional insurance cost, additional coordination among other contractors on other projects in a program, replanning effort to accommodate early completion, etc.).
5. The owner may need to make adjustments to accommodate the early completion.
6. An early completion schedule may reflect the contractor's decreased on-site and home office overhead due to completion of the project in less time than provided in the contract.
7. Ambiguity or lack of clear provisions stating intent toward acceptance or rejection of early completion schedules or float usage in the instructions to bidders or contract terms may cause confusion.

2.6.4.1 Early Completion Schedules—Intentional

Guidelines

Definitions

An early completion schedule (ECS) or early finish schedule situation occurs when the contractor submits a schedule that shows earlier completion of all project scope of work than the contract requirement, generally leaving float in the submitted schedule. This is also sometimes called the right to finish early.

Purpose

There are generally one or two reasons for an intentional early completion schedule: (1) for the contractor to finish in less time than the contractual project duration, so he can save money on general conditions and/or field overhead; or (2) to provide a buffer for the contractor, in case of production problems, to minimize the risk of the contractor finishing late.

Default Condition

While this condition often occurs during routine schedule updates, when the contractor gains time and shows a predicted earlier completion than contractual completion, that condition would not generally be defined as an early completion schedule. This condition usually only occurs with submission of the as-planned schedule at the inception of the project.

Sometimes this condition occurs when the submitted as-planned predicted interim milestones show earlier completion than required by contract.

Best Practices

This situation should be reviewed from both the contractor's point of view and the owner's point of view, since both may be affected. There is case law that indicates some risks to both parties, depending on the jurisdiction and how this situation is handled.

Owner Perspective

While the project documents are being developed for the tendering process, the issue of ECS should be addressed in the contract documents so all bidders are required to take this issue into account in the preparation of their bid. Attempts to eliminate the risk of ECSs could be handled several ways: by requiring that the submitted as-planned shows contractual completion, requiring a constraint on the contractual milestones and not allowing float in the as-planned schedule, or indicating that early completion schedules will not be accepted.

Contractors who submit early completion schedules usually do so by mistake, moving the discussion of this situation to a different section, "Early Completion Schedule—Inadvertent," which should trigger a number of review concerns. See Section 2.6.4.2 for comments about this condition.

The first step when receiving an ECS is for the owner to check all activities that are his/her responsibilities or activities that will drive owner responsibilities, to ensure that the ECS does not impose unusual or additional requirements on the owner, such as shortened review time, early equipment delivery, or coordination with other projects earlier than possible. Any of these conditions should be cause for rejection of the schedule, irrespective of the early completion issue.

Second, it is important to identify any notification, even constructive, from the contractor bidding the job with the reduced time frame or not having general condition costs in the budget for the full contract time. This would be the first indication that an ECS is planned.

There are some risks in accepting an ECS:

- There are concerns to be taken into account if the owner accepts the project early, such as:
  - If the owner has the ability or can adjust their acceptance and occupancy of the project, it might be in their best interests to accept.
  - There are normally many ramifications to taking early completion:
    - The owner will pick up any maintenance and operating charges from the early completion date.
    - The owner may have to change their schedule for procurement of equipment.
    - The end user will need to occupy early in order to assume operating costs.
    - Salaries will start early.
    - Outside coordination may be difficult (utilities, etc.).
- The contractor could gain the right to finish early but not own the float, if the specifications allow the contractor this right, but the specifications may state that total float belongs to the project, and/or the contractor is required to insert a constraint on contract completion.
- The time between the early completion and contract completion could become "contractor-owned float" if the ECS is accepted under certain conditions:
  - This means that any owner changes that occur in this period are subject to being compensable, even if the changes do not drive project completion beyond the ECS.
  - It also means that the contractor could take this float time as necessary, so an ECS might still finish on the contract date without penalty.
  - It increases the risk that the contractor will submit a claim for extended general conditions.

Recommended Practice

The owner should consider whether it is possible to take possession of the project on the ECS date, reviewing the risks noted above. If it is possible, the recommended practice is for the owner to issue a change order with a reduced completion date, at no cost, to align the contractual completion date with the ECS. This would eliminate the discussion about float in the as-planned schedule, and place the liability for completion on the ECS date on the contractor, as well as provide the owner with a greater likelihood of uncertainty about the predicted completion date (absent change order management).

If the contractor's purpose in submitting the ECS was to minimize his general conditions costs, he or she will generally be supportive of this approach. If his/her purpose was to build some contingency into the schedule, he or she is less likely to support this approach. In the event that the contractor is not in agreement with this approach, the owner should discuss the contractor's needs and the reasonableness of his/her schedule to meet those needs. Often, this step will cause the contractor to withdraw their request for an ECS.

There is still a legal risk of delayed early completion that should be reviewed with the claims avoidance consultant and construction litigation attorney for additional protection. Part of the risk for the owner is that case law exists that indicates that both failure of early notification as well as specification language precluding early completion schedules is not an absolute bar to recover damages for owner-caused delays to project completion.

Contractor Perspective

Often when the contractor submits an intentional ECS, the schedule may still have float problems, in that, unknown to the contractor, the schedule may not represent the entire scope of work. When the procurement process is not included in the schedule, even when the contractor believes it will not be critical, the calculations determining that the project can be completed early may not be accurate. Another problem area that shows up in an ECS is the issue of resource planning; this is generally not well thought out and results in inaccurate and misleading float values, often showing that the project can be completed early. However, once the accurate resource planning is implemented in the schedule, the early completion buffer disappears.

This makes it imperative that, when the contractor wants to submit an ECS, he or she should carefully perform a quality check on the as-planned schedule to identify any problems with the logic. With the owner's ability to simply reduce the contractual completion time to the ECS submission, it is very important that the contractor is comfortable with the predictions of completion.

However, once the contractor is comfortable that the ECS is achievable, he or she should take specific steps to protect his position. The first step is to put the owner on notice that the contractor needs to finish on his ECS in order to meet the profit goals included in the cost estimate used for the bid. This should be done specifically, referencing the amount of general conditions estimated and any resource allocations needed at the end of the project. The clearer this notification is, the more likely that it will initiate a discussion between the owner and contractor to negotiate a reasonable solution during schedule review, instead of allowing this situation to become a dispute later in the project.

One of the risks for the contractor with an ECS is that, if the project can be completed on that date and is on track to meet that date, and if the owner issues change orders that require the contractor to stay on the project longer than the ECS date, he or she may not be able to charge for the extended general conditions, either in those change orders or in separate requests, between the ECS date and the contractual completion date.

The contractor should ensure that the ECS schedule is realistic and reasonable, and then accept the reduction in completion date, or initiate the request if necessary. This will protect him against extending general condition costs that are not recoverable, but may expose him to completion damages for late completion.

There is still a legal risk of prevailing in a delayed early completion case that should be reviewed with the claims avoidance consultant and construction litigation attorney for additional protection. Part of the risk to the contractor is that there is case law indicating that, in order to recover damages for delayed early completion, the contractor must show from the inception of the contract that: he or she intended to complete early, had the ability to complete early, and would have actually completed early absent the owner's actions (*Interstate General Contractors v. United States*, 1993).

Advisories

Jurisdictional differences in litigation outcomes make the resolution of early completion delay claims uncertain.

The adequate quality of the as-planned schedule must be validated before decisions are made concerning the ability of the project team to finish a project earlier than the as-planned schedule. Many factors affect that ability, and making a decision to submit an early completion schedule without solid understanding of those factors could undermine the ability to meet the schedule.

Ownership of project float could become an issue in this situation; as with any potential dispute, expert advice is very useful during the planning stage.

2.6.4.2 Early Completion Schedules—Inadvertent

Guidelines

Definitions

An inadvertent early completion schedule is a submitted as-planned schedule showing an earlier completion of the interim or substantial completion milestone than contractually allowed or mandated that was not done in an intentional manner to attempt to finish the project early. Generally, an inadvertent submission is due to the contractor's failure to adequately develop the schedule.

Purpose

The purpose of an inadvertent early completion schedule is to provide some level of buffer in completion, or to complete the schedule development process in order to achieve submission. Sometimes the purpose is to provide a schedule submission without the involvement of the full project team, reducing the reasonableness of the as-planned schedule.

Default Condition

This condition happens when the contractor believes the schedule represents the full scope of work and reasonably models the project and his/her means and methods.

Best Practices

There are two perspectives to this topic: the owner's and the contractor's.

Owner's Perspective

When the owner receives an early completion schedule that is not accompanied by any notification of intent of early completion, review should be immediate and thorough. Usually contractors who submit early completion schedules do so by mistake, and this submission should trigger a number of concerns:

- Is the schedule reasonable?
- Does the schedule capture the entire scope of work, including all activities that are likely to affect completion?
- Are durations and logic sufficient?
- Is the tendering, submittal/approval process, and procurement represented in the schedule?
- Was the full project management team involved in the development of the schedule, specifically the subcontractors?
- Does the schedule include resource planning in the logic and sequencing, or is it just a static schedule that looks good in bar chart form?
- Does the schedule include adverse weather planning?
- Does the schedule include sufficient risk management planning, including any time necessary for the coordination of trade work?
- Is there sufficient time available for owner coordination?

Once the review is complete, the results should be shared with the contractor to ensure that he or she is aware of the shortcomings of the submitted as-planned schedule. This may call for a discussion of those shortcomings and the written report, but the specific issues should be discussed.

Once these issues are discussed, the contractor should be encouraged to revise the schedule to accommodate the missing or inadequate logic, durations, and sequencing. This should be done not by directing the contractor regarding any means and methods of accomplishing the goal, but merely by pointing out the issues that make the schedule unreasonable and less accurate as a result.

Part of the issue is often the lack of an understanding of best practices, as well as lack of any quality control process for the schedule development. These recommended best practices should be encouraged and included in the list of questions about the contractor's process.

Often once the resubmission is provided, the project will no longer show early completion.

Contractor's Perspective

When the contractor completes the as-planned schedule and it shows early completion that is not intentional, this should be a flag that clearly calls for an additional in-house review, or a need to bring in more expertise in quality control.

Very often, no assessment of risk or schedule contingency has been made. There are a number of steps that should be taken for quality control and completion of the as-planned schedule, to reduce the risk of late completion. These steps include some of the following:

- Risks should be identified during the schedule development session in order to allow for risk planning. See Section 3.12, "Risk Management Implementation."
  - Develop a good and reasonable risk register and a risk management process. PMI has excellent risk management publications one can use for further guidance.

- Risks can be identified, analyzed, and resolved (shifted, avoided, prevented, sold, or assigned) as much as possible; remaining open risks should be incorporated into the schedule by time allowance or sequencing control (usually with resource logic).

- The schedule is normally initially developed with customary durations (calculated by quantity and standard production rates).
  - Once generally developed, time allowances to cover increased risks due to specific conditions can be added by increasing appropriate durations in stages.
    - First, durations can be increased at choke points: those activities which control multiple successors, in recognition of general failures to achieve original durations in these historically dangerous points.
    - Second, durations should be reviewed on critical and near-critical paths and may be increased at high risk areas such as changes in trade contractors.
      - Durations used to protect against mobilization and demobilization issue risk between trades when trade activity durations may not account for these predicted time losses.
      - Durations used for activities that tend to appear on multiple critical paths (called "Criticality Index" in Pertmaster) which have enhanced ability to create delays in the project.
- Specific discussion should occur concerning trade contractors.
  - Weak contractors should be analyzed for risk to project, and allowance time added to their work to reflect the unlikelihood of those contractors meeting their durations, preferably through preferential logic and/or lags added after their work activities (to provide additional completion time, but not to show the subcontractor the additional time.)
  - Contractors in choke or wagon-hub positions should have time allowances added, regardless of strength of contractor (again, this can be in the form of lags).
- Should ensure that the entire tendering and procurement process is included in the schedule; this is critical for control of float.
  - Each procurement string should have four activities modeling the process:
    - Shop drawing/submittal
    - Review and approval
    - Fabrication/lead time
    - Delivery of materials
  - Once these activities are developed by specification section:
    - The quality control process should include sorting by early start, then total float in order to validate the reasonableness of the logic.
  - Isolate the fabrication/lead time activities, and review for risk.
    - Can build in more accurate durations for all shop drawings that have historical problems.
    - Should review sequencing and build in preferential logic to control sequencing within a trade, to match the planned sequencing required by the trade contractor.
  - Add repeat cycles of submittal/approval for all historically likely trade submittals.
- Include all owner responsibilities in the schedule.
  - These tend to calculate with high float during updates, and protect against pacing delays by the owner.
- Provide resource planning and leveling during schedule development (done correctly, this will solve most early completion concerns).
  - Should add required crew resources to all activities in order to effectively review crew loading.
  - It is useful to review resource profiles for needs to manually level by trade.
    - First review early start sort.
    - Next review late start sort (this will point out serious crew over-manning).
    - Add resource logic to control flow of crews on the project, from area to area and floor to floor.
    - Can be done on a trade-by-trade basis to double-check weak subcontractors.
- Schedule can be sorted by late start during the development quality control (QC) stage.
  - Emphasizes missing relationships that can be fixed.
  - Reduces average float values across the board when missing relationships are added.
- Schedule will be organized by early start date, totaled by week, during QC stage.
  - Provides a list of work that could be happening each week of the project.
  - A good way to determine if there is out-of-sequence work caused by missing relationships.

- If the project shows an overall duration that is shorter than owner expectations:
  - If the schedule is reasonable but still slightly optimistic, increase durations in any areas that appear to be light, especially with resource stacking issues by trade and location.
  - If the schedule seems reasonable and most likely, increase durations in activities scheduled late in the project because these are more likely to struggle with meeting the general original duration; verify that this is reasonable.

Recommended Practice

The recommended practice is to ensure that the submitted schedule is as accurate, reasonable, and practical as possible—incorporating resource planning in detail, with risk management taken into account—and developed with a good final quality control process. This will lessen the chances of submitting a schedule that predicts completion earlier than reasonable. The contractor should validate the legitimacy of the schedule submission.

The owner should review the submitted schedule carefully to ensure a high level of quality control, which generally encourages the contractor to revise the schedule to a higher level of quality.

Advisories

Avoid presenting an early finish schedule during the development stage. Most likely, all of the scope has not been sufficiently detailed in the schedule during the initial process. Don't overstate anticipated project performance unless you are sure it can be delivered.

Avoid overly optimistic as-planned schedules that are a result of poor quality control, especially weak resource planning and failure to account for historically recognized risks that could be identified through lessons learned efforts.

2.6.5 Planning For Adverse Weather

Guidelines

Definition

Historical data includes sources of objective, factual information recording actual weather conditions, generally at least daily, in a widespread range of locations from professional weather bureaus.

Purpose

Historical data sources are used to plan for future weather in a schedule under the assumption that the average weather in the past will represent a reasonable model of the future weather. It is important that legitimate sources of actual weather conditions are used for the basis of planning so the plan will be as realistic as possible.

From a legal dispute resolution standpoint, the choice of data sources is important as it may be questioned in the event of a dispute. Use of a less accurate source could undermine the legitimacy of a time extension request.

Default Conditions

Historical adverse weather data sources would be used when a project has activities that will be performed under the influence of weather. This includes all forms of precipitation—rain, snow, hail, and sleet—as well as any other weather influences, including high or low humidity, high winds, high or low temperatures, shortened daylight times, or airborne particle conditions such as dust.

Secondary effects from the primary adverse weather conditions could include a variety of issues such as: mud conditions limiting accessibility or halting earthwork operations; mold or mildew conditions requiring abatement; snow and ice removal needs; masonry, concrete, or roofing work stoppages due to low temperatures; and reduced crane operating hours due to high winds.

Adverse weather is variable based on locations, time of year, and other local conditions. Since weather is locality driven, the adverse weather planning data should be captured from a source that suffered weather conditions similar to the location of the project.

Those activities that are weather dependent or related should be identified such that they can be filtered out separately from the non-weather related activities. This will allow weather planning to be applied only to the activities that are likely to suffer from adverse weather.

Weather planning is not used for projects that are unlikely to be affected by adverse weather, such as indoor renovation projects, or projects in stable climate regions.

Best Practices

The most common and available source for historical weather conditions in the United States is the U.S. Department of Commerce agency, the National Oceanic and Atmospheric Administration (NOAA). NOAA operates the National Weather Service (NWS), which produces forecasts and warnings, as well as radar tracking of storms for regions across the United States, available on the internet at www.weather.gov. NWS produces contemporaneous precipitation analysis with archives of records, based on readings taken at the NWS offices across the country. The NWS also publishes the National Weather Service climate pages, which offer local weather forecast office data of weather information.

NOAA also operates the National Climatological Data Center, which is the world's largest archive of climate data, offering some free data and some subscription-based services.

There are private organizations that record and provide weather data, such as Weatherbase, with its database of information for over 15,000 cities; *The Washington Post,* providing information for 2,000 cities; and WorldClimate.com, offering worldwide climate data in a database of over 80,000 records.

The U.S. Army Corps of Engineers (USACE) provides a summary of non-workdays per month due to predicted adverse weather for various regions around the country, based on the USACE offices. The USACE uses NOAA data, analyzes that data, and summarizes it into reasonable expected loss of time due to adverse weather.

Other sources of local historical weather data include the Department of Transportation (DOT) in each state, providing workdays by month; local associated general contractors (AGC) offices, providing a count of rain days; airport records providing wind and rain data; and state meteorologists.

Only NOAA can provide certified records that might be required as support documentation when providing analysis related to delays or disruption due to adverse weather.

Recommended Practice

The most widely accepted and validated source of historical adverse weather data is NOAA through the National Climatological Data Center, and this is the source recommended for use.

Since the USACE handles the research, statistical analysis of the NOAA climate data, and decisions such as what constitutes a full workday, as well as providing data for each of the local USACE offices, using the data supplied by USACE is the quickest and easiest way to provide average historical adverse weather data.

Advisories

The amount of information available on the NOAA sites is almost overwhelming, so check into the data in advance of the need to use the information in planning.

The data compiled from NOAA can be voluminous, and hard to read and interpret.

A decision will need to be made as to what constitutes a historical non-workday due to adverse weather. Weather records may supply the inches of rainfall or snowfall, but do not indicate if it was possible to work during that time. Generally, precipitation of more than 1/10 of an inch is considered to be significant enough to halt activities that are under the influence of that weather. When considering actual data for a particular project, it is generally considered a non-workday if more than 50% of the workday is affected by the adverse weather, or if more than 50% of the workforce cannot function.

A decision will need to be made as to what period of time is statistically significant when selecting historical weather data. Generally, an average of five to ten years of data is considered to provide a sound basis for prediction of future adverse weather. Other scientifically pure, statistically significant procedures can be used to select high probability future non-workdays due to adverse weather.

2.6.5.1 Interpretation Of Historical Weather Data

Guidelines

Definitions

Interpretation of historical data involves taking the available statistical data and rendering it useful and relevant for planning for adverse weather in the as-planned schedule.

Purpose

The purpose of interpreting historical weather records is to provide legitimate and relevant anticipated adverse weather for the period of the project so it can be used to make appropriate allowances for non-work time in the project that could be expected from the effects of adverse weather. This translates the historical records into reasonable usable predictive data that will be integrated into the as-planned schedule.

Default Condition

Interpretation of historical weather records is only used if the specification does not provide an average expected non-work time for adverse weather on a periodic basis to be used in the as-planned schedule.

Best Practices

There are two basic ways to interpret historical weather records: by use of simple non-work averages, and by use of statistical analysis. Both approaches require use of historical weather records from the same location as the project being planned.

The historical weather data can supply the average non-workdays lost to adverse weather in the previous three to five years, with the average precipitation each day, the average wind speeds, humidity, temperature, cloud cover, and other adverse conditions. The scheduler should provide the parameters for each of these conditions that would result in adverse weather, meaning weather that forces shut down of 50% or more of the project, the workday, or the personnel. The parameters could be in these ranges:

- Precipitation
  - More than ½″(1.3cm) accumulation of rain, snow, ice, or sleet
  - Affects all exterior work
  - Mud conditions on an exposed site can cause increased non-work time that extends beyond the precipitation exposure. Judgment should be used in determining what is reasonable to expect. For example, on a stripped earthwork site with poor drainage, it is likely that one day of more than 1″(2.5cm) accumulation of precipitation will create muddy conditions for at least another day. The greater the amount of precipitation, the more mud days that will follow.
- Wind speeds
  - Over 40 mph (64 KPH)
  - Affects tower crane use, or other hoisting or erection of wind-sensitive materials, as well as work in desert or beach conditions due to sand and dust storms.
  - This is materials-sensitive, in that some materials such as siding cannot be hoisted, but other materials could be. So the activity description affects this determination.
- Humidity
  - Very high humidity in the range of 90% may make work conditions seem much hotter than the temperature, and can cause humidity-sensitive materials to swell and impede efficient installations.
  - Very low humidity in the range of 25% may make it very difficult to install pavements due to high dust, and may cause humidity-sensitive materials to shrink such that severe swelling should be anticipated once the humidity returns to normal.
  - Affects wood materials
- Temperature
  - Low temperatures below the range of 40°F may prevent installation of materials, including adhesives, cements, or high temperature installation conditions.
  - High temperatures above the range of 95°F may cause problems with installation of concrete and coatings.
  - Affects concrete, masonry, paving, coatings, painting.
- Other conditions should be reviewed to anticipate the likelihood of affecting the specific project.

A statistical approach has been developed, which requires the use of NOAA data in detail, converted to a spreadsheet or database in order to perform data filtering and calculations. Once the data is extracted into the database or spreadsheet, the conditions can be summarized to a value daily by year.

Once the conditions are organized, an assessment must be performed of what is significant in adverse weather with the type of condition, to allow for identification of specific days and the probability of the condition occurring on that particular calendar day. Then a threshold must be chosen to limit the days based on the probability of the condition occurring, and that provides a chart of days of adverse weather per month, identifying the probable days with the adverse weather condition, such as precipitation.

The next step is to compare the average available workdays with the historic average adverse weather days. Once these two data points are correlated, a non-work calendar of predicted adverse weather can be compiled.

There is a third approach that is a blend of the two, performed by the USACE in its publication of monthly non-workdays due to adverse weather in various office locations. If this data is available, use of the results is economical, reasonable, and likely to stand up in a technical forensic analysis. This data is only available for the United States, and may not be relevant in other countries.

Other sources for weather data outside of the United States include:

United Kingdom UKMET

Japan JMA (Japan Meteorological Agency)

Europe ECMWF (European Centre of Medium Range Weather Forecasts)

China CMA (China Meterological Agency)

Recommended Practice

We suggest that if USACE records are available, the recommended practice is to use the non-workdays for your project location. If USACE records are not available for the location of the project, then using simple non-work averages is recommended due to the simplicity of interpretation and ease of understanding by the project participants and other audiences.

Advisories

All parameters should be defined in the written narrative so that reviewers have an opportunity to consider the reasonableness of those parameters in interpreting the historical records. With this definition, the ranges of adverse weather conditions are available for anyone to accept, challenge, or discuss adjustments.

The time of day for adverse weather should be reviewed. If an area typically experiences most of the adverse weather near or after the end of the workday, that reduces the effect of that adverse weather on project performance.

The determination of the parameters to use in planning is clearly subjective, so the goal is to be as reasonable as possible and provide rationale for the determination, especially if it may appear to be biased toward more or less adverse weather planning.

2.6.5.2 Methodology for Weather Planning

Guidelines

Definitions

Methodology for planning for adverse weather is the strategy and implementation used to develop a schedule that produces reasonable and historically consistent early start dates which take into account the adverse weather conditions expected for a specific project in a specific location during a specific time frame.

Purpose

Planning for adverse weather helps produce schedule dates that have a higher likelihood of accuracy, so that the schedule is resilient enough to be useful in a specific location and time frame. Adverse weather may easily reduce the productivity of work on a project to a greater extent than planned, including complete shutdown of the project's weather-sensitive work. If a schedule is produced that does not take into account that the history of adverse weather conditions at the project site and time will likely be similar to what will be experienced in the future, there is a high likelihood of slippage of planned dates, with the resulting reduction in credibility of the schedule.

The planning involves choosing a methodology that is credible, reasonable, and easy to maintain, while requiring as few schedule revisions to maintain the system as possible.

Default Condition

Use of a methodology to plan for adverse weather is used when the project has activities that are exposed to adverse weather conditions, and historical adverse weather records are available and have been interpreted for use in planning.

In addition, planning for adverse weather using a transparent and reasonable methodology provides a baseline for the project expectations for adverse weather losses. Unusually adverse weather, defined as weather that is worse than the historical records would suggest, can be analyzed for extensions of time requests compared to this benchmark of planned adverse weather. Generally, unusually adverse weather would entitle the contractor to an excusable time extension.

These recommendations are made in order to accurately plan for weather delay, and therefore avoid situations where a delay to the end date is caused by weather that should have been anticipated through historical data analysis, and to avoid situations where potentially legitimate claims for time and/or money are rejected because of a general lack of consideration of weather as an expected factor in contract completion.

Best Practices

Plan for the right type of activities to allow for work to continue throughout the weather conditions, looking at the scope of work to see the right level of weather planning required. Owners can request that contractors mitigate in planning for adverse weather, if they are willing to fund any additional costs due to that mitigation.

The practices that appear to be used most often in the construction industry for planning for adverse weather include using weekends for "make-up" days, utilizing an activity just prior to substantial completion to house adverse weather time for the entire project, and the use of weather calendars.

For critical path delay issues related to adverse weather, the most common impact is from work activities that fall during good weather periods in the baseline schedule, but with updates and changed conditions are shifted into areas of greater non-work expectations. With good weather planning, the schedule should show a delay immediately upon updating or incorporation of a changed condition model in the schedule, when work might be shifted into greater areas of non-work weather periods. Analysis of the update or changed condition would then include preparation of a request for time extension.

Extended Shifts to Make-up Time

Weekend Make-up Days

The use of weekends to make up for lost weather time is a popular methodology for contractors because it is simple, requires no work to implement, and appears on the surface to be a legitimate approach. Yet, in effect, it does not provide dedicated weather planning. The approach can be appropriate when the climate does not typically demonstrate large swings in adverse weather. When a contractor plans using this methodology, it is helpful to also note that it is based on the historically derived source, and attempts should be made to convince the owner that the plan is only up to the limit of that historically derived source. Factors to keep in mind with this approach include:

- Works under all conditions except for those situations where required planned non-workdays exceed the number of weekend days.
- Should provide a limit of two days a week before excessive adverse weather merits a time extension.
- An owner could take the position that the contractor has planned for two days of adverse weather in each five-day workweek.
- The weekends may not fall just right in allowing make-up time.
- Subcontractors may ask for overtime when required to work weekends, unless it is addressed contractually.
- Contractor supervision will be required on the extra weekend workdays.

- Any owner-furnished supervision or inspection will have to be available if weekend work is needed. Some municipalities may not be willing to inspect on weekends at all.
- Does not account for seasonal variations.
- It reduces the contractor's opportunity to use weekends to make up low productivity weeks, as is commonly done.

Activity to Store Predicted Adverse Weather Time

The methodology of using an activity just prior to the "substantial completion" milestone or the "dry-in" milestone to house adverse weather time appears to be somewhat popular in some areas of U.S. Federal Government work. This methodology includes summing up all the expected adverse weather non-workdays and using that total as the duration for a weather activity (sometimes called a "weather bank" or "weather bucket") that is inserted into the project immediately prior to the substantial completion or dry-in activity. This duration is typically monitored on a monthly basis, and reduced as necessary to accommodate the amount of actual adverse weather experienced during that month.

The actual adverse weather is generally monitored by the project team, with the owner/CM and the contractor determining each week the total number of days that were lost due to adverse weather and totaling those for the month. This includes determining if the project resources were unable to work for more than half a day on a lost workday, which would include adverse weather conditions as well as secondary conditions such as muddy site conditions. A report is usually issued that identifies the actual adverse weather and authorizes the reduction of the weather bucket activity duration.

Often, the project team analyzes the remaining amount of time in the weather planning activity duration to determine if it is adequate for the completion of the project. Add a constraint to calculate accurate float as predecessor to LDs (dead zone or band). The use of an activity to house the total adverse weather planning time has the following disadvantages or risks:

- All activities in the project or prior to the "substantial completion" or "dry-in" milestone are subject to the adverse weather.
- There may be a failure to provide adverse weather planning for site development work that is outside the path of the dry-in activity if that is the activity chosen as the successor to the weather bank activity.
- The inclusion of the weather-planning activity at the end of those paths containing non-weather-related activities will artificially reduce float values along those paths, making those activities appear to be critical more quickly or in general more likely to appear on the critical path.
- The critical path is less reliable, since the network does not calculate properly for those activities that are falsely affected by the weather bank activity. The result is very similar to too much logic, which tends to increase the number of activities on the critical path.
- An owner's CM would (or should) likely reject that schedule because it artificially conceals float on the non-weather-related activities. This approach sequesters float when the project does not experience adverse weather; float that is gained should be returned and available to the project for the use of the project.
- The weather bank requires additional work in monthly monitoring and adjusting of that weather bank activity.
- Weather planning is removed from the issue of activities related to time-of-year level planning. This is very dangerous because this weather planning does not consider the time of year risk of adverse weather. There is no directed use of the time allowed for weather planning; every need is satisfied by reduction of the weather bank without this consideration.
- Early dates of the activities in the schedule do not include weather planning, so if there is adverse weather, early dates are too optimistic. *The ONLY activity in the entire schedule which has dates adjusted by weather planning is the milestone that is the successor to the weather planning bank activity.* This makes the dates used to manage the schedule much less realistic, and it doesn't make sense to plan for weather but not use that planning to provide more reasonable dates in the schedule.
- This approach does not allow the schedule to automatically and immediately predict delay when activities are shifted into heavier weather periods. There may be a delay caused by a changed condition that shifts weather-related activities into a period of worse adverse weather than originally scheduled. With a weather calendar, when weather-related activities are shifted, the project automatically shows a

delay. With the weather bank, the delay goes unnoticed at the time because the time is just taken from the bank activity, and mitigation is actually provided by removing weather planning from the rest of the activities in the schedule.

- The delay is only a weather delay after the weather bank is used up, so it doesn't matter when the actual delay occurred.
- Understanding if the owner or contractor owns the float in the weather bank.
- The owner may develop an unrealistic feeling that there is contingency time in the schedule and tends to forget that this contingency is really only for adverse weather and not available for their use.

Weather Calendars

The use of weather calendars to model adverse weather is a very popular method of weather planning for the as-planned schedule. Calendars should show non-workdays on a monthly basis, with the non-workdays selected at random across the weeks of the calendar, using the industry average number of days as determined in the interpretation of adverse weather data. The assignment of the non-workdays should be over a seven-day week, since weather records are compiled on seven-day weeks, which will cause some of the non-workdays to fall on weekends.

It allows the CPM network to automatically calculate and keeps the adverse weather planning in the appropriate season, forcing weather-related activities, as they shift due to changing conditions, to take on the appropriate non-work time of the season. This approach accommodates delay analysis and provides accurate predictive results as a result of adverse weather in any conditions of delay and disruption.

In planning for an average number of weather days to include in an as-planned schedule, the following chart represents adverse weather predictions for Tidewater, Virginia, collected as the National Weather Service's (NWS) 10-year average for foul weather days in this region. These numbers are specifically pulled from the USACE but the numbers are very similar to those used by other federal and state contracting agencies. The USACE captures their adverse weather days to allow from the local NWS publications. The USACE figures are useful because extracting adverse weather days directly from the NWS requires a judgment of how much precipitation is required for a non-workday (the figures are normally available in inches of precipitation per day). The USACE has already made good judgments, backed by historical records, in converting inches of precipitation per day into non-workdays.

Using NWS data for estimating purposes, as shown in Table 2-1, the contractor should plan for the following number of adverse weather days, based on a schedule planned in 2005:

Month	J	F	M	A	M	J	J	A	S	O	N	D
Adverse Weather Days	9	9	9	6	7	6	7	7	5	6	7	9

Table 2-1: Adverse weather days chart

Weather days in excess of these numbers are deemed unusually severe weather days and as such would normally be subject to a legitimate time extension. In order to track these normal adverse weather days, and plan for the activities they affect, the following procedure should be applied:

1. Develop the baseline schedule based on a five-day workweek.
2. Identify all activities that are subject to weather and code them for easy filter selection.
3. Develop a separate project calendar (the weather calendar) within the scheduling software, showing the appropriate number of adverse weather days per month. Ensure that this calendar matches the main project five-day workweek.
4. Using the predicted days of adverse weather per month, apply the count of days randomly across either the month, or assign them in the weekly proportion across each week. Spread the days out so they are not contiguous because that will tend to show gaps in the work and confuse the project team.
5. Include the weekends in the full week of assigning non-workdays, since the NWS tracks calendar-week adverse weather, not workweek adverse weather.

6. Apply this calendar to the activities affected by weather activities, identified in Step 2 above.
7. Calculate the new finish date and compare it to the benchmark. If the project shows a delay, check to see if the delay is due to unusually adverse weather conditions.
8. Review planned non-workdays that may appear in a contiguous fragnet, such as between completion of formwork and the concrete pour. If the schedule user looks at this carefully, it could appear odd.

In this way, should a spate of unusually severe weather days occur, the project manager now has the means to claim for time, since he or she has reasonably and responsibly planned for weather in the submitted and approved project schedule, and he or she can document when the number of days that actually occurred were in excess of historical averages. It is important to note, from a claims perspective, that in order to claim for time in the case of "unusually adverse weather" the weather must not only occur (and be documented), it must also affect the completion of a critical path activity (i.e., an activity with no float and/or on the longest path).

It is also necessary to define what a lost weather day really means: the job records must show that work ceased, or manpower was effectively reduced to approximately half of the typical workforce, or the work was shut down for the day or a large part of the workday, and that the work cessation was not at the end of the workday. Lost weather time can also include conditions such that work could not occur, such as mud days when the site is too muddy to put equipment to work.

Not properly accounting for these days, recognized as authoritative by both federal and state contracting agencies, will have two potential impacts. First, the schedule will be flawed and will not realistically represent when the work will be performed, which can potentially mislead the contractor and/or the owner. Secondly, the impact of any delay will be masked because of the inaccurate calendar, and in absence of any reasonable plan, a claim will likely be rejected.

The use of weather calendars has the following disadvantages or risks:

- When using weather calendars, there is an effect on the float path from changes in calendars as activities move from a project calendar to a weather calendar and back, during updates of the schedule.
- If a schedule is organized by total float, there will likely be a jump in the total float value when the calendars change from a regular calendar to the weather calendar and back.
- If the weather calendars are not actualized, actual durations for those activities affected by weather will not be accurate.

Recommended Practice

Of the several methods to plan for weather, the use of weather calendars has the most advantages and least disadvantages, so the best practice when using weather calendars is the recommended practice.

Advisories

One approach that is sometimes used for planning is that of increasing durations to accommodate adverse weather. This is a poor method and one that we specifically do not recommend using. This approach reduces transparency such that durations can no longer be verified by calculations of resources and quantities, and the amount of time that is concealed in the durations is unknown, so no one will know whether the durations include contingency for adverse weather. There is also one other more serious drawback: the failure to accommodate a dynamic schedule. The additional time for adverse weather that is added to the duration is only season-related in the static baseline schedule. As soon as the project schedule changes, the durations become inappropriate for the activity season schedule and activities with increased duration for winter work will be scheduled for summer work, while activities with no planning will be scheduled for winter work.

With the weather bank approach, it is important that each monthly reconciliation includes an analysis of any lost weather time that exceeds that month's planned time. This requires a separate list of monthly planned time for comparison. Without this reconciliation, there is a risk of using up weather planning, when there should have been a time extension due to unusually adverse weather.

There will be a lack of credibility if some standard number such as "three days per month, every month, and all year" is used, as it indicates that no analysis techniques were employed to arrive at the conclusion.

2.6.5.3 Accounting for Actual Weather

Guidelines

Definitions

The methodology for accounting for actual adverse weather explains how to ensure that the as-built schedule is accurate when it comes to adverse weather records for the specific project.

Purpose

Since the as-built schedule is often used for analysis both in prospective trending and predictions of completion and for forensic analysis situations, there should be some methodology developed for maintaining the records of actual adverse weather so that the as-built schedule is as accurate as possible. This methodology provides a way to compare the predicted or planned adverse weather to the actual adverse weather. This recordkeeping is used in analyzing potential extensions of time that might be legitimately earned due to that unusually adverse weather.

Default Condition

With each formal schedule update, the methodology for accounting for actual adverse weather is implemented.

Best Practices

The implementation of the selected methodology for accounting for actual adverse weather would normally include recording actual lost days of work due to adverse weather and providing some type of report showing the days and parameters for selecting non-workdays.

In the use of weather bank activities, this methodology includes identification of the non-workdays due to adverse weather, with generally some type of weekly compilation and negotiation between the contractor and owner/CM, as well as keeping records of the total actual monthly non-workdays. These records are generally captured in a report that provides the basis for draw down of the weather bank activity duration as needed.

In the use of weather calendars, this methodology includes changing the weather calendar from the planned adverse weather to the actual adverse weather. The results of this maintenance are that the actual durations for all activities that were affected by adverse weather are accurate. With some reports, such as float dissipation or time performance reports, which rely on the actual durations, the accuracy and legitimacy of these reports for analysis are greatly enhanced. If activity bar charts have the settings adjusted to "neck" for non-workdays, the bar charts will show the adverse weather days on the schedule bar chart. This can be handy for a quick visual check of non-work time in the schedule.

This methodology also includes review of the critical path and delays to determine if any critical path delay is due to unusually adverse weather that is greater than the planned adverse weather. In this review, the analysis should identify any need for an extension of time due to unusually adverse weather losses.

Recommended Practice

Along with recommending the use of weather calendars, the recommended practice for accounting for actual adverse weather includes updating the weather calendar with actual non-work weather days, and reviewing the lost time to identify any unusually adverse weather delays.

Advisories

If the weather calendars are not maintained with the schedule update, any reports relying on actual durations will not be accurate.

Generally, any time gained during the period due to less adverse weather than planned will be returned back to the project float values if weather calendars are used, but an owner should not expect to shorten the project by the amount of gained weather planning not used. The float gained will be available to the project for the first need.

SECTION 3

Schedule Development

Development entails producing the actual schedule, based on the schedule design. Schedule development includes defining activities, durations, and relationships, entering this information into the scheduling tool, and performing the schedule calculations. The detailed scope of the project, means and methods to be used, availability of resources, contract requirements, and physical constraints are among the inputs for schedule development. The purpose of schedule development is to complete the process that began during schedule design, document the project plan, and produce the baseline schedule for the project.

3.1 SCHEDULE DEVELOPMENT PROCESS OVERVIEW

Guidelines

Definition

Schedule development is the process of producing the actual schedule, based on the schedule design. Schedule development includes identifying the detailed activities, durations, and relationships that form the network schedule. It includes entering this information into the scheduling tool and performing the schedule calculations. The detailed scope of the project, means and methods to be used, availability of resources, contract requirements, and physical constraints are among the inputs for schedule development. The output includes the first draft of the schedule, which is then subjected to review and quality control checks. The schedule may also be resource-loaded and cost-loaded during schedule development.

Purpose

The purpose of schedule development is to complete the process that began during schedule design, document the project plan, and produce the baseline schedule for the project. The inputs to schedule development include all of the outputs from schedule design. The outputs may include:

- An initial baseline schedule that documents the plan for the first 30, 60, or 90 days of the project, for use until the remainder of the schedule is published
- A detailed baseline schedule, which is typically the primary means for documenting the complete, detailed plan and communicating that plan to stakeholders including the owner and its agents, prime contractor employees, subcontractors, and suppliers
- A written narrative of the plan
- Resource and/or cost loading
- Notes or attachments providing additional details regarding resources, assumptions, constraints, or other data relevant to understanding the plan or conveying its intent

The detailed baseline schedule is typically developed by a contractor for submittal to the project owner for its review and acceptance. It is the primary means through which the contractor documents and communicates its sequencing for executing the project within the contractual requirements.

Contracts often call for the parties to reach agreement on the baseline plan. Then, it is updated over the course of the project to track progress. Thus, the baseline schedule is the ultimate parent document to all schedules generated over the course of the project. If changes occur or the project is delayed, comparisons may be made to prior schedules to assess the cause of delays. Ultimately, updates and revisions may be compared back to the original plan. In many cases, responsibility for delays will be evaluated, and one or more parties will be assessed a cost associated with the delay.

Considering its significance in documenting the project execution plan, communicating that plan, measuring progress against the plan, assessing delays and changes, and assigning responsibility for those delays and changes, the baseline schedule is typically one of the most important documents in executing any major project. The purpose of schedule development is to produce the baseline schedule and associated deliverables identified during schedule design. Schedule development must be performed in a detailed and organized fashion so that the baseline schedule is the best possible tool for managing the work.

Default Condition

In the default condition, personnel responsible for schedule development have a good understanding of the details of the scope to be performed, the means and methods to use, and the available resources. They also have a good understanding of the fundamentals of network scheduling techniques and best practices, and a thorough knowledge of the scheduling tools that they are using. The team's knowledge and experience is applied to develop the detailed activities and logic of the project execution plan.

Best Practices

There are numerous textbooks and references available for performing the schedule development process. PMI has published several documents that reference schedule development. These include:

- The *PMBOK® Guide* – Fifth Edition, in particular, Section 6, "Project Time Management," outlines processes to define and sequence activities, estimate resources and durations, and develop the schedule (PMI, 2013)
- The *Construction Extension to the PMBOK® Guide Third Edition*, in particular, Chapter 6, "Project Time Management" (PMI, 2007)
- The *Practice Standard for Scheduling* – Second Edition, in particular, Chapter 2, "The Schedule Development Process" and Section 3.3.2, "Detailed Baseline Development" (PMI, 2011b)

In addition, AACE International has published numerous recommended practices on developing the schedule, reviewing it, and documenting the underlying assumptions. These are posted on the AACE website www.aacei.org, and include:

- 23R-02: Identification of Activities
- 24R-03: Developing Activity Logic
- 49R-06: Identifying the Critical Path
- 55R-09: Analyzing S-Curves
- 38R-06: Documenting the Schedule Basis
- 48R-06: Schedule Constructability Review

Based on review of these guides, standards, and recommended practices, a consistent set of tasks can be identified as the typical scope of the schedule development process. In these *Best Practices and Guidelines*, certain tasks outlined in these references—such as those related to developing the work breakdown structure (WBS) and activity coding structures and defining the major constraints—have been described as part of the schedule design process. Thus, schedule development begins with the definition of the specific activities to provide the project execution details within a previously defined structure. Tasks to be executed during schedule development include:

- Define the detailed activities for each part of the project
- Define the resources to be used to execute the activities
- Define the durations of those activities
- Define the logic between the activities
- Perform the schedule calculation
- Iteratively review the output, revise as needed, and recalculate

Detailed Activity Definition

If the overall WBS or other activity coding structure has been well defined, and the project team has a well-defined scope and approach strategy, developing the details to execute the project, while time-consuming, should be reasonably straightforward. For each work package, the schedule developers must detail the individual activities to complete that segment of the project. Understanding the details of the scope is the most important consideration in defining activities that have clear starts and finishes, concise and consistent descriptions, and together, correctly define the complete scope of work for the package with no gaps or overlaps. While developing the activities is straightforward, achieving all of those goals is not necessarily easy. Defining activities requires technical knowledge, organizational skills, and good communication so that those executing each activity understand the scope of the activity.

Activities should be defined to the level of detail that they can be managed. Again, consideration should have been given to how the activities will be managed and how status will be reported during the schedule design process. If not, revisit the approach now to ensure that all those who are developing the schedule will create activities to the appropriate level of detail for managing each portion of the scope of work. In many projects, this will mean a consistent level of detail for most or all work packages in the WBS. For some projects, certain elements may require more detail than others. For example, executing technically complex portions of the project or portions with more stringent time constraints, such as when connecting new mechanical or electrical systems to existing systems during an industrial equipment outage or when performing interior renovations in an occupied building.

Resource Considerations

While there is general agreement that these activities are part of the schedule development process, there is significant debate as to the order in which they should be performed and the level of detail to which they must be performed. Among these tasks, there is no greater debate than the one regarding resources.

Some practitioners have stated that a schedule that does not consider resources is of little to no value. Those analysts argue that if resources are not considered, they are assumed to be infinite. In reality, resources are not infinite, and any schedule that fails to consider them runs the risk of placing an unrealistic amount of work in one time frame. Resource constraints affect most projects, but perhaps not all. Depending on contractual and spatial considerations, it may be possible to increase the amount of resources applied to a task tremendously, if not infinitely.

For example, construction sites in some third-world countries have a readily available pool of labor available for some manual tasks such as pulling cable, digging trenches, or moving material. As another example, crowdsourcing approaches may effectively bring virtually unlimited resources to bear on a particular task. On the other hand, the performance of work that requires skilled manual labor is typically constrained by both the available pool of trained craftsman and the labor rates that those executing the project are willing to pay. Paying substantially in excess of going market rates can attract large pools of traveling labor in many cases, but physical constraints will often limit the number of workers who can perform tasks in one area.

During schedule development, it is certainly a best practice to consider what resources are required and available for a given project. In fact, initial resource considerations may be made even before detailed schedule development begins as significant resource issues may affect the entire approach to the project. Once schedule development begins, resource considerations may be incorporated into revising task durations, adding relationships between tasks to model the flow of resources, or leveling tasks within their available float, in order to schedule work within resource limits.

Resources may be optimized by scheduling activities within their available float, as opposed to scheduling all work to be performed on its early dates based on the typically published output of a standard CPM calculation. This practice—termed "resource leveling"—is an effective way to balance work when used properly. Again, those using computer algorithms to automatically resource should understand those algorithms and review the output to ensure that the effort to distribute resources has not resulted in an impractical plan or one that violates other considerations. This may occur if the hard logic in the schedule has not been completely detailed to model all of those considerations.

Setting Activity Durations

Initial activity durations may be defined by the experienced judgment of those developing the schedule or they may be taken from the project estimate or other previous development. As the schedule is developed, the durations may be revised based on resource considerations, or due to a better understanding of the scope of activities that arises out of the detailed schedule development effort.

Different scheduling durations may call for different approaches to defining activity durations. As all of the work is planned, the durations are estimates. Some may have more certainty than others, but the actual durations are not known with certainty. Traditional CPM approaches call for those knowledgeable about the scope of a task and the resources to be applied to make their best determination as to its expected duration. There is significant debate as to how much those estimating task durations tend to put a schedule contingency within the duration. Whether or not the person estimating the duration of the task is the same person that will execute the task may have a significant effect on how durations are executed, particularly if any personal incentives are at play. Critical Chain Project Management (CCPM) calls for typical task durations to be estimated at a 50% confidence level. Project Evaluation and Review Technique (PERT) calls for three duration estimates—optimistic, pessimistic, and most likely—which are then combined to compute the estimated activity duration: [(optimistic + 4 x most likely + pessimistic) / 6].

After the initial estimate, task durations may be revised iteratively during the schedule development process. The revisions may be made manually, or tasks may be revised automatically. They may be "crashed" or "stretched" if more or fewer resources are applied than envisioned in the initial development. Many software algorithms allow task durations to be recalculated automatically based on changes to the applied resources. When using these features, it is important that the schedule developers understand how changes to resources affect planned durations and vice versa. Especially when multiple persons are working on the same schedule development, understanding how some changes to data in the schedule model may create changes to other data is critical to a smooth schedule development process.

Inserting logic between activities that are expected to share resources is another way to manage their application over the course of work. When there are several available options for work sequencing, the selected option is often modeled based on workflow—i.e. which tasks do the project team prefer to execute first, second, third, etc. Sequencing of this type is often referred to as preferential or "soft" logic, in contrast to the "hard" logic required by physical or contractual conditions.

Developing Activity Logic

As the activities are defined the logic between them is developed to model the physical and workflow relationships between them. Contractual relationships may also be modeled. Milestones may be used to model contract requirements, and appropriate portions of the scope of work are tied to the milestones with relationships. As the relationships among the individual activities within each work package are defined, the relationships between work packages are also defined. Throughout this process, an effort should be made to keep the logic as simple as possible, while modeling the relationships among activities as accurately as possible.

This means that redundant logic typically should be eliminated, and simpler relationships between more specific activities typically are preferred over more complex relationships between less specific activities. For example, consideration should be given to whether activities that are tied together with start-to-start and finish-to-finish relationships with lags would be better modeled by several more specific activities tied with finish-to-start relationships. Simpler relationships are not always better, and when more complex relationships are appropriate, they should be used. However, simplifying where possible will make the overall schedule a more easily understandable and usable tool to more users.

Organization-Specific Development Best Practices

Schedule development practices are sometimes driven by an organization's overall approach to planning and scheduling its work and the type of projects it executes. In many industrial environments, the schedule development process for equipment or unit outages is performed by importing previously defined tasks from a work management system. The tasks may include durations, resources, and codes that are defined by personnel that perform planning for routine maintenance or major overhaul activities. If a quality schedule design process is in place, this allows for the relatively quick development of outage schedules by importing tasks into the appropriate element of the WBS and linking tasks as appropriate, based on the overall outage plan. Some industries have strictly defined roles for "planners," "schedulers," and "project controls managers," while the roles overlap or are synonymous in other organizations. While these *Best Practices and Guidelines* seek to document best practices, it should be understood that particular industries and organizations may have practices that are efficient and effective, and therefore best practices for them, while those practices may not be specifically documented herein.

Schedule Review and Quality Checks

All organizations should have a process for reviewing their detailed baselines regardless of the specifics of the development process. Reviews should include the following considerations:

- Review the overall critical path to ensure that it appropriately represents the work that is driving the project completion date.
- Review the longest critical paths to intermediate milestones, when required.
- Review the near-critical paths to ensure that there is an understanding of the work that is most likely to affect project completion, even if it is not absolutely the most critical work at the outset of the project.
- Review the level of detail of the schedule for consistency and appropriateness.
- Review activity late dates to determine whether float has been overstated due to insufficient logic—i.e., absence of soft logic.
- Review the scope of work modeled against the schedule input documents—e.g., the contract, drawings, specifications, etc.
- Review coding to ensure that it has been completed consistently.
- Evaluate resource application by reviewing resource curves (if the schedule is resource-loaded) or by reviewing activities by trade or functional area.
- Review sequences and workflows for reasonableness and constructability.
- Assess whether the schedule is clear and understandable. Consider revising layouts if needed to more clearly present the information.
- Review activities to ensure they are on the correct calendar.
- Send the schedule to subcontractors and suppliers, in whole or in part, if their review is appropriate.

Narrative

Writing the schedule narrative is often the final step of the schedule development process. The narrative should document the content and intent of the schedule in a clear manner. The narrative is an opportunity to document assumptions, intended resources, and execution strategies. Modern scheduling software allows extensive notes to be incorporated into the schedule database, but many reviewers will not review the electronic file at that level of detail. The narrative is another opportunity to present the plan to stakeholders, obtain comments, and ideally, achieve buy-in to the execution plan. See Section 3.2.5, Use of Narratives, for a look at what a narrative should contain.

Recommended Practice

Consistent with the recommended practice for schedule design, the recommended practice for schedule development consolidates the best practices of the practitioners from the previous section into a concise set of guidelines. The recommended practice represents the minimum set of recommendations that are applicable to almost all projects. Schedulers should review all of the best practices in the previous section and—to the extent time and resource constraints allow—should incorporate all of those practices that they believe will benefit their project.

- Before beginning development, perform schedule design
- Make sure that the schedule design and philosophy is synchronized with the schedule requirements per the contract

- Develop the schedule within the framework of the schedule design
- Revisit the schedule design process if necessary
- Continue communication throughout schedule development
- Include input from major subcontractors
- Define work to the level of detail at which it will be managed
- Define activities that are clear, concise, complete, and correct
- Simplify activity logic where possible without compromising accuracy
- Review the schedule thoroughly and execute quality control processes
- Evaluate the schedule for risk
- Obtain review by those who will execute the work
- Present the schedule to stakeholders; allow for comments and questions
- Involve project leadership and clients and obtain their buy-in
- Develop an initial baseline if execution begins before development finishes
- Obtain acceptance of the detailed baseline schedule whenever possible
- Complete development and begin updating soon after starting execution

Advisories

Schedule development should be based on the plan developed during schedule design. For a small project, the schedule design process may be less defined. One individual may design and develop the entire schedule. However, planning the development of the schedule to the extent possible before beginning development is advised.

When working with several individuals on the same schedule, different understandings of the project approach or schedule development approach can result in unproductive development time. Communicate the schedule design to overcome these issues as much as possible.

Once development is complete, the absence of a review process is the most significant risk to a quality schedule. Perform a thorough review. A checklist may be useful.

Do not assume that the schedule predicts the future. Even the best schedules are still only forecasts and cannot include every possible event that might occur. Schedule risk analysis methods may be used to evaluate the probability of successful execution. In addition, change must be well managed during the schedule updating process.

3.2 Schedule Development Philosophy And Theory

Guidelines

Every project, regardless of size and complexity, should develop and maintain a project schedule. The complexity and content of the project schedule will vary based on a number of factors, including the duration of the project, complexity of the project, owner requirements, performing organizations requirements, desired level of control and frequency of updates, and position of the project in its life cycle.

The effort of developing and maintaining a project schedule is an iterative one and should involve as many of the project staff, including subcontractors, as possible. A well-constructed and maintained project schedule becomes an indispensable and integral tool in the successful completion of any project.

Definitions

The PMI *Practice Standard for Scheduling* – Second Edition (PMI, 2011b) provides an excellent overview of the scheduling philosophy in its initial chapters. It then defines the essential elements that should be present in any schedule and how to obtain/create them.

Purpose

The project schedule in its most basic form represents the plan for accomplishing the project scope over time. The project team defines how the project efforts are to be sequenced and accomplished and the project controls staff captures this information and displays it over the duration of the project (time). Once the schedule is created, it must be maintained and statused.

The schedule can then be utilized to sequence future work endeavors, and manage cash flow, resources, risk, etc. The schedule can also be utilized by the owner/client to check on project performance and other issues.

Default Condition

Every project regardless of size and complexity should develop and maintain a schedule. For small, easy projects the schedule may only be a few lines, but for larger projects it could contain hundreds or thousands of activities. Regardless of the project size, the schedule becomes the tool used by all parties to manage the project execution from inception through completion.

Best Practices

Once the scope is determined and finalized, schedule development should begin. This development effort should include project milestones, activities, schedule logic, durations, and assignments of resources, to mention just a few events that comprise the activity of creating a schedule. Once the schedule is developed and agreed to by all project stakeholders, a baseline or copy of the schedule should be created. This baseline will be utilized as the project schedule is statused and maintained, to track project performance and project future events, including project completion.

The project schedule must be statused and maintained on a pre-established sequence.

Recommended Practice

Every project needs to have a schedule, and the project schedule needs to be approved by all the stakeholders. Once approved, every project needs to maintain a copy of the approved schedule, called a "baseline." The project schedule needs to be developed by all the project stakeholders and project team members, and the project schedule needs to be maintained by all the project stakeholders and project team members.

Advisories

Care should be taken to prevent the development of broad-based schedules that are not soundly grounded in logic. This often occurs when the management team attempts to develop documents that visually reflect meeting milestones or end dates; however, the schedule activities are not rooted on sound logic. The end results are schedules that initially reflect project performance to meet project scope requirements, but which fail for a variety of reasons once implementation begins.

3.2.1 Initial Baseline Development

These include the scope of work to be performed, the schedule for accomplishing the work, the organization tasked for doing the work, and a budget for the work. These various considerations become the basis of the plan for accomplishing the project. This plan can be documented in a baseline. In large, complex projects requiring more than a year to complete, there may need to be a separate initial baseline for accomplishing the early work, while a formal detailed baseline is developed for the full project.

Guidelines

Definitions

The baseline is the official project plan for accomplishing a project scope within an authorized budget and within a specified period of time. The initial baseline is typically a schedule that covers the first few updating periods in detail and is used as a management and monitoring tool while the full detailed baseline is being developed. In construction it is common for the initial schedule to cover the first 90 days of the project in detail, while the balance of the work to be performed is defined more at the summary level.

The initial baseline should show in detail all activities for the first few update periods, and this specifically includes all procurement and administrative activities. Details like permits and all critical submittals must be fully detailed in the initial baseline. This allows monitoring of these usually critical items. While an initial or preliminary schedule usually only includes the first few months of the life of the project, the early activities, such as submittal preparation and review times, fabrication, procurement, and deliveries of materials/equipment that affect the critical path, should all be included.

However, there are many times that on smaller projects, less than a year, an effort may be made to include the majority of the work for the project in the preliminary schedule. This gives the reviewing parties additional information, and less time is needed for the approval of the final baseline schedule.

Purpose

The primary purpose for developing an initial baseline is to define the preliminary plan for accomplishing the project by its required completion date. It should represent the work plan and commitments that all stakeholders have agreed to. It is impossible to know if the project is proceeding according to plan if there is no plan. The baseline establishes a means of progress reporting that allows identification of schedule variances and their impact, and enables corrective action to be initiated. It is essential that all affected parties agree to the project schedule baseline so that it can be used as a common measuring stick for progress and status.

This is not to say that the plan for accomplishing the project work will never change. As a project progresses, circumstances may change and even the project scope may change. As changes come up, it may be necessary to adjust the plan, but the baseline is always available for comparison back to the original plan.

There should only be one baseline schedule. This is the schedule created by the contractor and approved by the owner at the beginning of the project. Later revisions are either a change order or recovery schedule, and it should be noted as such instead of causing confusion by referring to several versions of the schedule as the baseline. Later revisions can be designated as target schedules that can be compared with each other, the current working plan, or the original baseline.

Timing of the Initial Baseline Preparation

There are many approaches that can be taken when establishing an initial baseline. The timing issue may be difficult. The ideal conditions are that the initial baseline would be ready at the preconstruction meeting, and this is a goal to strive for, though many times not achieved. This is not unreasonable and should be done whenever possible. The contractor makes a much better impression by showing up at the pre-construction meeting with a fully developed initial baseline that can be discussed with the client. This would cover the first 90 days of the project. Typically there is sufficient time between the notice of award and the notice to proceed, which is usually issued at the preconstruction conference, for development of the initial draft.

There should be a planning period from notice to proceed until mobilization, and this period should include purchasing, start of the submittal process, permit acquisition, and schedule development.

Default Condition

The initial baseline establishes a means of progress reporting on early project activities that allows for identification of schedule variances and their impact, and enables corrective action to be initiated.

Best Practices

Ideally, the initial baseline is developed after contract award and prior to the preconstruction meeting. It is essential that all stakeholders agree to and approve the initial baseline so that it can be used as a measurement tool. Time should be spent in development with all stakeholders planning the project from start to finish.

Recommended Practice

Typically, the initial baseline may be due within 90 days after contract award or at another predetermined time frame as required by specifications and contract documents. The initial baseline schedule should provide a manageable level of detail for work to be done in the first few months and conceptual, but accurate, work for the balance of the project. This schedule should be approved by all stakeholders prior to the first update and payment cycle. It should show detail for the first few update periods, and specifically includes procurement and administrative activities. Permits and critical submittals are fully detailed in the initial baseline to allow monitoring. Submittal preparation, review times, fabrication, procurement, and deliveries that affect critical path should be included. Include all required submittals.

The goal is to have the schedule submitted as soon as possible. In order to facilitate that, the recommended practice is that schedule requirements be spelled out specifically in the bid documents. This includes the need for an initial baseline schedule that will be developed by the contractor based on owner requirements and then submitted for owner approval within a specified number of days after contract award. It is strongly recommended that there be a progress payment tied to submittal of an initial baseline by the contractor and another progress payment tied to approval of the proposed baseline by the owner. This will help motivate and expedite the preparation of an initial baseline. For those who have issues with the owner "approving" a contractor schedule, the contractual wording may be changed to state acceptance of the schedule by the owner.

There is a logical, sequential approach that can and should be used when developing the overall project schedule baseline. There are interim steps that may be necessary so that there can be a "working baseline" or initial baseline while the detailed baseline is being established. The major steps in developing the official project baseline schedule include the following:

1. Define the total project scope.
2. Identify the organization structure for performing the project.
3. Identify the general contracting strategy, so that interfaces between contractors can be adequately represented in the schedule.

These first three steps relate to definition of the project before it is actually scheduled. This early definition enhances understanding of the project and allows schedule development to proceed more effectively. The next steps relate to actual schedule development.

4. Develop a summary schedule with major milestones.

The major milestones are typically dictated by the owner of the project, and are based on the economics used to justify the project in the first place. They may also support other specific owner needs. At this time, it is critically important to insert another step that can make or break the entire baseline development effort.

5. Conduct a schedule planning meeting, or baseline development meeting.

No matter what it is called, this meeting serves the purpose of bringing everyone associated with the implementation of the project together in one place to promote mutual understanding and ensure that all parties' needs are satisfied.

On some projects, a single contractor, project manager, or scheduler largely develops the schedule in isolation. This is not the best practice or even a recommended practice in this guide. The problem with this approach is that it does not adequately represent the abilities, resource limitations, or work strategy of all the key project participants. All stakeholders must be represented if project participants on both the owner's side and on the contractor's side are later going to accept the plan as their own. Typically, this includes the project management team, with plans in hand and their knowledge of the project, ready to discuss sequencing of the project in detail. If they have not discussed the project sequence with the major subcontractors, the major subcontractors should also be present. This means that the general contractor and subcontractors, such as concrete, grading, steel, and electrical, should be represented in the effort of developing a cohesive project detailed baseline. This includes superintendents, project managers, schedulers, and the estimators that put the project together. Allowing all affected parties input to the official baseline by creating the network schedule works best in our experience.

The schedule development meeting generates a number of things outside of the planned sequencing and identification of means and methods; it also yields requests for missing information from the plans, a list of issues for the superintendent and project manager to research, risk identification, and much more knowledge about the project than the project management team would normally have at this point. This is the best way to "jump-start" a project.

The schedule development meeting also allows the parties involved to buy off on the schedule from the beginning, instead of it being arbitrarily dictated. This has the added advantage of enabling a better chance that the superintendents will actually follow the schedule instead of constantly changing the logic because of a need to assert control over the process at a later time.

6. Identify the detailed activities necessary to support the summary schedule.
7. Assign responsibility for each activity.
8. Develop the detailed critical path network logic.

As the schedule is being built make sure to connect logic so that each activity has at minimum one predecessor and one successor. This will help in defining the critical path once the schedule is built.

9. Determine initial activity durations.
10. Use scheduling software to perform critical path calculations.
11. Compare the dates developed from the "bottom-up" approach in step 9 with the "top-down" approach used in steps 4 and 5.
12. Revise the schedules (both summary and detailed) if necessary to ensure consistency.
13. Build a table of all resources needed for the project.
14. Load the resources for each activity.

The baseline must consider the availability of resources so that activity durations are realistic. This may result in adjustments to the initial activity durations established in step 9.

15. Specify available resources and compare them with those required by the resource-loaded CPM schedule.
16. Resource level the schedule. This may be computer-aided but will require manual intervention by the scheduler and the project team to define priorities.
17. Have the project team conduct a detailed schedule review, ensuring that all work scope is included, resources are reasonable, schedule logic is accurate, and required milestone dates are met.
18. Revise the schedule as needed.

This step is important enough to merit some additional discussion. Before the schedule is formally accepted, there needs to be a quality control checkpoint. At this juncture, the schedule should be evaluated by a quality control checklist to make sure that best practices are followed. This includes running some basic metrics on the project, along with analytical reports like a late start sort, in order to see if the worst-case project planning (because the logic shown by the backward pass may very well become the project plan) is even possible. This view may show that there is clearly logic missing that would distort planning of the work. In fact, this is also an appropriate time to verify that the schedule logic is accurate. Are there activities with no successor? If so, that suggests the activity does not even need to be performed in order for the project to be completed. Does the logic reflect real requirements or "nice-to-have" wishes? While those responsible for the work may want to have every bit of information available before beginning their assigned task, it is unlikely in a project environment that such logic will support required milestone and completion dates. Activities may need to be done in parallel rather than in order to support the schedule objectives of the project. Once there is confidence that the planned baseline is accurate and can be supported by the various parties, it is time for the final step.

19. Approve the schedule baseline.

This approval should only occur after all major parties agree to the schedule. This includes the owner, owner's engineer, and the construction contractor as a minimum. Once approved, the detailed baseline should be "frozen" for future comparison against the current working plan as schedule status is incorporated. This will allow schedule analysis to be performed and schedule performance to be measured. There are potential concerns about approving the project schedule and administering the approved schedule. These will be discussed in the "Advisories" section below.

While this is a lot of effort, the development of a realistic project plan that allows progress measurement and visibility into problems early enough to allow effective corrective action is essential to a successful project.

Advisories

Underdeveloped Baselines—In the low-dollar, hard-bid construction industry we all too often see the contractor only willing to perform the minimum scheduling requirements contained in the contract. This leads to under-developed baseline schedules. At bid time, contractors often do not fully review the schedule requirements or adequately budget for the schedule development or management. This equates directly to the level of detail in the submitted schedules and their later usefulness as a management and monitoring tool.

This is not a one-sided contractor problem. There is often the problem of the owner not following through on the scheduling requirements, or not knowing what their requirements are. Far too often the project starts without a baseline, and the owner does not put the baseline requirement in the forefront until the project is in trouble.

By allowing the contractor to proceed without a preliminary or baseline schedule being submitted, the owner encourages the same practice on future projects and then contractors will ignore future requests for establishing a schedule baseline.

A similar problem is sometimes encountered when contractors are negotiating their work. They feel they have an established relationship with the owner, so they don't want to make it look like they are documenting a claim or don't need the planning capabilities.

Specifications that have a minimum number of activities support this problem with underdeveloped baselines. The contractor will develop a schedule with 501 activities because the specification calls for a 500-activity schedule. This is not the way to design a schedule. The level of detail in the schedule is a function of many other factors such as the end users, the level of management use, the complexity of the project, and the length of the update period.

These are very important considerations. This makes it essential that very specific schedule requirements are defined in the initial request for proposal without trying to tell the contractor *how* to prepare the schedule. Besides being defined, progress payments should be identified specifically related to schedule deliverables, such as submittal of initial project schedule, submittal of proposed schedule baseline, and approval of schedule baseline by the owner. In addition, company management has to be willing to eliminate a bidder from consideration if they do not comply with the submittal and reporting requirements. In the absence of these conditions, it is difficult if not impossible to get a useful schedule from a contractor.

Compounded Activities—In the development of the initial draft and baseline schedules, we often see compounded activities. For example, the schedule may have a single activity incorporating mechanical, electrical, and plumbing. This is often done for expediency or to keep the schedule simple. The problem is that these are three separate trades, and typically represented by at least two but more often three separate subcontractors. Each should have their own separate activities. Further, by compounding activities, the scheduler eliminates the ability to fully manage the resources of the project. Say a compounded mechanical/electrical/plumbing activity is slipping, and let's assume it is due to the electrical subcontractor not having sufficient manpower. How can the project manager or schedule reviewer fully analyze the situation? Compounded activities also preclude the staggering of these different trades. The mechanical/electrical/plumbing example is used here, but the same scenario also applies to concrete work. An example would be activity descriptions such as Form/Rebar/Pour Foundation XYZ. This practice should be avoided.

It is useful to insist on having separate activities for each resource, as well as for every point in the project where there is a change in responsibility. When multiple tasks are combined in a single activity, it is difficult or impossible to establish who or what is delaying the schedule. Likewise, if any interface points are missing, such as the receipt of vendor drawings for system design, it is possible that the critical path is inaccurate.

Another area to avoid is compounding several areas within a phase into single activities. One example would be a schedule for a school that needs a recovery schedule. There may be several buildings in each phase, and say the activities are combined for all of the buildings within a phase. This makes it impossible to track, since there may be delays in some buildings while the others could continue. Any recovery schedule would need to separate each of the buildings, so that it would be possible to better track progress. Field personnel may still complain because it takes longer to update each week, but why bother even using a schedule that cannot serve its intended function?

In the fully detailed baseline, it is important to divide the project into areas within which progress is relatively uniform. For example, the corridors in a building usually have mechanicals running in the ceiling, are delayed from completion by traffic and the potential for traffic damage, and will never progress at the same rate as adjacent rooms. If the corridors are included in the adjacent room activities, either there will be activities that are progressed to 90% and left stagnant until the corridors are ready for finishing, or there will be corridor work that is no longer monitored because activities covering this work are advanced to completion with the adjacent offices. During proper schedule design, it is recommended that areas be clustered with areas with similar expected rates of progress so that the update process will be reasonable.

Details of Submittals in Baseline Schedules—There needs to be discussion among the project parties regarding how much detail to provide on submittals of information to the owner. Opinions may be sharply divided on this subject between contractors and owners.

Construction contractors like to group submittals into a single or few activities (e.g., concrete, asphalt, electrical submittals) unless there is a specific piece of equipment or material that is going to take a long lead time to arrive on-site. Architect-Engineering firms will not want to schedule submittal of each specification and drawing. There are some projects where the owner wants to have all of the submittals to help schedule their own activities, such as review and approval of each of the submittals. This may result in more submittal activities than actual work. Contractors argue that having so many submittal activities in the schedule causes confusion, and they will filter them out in order to focus on the work activities. They may argue that an excessive number of submittals are not really required for that project.

Owners will argue in response that there cannot be too many submittals in a detailed baseline. Further, the specifications are part of the project contract and, therefore, if a submittal is called out in the specifications it is required for the project. They will state that the criticality or near criticality of a particular submittal cannot be determined until it is included in the schedule and properly tied to the physical work activity that is dependent on the submittal being made, reviewed and then procured in a timely manner. They will state that the criticality of any submittal is a function of the building systems employed, site conditions and geometry, and operational conditions/restrictions. While an experienced person can guess what submittals may be driving the project and if they are critical or near critical, no one can know for certain until they are included in the schedule. In unusual cases, there have been instances where the miscellaneous steel or rock anchor submittals were driving the critical path due to the phasing and geometry of the site.

As a best practice, include all potentially driving submittals in the initial baseline, and all submittals in the detailed baseline. Experience has shown that often submittals really are driving the critical path, but project management may not believe that non-work activities should be critical. In addition, it is good practice to place several buyout activities in the schedule so that discussion about how far along the buyout (awarding of all subcontracts and purchase orders) is can be forced at each update. Very often, the failure to either draft or execute a subcontract will prevent the superintendent from starting critical work. This may cause some to say, "We can't see the building in the schedule because of the administrative paperwork." However, that may actually be the case if the failure to pursue administrative work (permits, procurement, etc.) has allowed these items to completely take over the critical path and obscure any work.

Another point on submittals is that it is critical for the general contractor to confirm with subcontractors the number of submittals to be made for a particular system. For example, on a recent project the baseline reflected a singular submittal for Heating Ventilation and Air Conditioning (HVAC). This submittal was on the critical path and it was actually submitted in five different packages over a period of months. Further, the first of these submittal packages was submitted a few days late. As the initial submittal package was a couple of days late, this would have been a contractor's delay and it should have been possible to recover. However, as the total submittal package was actually broken down into five different packages, the overall delay impact was much greater. This confusion could have been avoided if the general contractor had communicated the actual detail with the subcontractor and then incorporated this detail into the detailed baseline.

The initial draft schedule should include all required early submittal and procurement activities. All too often, projects get off to a bad start by only including submittals that one party believes are important or "critical" to them. We have seen situations where the construction manager for a community college district was only interested in the submittals that had to be reviewed by the department of the state architect (the building authority in this case), while the contractor's project manager only wanted to include submittals that he felt were critical. His judgment of what was critical was based upon his experience. In reality no one fully knows what submittals are going to be critical or near critical until all are included in the schedule and properly logically tied into the network. Personal judgments of importance or criticality do not take into account the design, site, phasing, or appropriate logic of the schedules. It is the scheduler's responsibility to educate non-schedulers about these issues and resist not fully developing this portion of the schedule to satisfy the desires of non-schedulers. You won't know what is critical or near-critical until it is in the schedule.

Another benefit of the submittal process is that, if done correctly, the schedule will automatically provide the priorities for reviewing and approving submittals. This is of great benefit for a project manager who is overworked and has multiple submittals in the inbox that need to be done. This may include items that will prevent the project manager from either starting with the earliest submittal to come in, or worse, from focusing on the simplest submittal (a judgment call) thinking that it can be done quickly. This is often a poor decision because it can take up too much time while critical submittals are ignored.

Approval of Baseline by Owner—All too often, once the initial baseline schedule is created, some parties tend to hold the schedule as an absolute and unforgiving picture of events. The detailed baseline, along with the updates, must be viewed as a living flow of events that can be measured against the initial baseline schedule to confirm or deny viability of progress or delays. Any project activity can be made a variable against the baseline schedule as long as the intent of that schedule remains the same and the accepted completion date is not compromised.

Some hold the opinion that any "approval" by the owner is a risky enterprise and should be clarified further (timing, conditions, forms, etc.). The review and checking of the schedule by the owner in order to satisfy himself/herself of the viability of the contractor's proposed sequence poses no problems, but an "approval" of a baseline schedule could potentially open the gates to a flood of claims for a variety of reasons by the contractor if any baseline activities/sequences are disturbed during the works. Any departure from the approved baseline document represents a potential ground for future disputes.

While the baseline schedule commits the project team to the plan they made before the project started, there are always changes in plans once the project is underway. If the owner puts too many restrictions on making changes in logic, or forbids adding additional activities for delays or newly defined work, the schedule no longer represents the project. It then becomes a document nobody follows, but is mostly used as a tool against the contractor for not following the original plan.

There should only be one baseline schedule. This is the schedule created by the contractor and approved by the owner at the beginning of the project. Anything else is either a change order or recovery schedule, and should be noted as such instead of confusing everyone by referring to several versions of the schedule as the baseline.

However, we need to keep in mind that the schedule should represent an agreement, or meeting of the minds, regarding the work plan and the commitments that all project stakeholders are making. While revisions to the schedule may be necessary to accurately reflect the changing conditions of the project, that circumstance does not grant the right for unilateral revisions. Unilateral revisions violate this meeting of the minds. Typically, the owner should restrict the contractor from making unilateral revisions. If a revision to the schedule is necessary, a formal revision request should be submitted by the contractor to the owner for approval. The contractor should accompany this request with the "before" and "after" conditions of the schedule change request so that the impact is clearly identified. This will avoid later confusion and provide documentation at the end of the project for any schedule delay claims. All proposed changes to the original baseline schedule should be accompanied by adequate justification for each change. This revised schedule is then reviewed and either agreed to or the necessary corrective actions should be taken to achieve agreement to a revised schedule.

In some cases, the project may change so much that an official revised baseline may need to be created at some point, but every change in circumstances and every schedule slip should NOT be declared as a new baseline. Useful schedule analysis requires comparison of the current working schedule against the originally approved baseline schedule, as well as against any "target schedules" that reflect later approved changes to project scope or schedule.

Calendars—A possible confusion factor when the baseline schedule is developed is the use of multiple calendars. Care must be taken so that realistic project conditions are reflected and that the true critical path is not obscured by careless calendar definition. There have been instances of confusion regarding project duration due to misunderstanding between schedulers and non-schedulers regarding activity durations. Does a one-week activity mean 40 working hours, five working days, six working days, or seven working days, possibly around the clock? If different calendars are unavoidable in the establishment of a baseline, then a careful review of the calendars should become part of the overall schedule baseline review at the beginning of the project. Full justification and explanation of different calendars used for the baseline should be provided as part of the submission of the baseline schedule. This is especially valid for procurement activities (usually required on a seven-day calendar) which may involve imports from countries with different statutory holidays than those considered for the construction activities.

3.2.2 Detailed Baseline Development

There are certain key components necessary for successfully defining a project. These include the scope of work to be performed, the schedule for accomplishing the work, the organization tasked for doing the work, and a budget for the work. These various considerations become the basis of the plan for accomplishing the project. This plan can be documented in a baseline. In large, complex projects requiring more than a year to complete, there may need to be a separate initial baseline for accomplishing the early work while a formal detailed baseline is developed for the full project.

Guidelines

Definitions

The baseline is the official project plan for accomplishing a project scope within an authorized budget and within a specified period of time. The fully developed detailed baseline is the comprehensive work plan for the total project and should include all elements of work at a level of detail to adequately manage and monitor the project.

Purpose

The primary purpose for developing a detailed baseline is to define the plan for accomplishing the project by its required completion date. It should represent the work plan and commitments that all stakeholders have agreed to. It is impossible to know if the project is proceeding according to plan if there is no plan. The baseline establishes a means of progress reporting that allows identification of schedule variances and their impact, and enables corrective action to be initiated. It is essential that all affected parties agree to the project schedule baseline so that it can be used as a common measuring stick for progress and status.

This is not to say that the plan for accomplishing the project work will never change. As a project progresses, circumstances may change, and even the project scope may change. As changes come up, it may be necessary to adjust the plan, but the baseline is always available for comparison back to the original plan.

Timing of the Detailed Baseline Preparation

The detailed baseline schedule submittal should be due no later than 30 to 90 calendar days from the notice to proceed date. This is assuming that the project is of sufficient length to accommodate this duration and that the project delivery system used is design/bid/build. If the project is shorter, say a modernization or renovation that will take only three to six months, the timing requirements for submission of the schedules will need to be adjusted accordingly. The length of lead time required will depend on the total duration and complexity of the project. In addition, if the project delivery system to be used is design/build or construction management, where the full baseline requirements will not be known until all of the bid packages are developed and/or bid, then further accommodations need to be considered.

The timing of the full detailed baseline is a much more difficult issue than the timing of the initial baseline schedule. The contractor is often still contracting parts of the project and may not have major subcontractors identified yet, so it becomes very difficult for them to focus enough on any schedule to provide quality input.

When a schedule is resource- and/or cost-loaded, this is another whole issue. The level and type of detail that a subcontractor is happy with on a resource-loaded schedule is entirely different from one that is not resource-loaded, so this automatically adds weeks to the information flow. Some organizations use a two-tier approach, completing the full schedule without loading and then later loading the result. However, this often generates changes as the subcontractors start compiling their costs and resources. Allowing 30 days to provide a full detailed baseline is too short in large projects, although it is an admirable goal. Depending on the duration and complexity of the project, it is quite possible that 90 days may be the shortest reasonable time for developing an effective detailed baseline schedule. The worst scenario is when the notice to proceed is issued and everyone is ready to go ahead. Under such circumstances, it is nearly impossible to get the contractor to focus on planning since implementation has already begun.

There should be a planning period from notice to proceed until mobilization, and this period should include purchasing, start of the submittal process, permit acquisition, and schedule development. Ideally a contractor takes two months to design and develop a good, fully detailed baseline schedule for an 18-month job.

Best Practices

Ideally, the detailed baseline is complete within 30 to 90 calendar days from the notice to proceed date. It is essential that all stakeholders agree to and approve the detailed baseline so that it can be used as a measurement tool. Time should be spent in development, with all stakeholders planning the project from start to finish.

Recommended Practice

The goal is to have the schedule submitted as soon as possible. In order to facilitate this, the recommended practice is that schedule requirements be spelled out specifically in the bid documents. This includes the need for an initial baseline schedule that will be developed by the contractor based on owner requirement, and then submitted for owner approval within a specified number of days after contract award. It is strongly recommended that there be a progress payment tied to submittal of an initial baseline by the contractor and another progress payment tied to approval of the proposed baseline by the owner. This will help motivate and expedite the preparation of an initial baseline. For those who have issues with the owner "approving" a contractor schedule, the contractual wording may be changed to state acceptance of the schedule by the owner.

The detailed baseline will expand the level of detail originally provided for future activities in the initial baseline. The same process should be followed as before, with contractor definition of schedule scope, sequencing, and logic, and review and approval by the owner. Once again, it is helpful if some form of progress payment is tied to delivery of the detailed baseline schedule and its approval.

There is a logical, sequential approach that can and should be used when developing the overall project schedule baseline. While there are interim steps that may be necessary so that there can be a "working baseline" or initial baseline while the detailed baseline is being established, the major steps in developing the official project baseline schedule include the following:

1. Define the total project scope.
2. Identify the organization structure for performing the project.
3. Identify the general contracting strategy, so that interfaces between contractors can be adequately represented in the schedule.

These first three steps relate to definition of the project before it is actually scheduled. This early definition enhances understanding of the project and allows schedule development to proceed more effectively. The next steps relate to actual schedule development.

4. Develop a summary schedule with major milestones.

The major milestones are typically dictated by the owner of the project, and are based on the economics used to justify the project in the first place. They may also support other specific owner needs. At this time, it is critically important to insert another step that can make or break the entire baseline development effort.

5. Conduct a schedule planning meeting, or baseline development meeting. No matter what it is called, it serves the purpose of bringing everyone associated with the implementation of the project together in one place to promote mutual understanding and to ensure that all parties' needs are satisfied.

On some projects, a single contractor, project manager, or scheduler largely develops the schedule in isolation. This is not the best practice or even a recommended practice in this guide. The problem with this approach is that it does not adequately represent the abilities, resource limitations, or work strategy of all of the key project participants. All stakeholders must be represented if project participants on both the owner's side and on the contractor's side are later going to accept the plan as their own. Typically, this includes the project management team, with plans in hand, with their knowledge of the project, ready to discuss in detail sequencing of the project. If they have not discussed the project sequence with the major subcontractors, then the major subcontractors should also be present. This means that the general contractor and subcontractors such as concrete, grading, steel, and electrical, be represented in the effort of developing a cohesive project detailed baseline. This includes superintendents, project managers, schedulers and the estimators that put the project together. Allowing all affected parties input to the official baseline by creating the network schedule works best in our experience.

The schedule development meeting generates a number of things outside of the planned sequencing and identification of means and methods; it also yields requests for missing information from the plans, a list of issues for the superintendent and project manager to research, risk identification, and much more knowledge about the project than the project management team would normally have at this point. This is the best way to "jump-start" a project.

This allows the parties involved to buy off on the schedule from the beginning, instead of it being arbitrarily dictated. This has the added advantage that there is a better chance that the superintendents will actually follow the schedule instead of constantly changing the logic because of a need to assert control over the process at a later time.

6. Identify the detailed activities necessary to support the summary schedule.
7. Assign responsibility for each activity.
8. Develop the detailed critical path network logic.
9. Determine initial activity durations.
10. Use scheduling software to perform critical path calculations.
11. Compare the dates developed from the "bottom-up" approach in step 9 with the "top-down" approach used in steps 4 and 5.
12. Revise the schedules (both summary and detailed) if necessary to ensure consistency.
13. Build a resource table of all resources needed for the project.
14. Load the resources for each activity.

The baseline must consider the availability of resources so that activity durations are realistic. This may result in adjustments to the initial activity durations established in Step 9.

15. Specify available resources and compare them with those required by the resource-loaded CPM schedule.
16. Resource level the schedule. This may be computer-aided but will require manual intervention by the scheduler and the project team to define priorities.
17. Have the project team conduct a detailed schedule review, ensuring that all work scope is included, that resources are reasonable, that schedule logic is accurate, and that required milestone dates are met.
18. Revise the schedule as needed.

This is important enough to merit some additional discussion. Before the schedule is formally accepted, there needs to be a quality control check point. At this juncture, the schedule should be evaluated by a QC Checklist to make sure that best practices are followed. This includes running some basic metrics on the project along with analytical reports like a late start sort, in order to see if the worst case project planning (because the logic shown by the backward pass may very well become the project plan) is even possible. This view may show that there is clearly logic missing that would distort planning of the work. In fact, this is also an appropriate time to verify that the schedule logic is accurate. Are there activities with no successor? If so, that suggests that the activity does not even need to be performed for the project to be completed. Does the logic reflect real requirements or "nice-to-have" wishes? While those responsible for the work may want to have every bit of information available before beginning their assigned task, it is unlikely in a project environment that such logic will support required milestone dates and completion dates. Activities may need to be done in parallel rather than in series in order to support the schedule objectives of the project. Once there is confidence that the planned baseline is accurate and can be supported by the various parties, it is time for the final step.

19. Approve the schedule baseline. This approval should only occur after all major parties agree to the schedule. This includes the owner, owner's engineer, and the construction contractor as a minimum. Once approved, the detailed baseline should be "frozen" for future comparison against the current working plan as schedule status is incorporated. This will allow schedule analysis to be

performed and schedule performance to be measured. There are potential concerns about approving the project schedule and administering the approved schedule. These will be discussed in the "Advisories" section.

While this is a lot of effort, the development of a realistic project plan that allows progress measurement and visibility into problems early enough to allow effective corrective action is essential to a successful project.

Advisories

Under Developed Baselines—In the low-dollar, hard-bid construction industry we all too often see the contractor only willing to perform the minimum scheduling requirements contained in the contract. This leads to under developed baseline schedules. At bid time, contractors often do not fully review the schedule requirements or adequately budget for the schedule development or management. This equates directly to the level of detail in the submitted schedules and their later usefulness as a management and monitoring tool.

This is not a one-sided contractor problem. There is often the problem of the owner not following through on the scheduling requirements, or not knowing what their requirements are. Far too often the project starts without a baseline, and the owner does not put the baseline requirement in the forefront until the project is in trouble. By allowing the contractor to proceed without a preliminary or baseline schedule being submitted, the owner encourages the same practice on future projects and then contractors will ignore future requests for establishing a schedule baseline.

A similar problem is sometimes encountered when contractors are negotiating their work. They feel they have an established relationship with the owner, so they don't want to make it look like they are documenting a claim or don't need the planning capabilities.

Specifications that have a minimum number of activities support this problem with underdeveloped baselines. The contractor will develop a schedule with 501 activities because the specification calls for a 500-activity schedule. This is not the way to design a schedule. The level of detail in the schedule is a function of many other factors such as the end users, the level of management use, the complexity of the project, the length of the update period, and others.

These are very important considerations. This makes it essential that very specific schedule requirements are defined in the initial request for proposal without trying to tell the contractor *how* to prepare the schedule. Besides being defined, progress payments should be identified specifically related to schedule deliverables, such as submittal of initial project schedule, submittal of proposed schedule baseline, and approval of schedule baseline by the owner. In addition, company management has to be willing to eliminate a bidder from consideration if they do not comply with the submittal and reporting requirements. In the absence of these conditions, it is difficult if not impossible to get a useful schedule from a contractor.

Compounded Activities—In the development of the initial draft and baseline schedules we often see compounded activities. For example, the schedule may have a single activity incorporating mechanical, electrical, and plumbing. This is often done for expediency or to keep the schedule simple. The problem is that these are three separate trades, and typically represented by at least two but more often three separate subcontractors. Each should have their own separate activities. Further, by compounding activities, the scheduler eliminates the ability to fully manage the resources of the project. Say a compounded mechanical/electrical/plumbing activity is slipping, and let's assume it is due to the electrical subcontractor not having sufficient manpower. How can the project manager or schedule reviewer fully analyze the situation? Compounded activities also preclude the staggering of these different trades. The mechanical/electrical/plumbing example is used here, but the same scenario also applies to concrete work. An example would be activity descriptions such as Form/Rebar/Pour Foundation XYZ. This practice should be avoided.

It is useful to insist on having separate activities for each resource, as well as for every point in the project where there is a change in responsibility. When multiple tasks are combined in a single activity, it is difficult or impossible to establish who or what is delaying the schedule. Likewise, if any interface points are missing, such as the receipt of vendor drawings for system design, it is possible that the critical path is inaccurate.

Another area to avoid is compounding several areas within a phase into single activities. One example would be a schedule for a school that needs a recovery schedule. There may be several buildings in each phase, and say the activities are combined for all of the buildings within the phase. This makes it impossible to track since there may be delays in some buildings while the others could continue. Any recovery schedule would need to separate each of the buildings, so that it would be possible to better track progress. Field personnel may still complain because it takes longer to update each week, but why bother even using a schedule that cannot serve its intended function?

In the fully detailed baseline, it is important to divide the project into areas within which progress is relatively uniform. An example is the corridors in a building. These areas usually have mechanicals running in the ceiling, are also delayed from completion by traffic and the potential for traffic damage, and will never progress at the same rate as adjacent rooms. If the corridors are included in the adjacent room activities, either there will be activities that are progressed to 90% and left stagnant until the corridors are ready for finishing, or there will be corridor work that is no longer monitored because activities covering this work are advanced to completion with the adjacent offices. During proper schedule design, it is recommended that areas be clustered with similar areas with expected rates of progress so that the update process will be reasonable.

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Another benefit of all the submittal process is that if done correctly, the schedule will automatically provide the priorities for reviewing and approving submittals. This is of great benefit for a project manager who is overworked, and has multiple submittals in the inbox that need to be done. This may include items that will prevent the project manager from either starting with the earliest submittal to come in, or worse, from focusing on the simplest submittal (a judgment call) thinking that it can be done quickly. This often is a poor decision because it can take up too much time while critical submittals are ignored.

Approval of Baseline by Owner—All too often, once the initial baseline schedule is created, some parties tend to hold the schedule as an absolute and unforgiving picture of events. The detailed baseline along with the updates must be viewed as a living flow of events that can be measured against the initial baseline schedule to confirm or deny viability of progress or delays. Any project activity can be made a variable against the baseline schedule as long as the intent of the baseline schedule remains the same and the accepted completion date is not compromised.

Some hold the opinion that any "approval" by the owner is a risky enterprise and should be clarified further (timing, conditions, forms, etc.). The review and checking of the schedule by the owner in order to satisfy himself of the viability of the contractor's proposed sequence poses no problems, but an "approval" of a baseline schedule could potentially open the gates to a flood of claims on a variety of reasons by the contractor if any baseline activities/sequences are disturbed during the works. Any departure from the "approved" baseline document represents a potential ground for future disputes.

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However, we need to keep in mind that the schedule should represent an agreement, or meeting of the minds, as to the work plan and the commitments that all project stakeholders are making. While revisions to the schedule may be necessary to accurately reflect the changing conditions of the project, that circumstance does not grant the right for unilateral revisions. Unilateral revisions violate this meeting of the minds. Typically the owner should restrict the contractor from making unilateral revisions. If a revision to the schedule is necessary, a formal revision request should be submitted by the contractor to the owner for approval. The contractor would accompany this request with the "before" and "after" conditions of the schedule change request so that the impact is clearly identified. This will avoid later confusion and provide documentation at the end of the project for any schedule delay claims. All proposed changes to the original baseline schedule should be accompanied by adequate justification for each change. This revised schedule is then reviewed and either agreed to or such corrective actions taken to achieve agreement to a revised schedule.

Some confusion has resulted in the industry because certain scheduling software vendors have loosely used the terminology for "baselines." The baseline is a formally reviewed and approved schedule that is retained as a starting point for the life of the project. Later approved changes to this plan are documented in "target schedules," which should not be confused with the original baseline plan. There is only one original baseline schedule. In some cases, the project may change so much that an official revised baseline may need to be created at some point, but every change in circumstances and every schedule slip should NOT be declared as a new baseline. Useful schedule analysis requires comparison of the current working schedule against the originally approved baseline schedule as well as comparison to any "target schedules" that reflect later approved changes to project scope or schedule.

Calendars—A possible confusion factor when the baseline schedule is developed is the use of multiple calendars. Care must be taken so that realistic project conditions are reflected and that the true critical path is not obscured by careless calendar definition. There have been instances of confusion regarding project duration due to misunderstanding between schedulers and non-schedulers regarding activity durations. Does a one week activity mean 40 working hours, five working days, six working days, or seven working days possibly around the clock? If different calendars are unavoidable in the establishment of a baseline, then a careful review of the calendars becomes part of the overall schedule baseline review at the beginning of the project. Full justification and explanation of different calendars used for the baseline should be provided as part of the submission of the baseline schedule. This is especially valid for procurement activities (usually required on a 7-day calendar) which may involve imports from countries with different statutory holidays than those considered for the construction activities.

3.2.3 Initial and Detailed Baseline Review

Review of the baseline schedule is the culmination of the development stage. It formalizes the presentation of the schedule for recognition by the project stakeholders and initiates its use for monitoring and control of activities.

Guidelines

Definitions—Baseline review occurs after all previous schedule preparation steps have taken place. It should be carried out by or on behalf of the management as a final check to confirm it is ready to use. This review allows stakeholders to give it recognition as appropriate for monitoring the activity progress of the project.

The baseline schedule submitted for review should include a written memorandum documenting the basis of the schedule. This provides a recorded explanation of the reasoning, assumptions, and all considerations that were applied during the development of the baseline schedule.

Purpose—A formal baseline review will help ensure the quality of the baseline schedule that is being presented. Verification of essential characteristics is made for such aspects as full scope representation, overall duration, recognition of the critical and near-critical paths, and confirmation of reasonable resource demands.

Furthermore, when properly presented in a project team setting, a review of this nature gives the various project participants the opportunity to gain a comprehensive understanding of the schedule as a representation of the overall project execution. It allows participants to confirm their relevance in the sequence of activities and to jointly confirm priorities.

Default Condition—Depending on the level of project complexity, contractual requirements, and organizational procedures, the baseline review may take place formally or informally. It may be done by a single management representative or go through a rigorous, established process.

Often times, not only is the contractor's organization involved, but the owner will also have the right for review and approval of the baseline schedule. In such cases, their requirements will need to be taken into account.

Best Practices

The baseline review should take place after all inputs have been incorporated, resource loading has been accomplished, verification of scope and format requirements have been confirmed, and CPM integrity check has been made to assure best practices have been utilized.

The review itself should comprise three steps:

1. Overview Presentation
2. Detailed Review of Schedule
3. Results of Review

Overview Presentation: Initial introduction of the baseline schedule via a meeting presentation should be made. This will give management or the owner/client a thorough briefing of how the schedule was put together and of what the resulting product will be. This serves to gain their confidence that the effort has been effective, and it helps them to become cognizant of the particularities of the project schedule at hand. It further provides a means for gaining their buy-in acceptance of the schedule. The meeting presentation should be about one hour long.

Recommended content is as follows:

- **Overall Summary:** A single summary slide showing a Level 1 type schedule, including total duration, identification of major phases, and most significant milestones
- **Methodology/Development:** Brief description of the steps used to develop the schedule
- **Project Execution Strategy:** Highlights of the primary execution strategies which are the basis of the schedule (i.e., interfaces with third parties, use joint venture partnerships, core subcontracting approach, path of construction, use of modularization, procurement approach, etc.)
- **Major Assumptions:** An extension of item 3, with a more specific listing of the most important assumptions made for each of the engineering, procurement, and construction portions of the schedule. This should include the basis of estimating the duration of most important schedule activities (e.g., 3-D model development and review, owner timing for review of submittals, permitting considerations, isometric production rates, pipe spool fabrication timing, construction installation rates, weather considerations, permitting or other site constraints, typical workweek, and use of overtime).
- **Primary Critical Path:** Single-page layout of the critical path sequence of activities extracted from the CPM schedule from the start of the project to project completion
- **Secondary Critical Paths:** Similar to item 5, but for sequences of activities with minor amounts of float. This should be limited to the three or four most relevant sequences of activities.
- **Float Analysis:** A table or chart showing the number of activities having various ranges of float (i.e., activities with 0 to 10 days float, 10 to 30 days float, 30 to 60 days float, and/or more than 60 days float)
- **Historical Benchmark Comparisons:** Brief, single-page comparisons of the project to other projects of similar type, scope, and size, which may have been available to use as a historical benchmark reference
- **Progress Curves:** Typically limited to the project overall, or major engineering/construction phases only
- **Staffing Histograms:** Typically limited to the overall engineering staffing and/or major construction craft only
- **Schedule Risk:** Simple list of the primary issues of uncertainty which may affect the schedule, causing significant delays and/or liquidated damages
- **Risk Analysis:** Simple graph presentation of the probabilistic completion date outcome if a Monte Carlo analysis and a risk ranging workshop was carried out
- **Path Forward:** Brief description of steps that will be taken to implement schedule monitoring, or to carry out schedule adjustments determined necessary before setting the baseline

Detailed Review: The second part of the process should be for management or the owner/client representatives to make their own detailed review. Typically, this can take about one week and requires a copy of the baseline schedule in native format. This will allow the independent assessment of aspects such as:

- CPM integrity (use of best practices)
- Sound activity logic sequencing
- Verification of full scope representation
- Application of appropriate WBS, milestones, format structuring, etc.
- Coding adequate for summarization purposes

- Use of resource loading
- Level of detailed adequacy for monitoring
- Verification of critical path
- Other contractual requirements

Part of this effort should also be to carry out the review of the corresponding basis of schedule. This should provide a recorded explanation of the reasoning, assumptions, and all considerations that were applied during the development of the baseline schedule.

Results of Review: This should come from the management or owner/client representative who carried out the review. A formal set of comments should be outlined in "exception report" style, i.e., a specific list of deficiencies, remarks, or issues of concern. A repetition of what has been submitted for review and is essentially correct is not necessarily needed.

Similar to other technical document submittals, a clear statement of "Approval," "Approved with Comments," or "Rejection" should be made with a list of actions needed for corrections and then resubmitted. It is very important for the reviewer(s) to meet and discuss directly with the scheduler any problems or issues causing a hold on the approval of the schedule. These need to be addressed and resolved in the most expeditious manner possible.

Issuing of review results should not take more than one week (or as per contractual terms). Final approval, including resolution of issues, should take place as soon as possible. This is to minimize any delays in the use of the baseline schedule to begin meaningful monitoring of activities and subsequent status updating of the schedule.

Recommended Practice

Make sure that a basis of schedule memorandum is prepared. Since the schedule constitutes a graphical representation of the intended sequence and duration of activities needed to carry out a project, it is reflective of the project execution strategy. As such, the basis of schedule provides an important complement to understanding the plans for carrying out the project. This constitutes a document upon which later analysis can be made in the event that a project has not been able to proceed as planned. This type of exercise will inspire the scheduler to perform a careful review of the schedule originally intended as a representative model of the project execution strategy, and hopefully ensure that a comprehensive set of predicted circumstances will be taken into account. Further benefits are the presentation of the details to both client/owners and management for their comprehension of how the schedule was put together and the presumed manner in which the project events are anticipated to unfold.

Be sure to have good project team review. Review by management and/or the client/owner representatives should take place prior to submittal of the baseline schedule. This will help ensure there is a project team commitment to the schedule because they will be satisfied that their input has been appropriately incorporated and fits in with the overall scheme of execution. Having strong project team buy-in to the baseline schedule should give management and/or the client/owners confidence that a good baseline schedule will be achieved.

Apply a similar approach when issuing a re-baselined schedule. In the event a new baseline is required to be established, it is advisable to carry out a review of similar nature to that for the original baseline schedule. This is for the purpose of gaining renewed verification of effective development, and project stakeholders' recognition and commitment to achieving the plan.

Use software available for schedule review. There are currently good program offerings on the market for the review of CPM networks. These include a series of recognized metrics for comparing specific schedules, and they may be useful in determining CPM integrity. The limitation, however, is in statistical quantification of characteristics of the network. These programs do not offer guidance for estimating duration or the correctness of work sequence logic. For this, it is necessary to rely on the experience of the reviewer or subject matter experts who can support the review.

Use historical data. When possible, comparison to past projects of similar scope, components, and size should be made. This will allow for assessment for overall project duration with respect to actual projects that may have been executed in the past.

Advisories

Avoid excessive scrutiny. Reviewers of a baseline schedule should be cautious about becoming overzealous in finding issues with the baseline schedule. They need to strike a good balance between what is essential in making the schedule effective and what can be considered preferential methods or details. Utilization of the guidance provided by the PMI Scheduling Community of Practice best practices and guidelines should help maintain that focus.

The review should be timely. A review should be initially completed within one week's time. Resolution of deficiencies or follow-up issues should be resolved within one week after that. This is necessary to avoid delays in implementation of the baseline schedule for monitoring and control.

Do not underestimate the value of the review. This is an essential part of baseline schedule development. It not only helps assure the final product will be a quality effort, but puts all project stakeholders on the same page from the beginning with regard to this primary component of project execution.

Give advance notice to management and/or the client/owner. If they are aware ahead of time about when the baseline schedule will be ready, this will help assure they have the necessary resources available to carry out the review in a timely manner and not delay final issuance.

Keep future project participants in mind. In the event that some participants are not present at the time of baseline development (such as future hire subcontractors), provisions should be made for them to get a briefing once they come on board, so they get a good understanding of where they fit into the picture.

3.2.4 Initial and Detailed Baseline Approval

Formal approval of baseline schedule development is the essential culminating step necessary for the schedule's successful use on a project. This should take place in an expeditious manner after the contractor has made every effort to meet the expectations of both the client and management. It remains a client's responsibility to exercise good judgment about promptly granting approval while balancing their objective demands with the practical effectiveness the contractor is able to offer.

Guidelines

Definitions

Baseline approval is the formal recognition that schedule development has been completed and the schedule is ready to use. This formal approval will typically be given by one or more of the following entities related to a project:

- The project manager or the project management team for the project
- Management of the project controls department of the contractor's company
- The client/owner, or their designated representative

Given that a schedule is representative of the execution plans for the project, the approval of the baseline by the approving management or owner representative acknowledges and confirms that such plans are adequate and the project team should proceed.

Purpose: Baseline approval signals that all appropriate steps in the detailed schedule preparation have been completed and the schedule is ready for use in the monitoring and control of project activity progress. From this point forward the baseline schedule can be used as the benchmark to compare to future schedules—the planned schedule versus the as-built to mark progress.

This action is an acceptance by all project stakeholders of the agreement to the expected overall completion date, as well as to major intermediary completion milestones. In the event of a dispute or claim pertaining to project completion, the approved baseline schedule will serve as a basis for evaluation of project delays, disruptions, or interruptions.

Default Condition

The formal approval of the schedule is typically subject to the contract requirements from the owner. A significant focus will most likely be on the completion date defined by the detailed baseline schedule. This is subject to the contract terms and/or the proposal schedule under which the contractor was awarded the project. Contractual terms will commonly also specify format, content, and timing for submittal.

Best Practices

The primary emphasis here is for an expeditious approval process. This is so that the baseline schedule will be made operational on the project promptly. Most likely, work has continued to proceed while the schedule is under development, and it should not go too far along without a basis for monitoring.

Promptly address any comments which may result from the review process leading up to the approval. Both management and the owner should exercise their rights to require full compliance with their expectations. In doing so, they may give instructions for modifications of the schedule which has been submitted to them. Should the project team not be in agreement or understand the need for such adjustments, prompt discussion and resolution must be carried out to avoid delays of formal implementation of the baseline schedule.

Schedulers will also serve their project well if they are fully cognizant of schedule submittal requirements and work those specifications into the schedule. This will prevent any surprises at the time of seeking approval, which could become a reason for rejection.

Be sure to notify all key members of the project team when the baseline schedule is formally approved. Issue a full copy to them for reference and advise them of any owner or management modifications that may have been required since they last saw the schedule.

Recommended Practice

Approvals are best recorded in writing. When using the submittal process, submitting the return approval with any notations is a good way to evidence that the baseline schedule is "official." In any event, a letter or email can serve this purpose.

The submittal should include a corresponding basis of schedule memorandum to further list all of the assumptions and considerations that were necessary for inclusion in schedule development. This should also serve to fully present all qualifications that go along with the baseline schedule, in case clarifications are needed later for interpretation.

On larger projects, which are considered to have a greater degree of complexity, it is a good idea to present the schedule to the owner and/or the contractors' own management. This will help demonstrate project team commitment to achieving the schedule goals, as well as show the extent of thoroughness in its development. Topics should include, at a minimum: project execution strategy, schedule development methodology, major assumptions, path of construction, primary critical path and near critical paths, and major schedule risks.

A similar approval process should be carried out in the event that it becomes necessary to carry out a re-baseline for the project.

Advisories

The primary situation to avoid is the lack of formal baseline schedule approval. The schedule should be developed in an expeditious, but also effective and thorough, manner. The approval should be the culmination of this process and set the record of agreement for all concerned parties that there is an understanding of this essential component of any project execution.

Contractors and their scheduling personnel should make sure they are in compliance as much as possible with the contract and client requirements, as well as with their own in-house procedural requirements. In other words, the expectations of client and management must be met for total project duration, schedule integrity, use of best practices, and good activity levels of detail with proper sequence logic. This will help facilitate a quick approval with minimum issues of concern from the approval entity.

By the same token, clients granting approval must exercise caution not to impose unrealistically short project durations, which will likely minimize the probabilities of being achieved by the contractor. Nor should there be overly demanding requirements whose implementation effort would not be proportional to the improved quality of control on the job. In general, contractors should be allowed to establish a plan which will allow them to execute the project according to their established expertise, then monitor that they are working to their plan.

3.2.5 Use of Narratives

Guidelines

Definitions

A narrative, as it relates to scheduling, is a written analytical report relating the results of an update to a schedule (no matter how often it is updated) to any team member who has a vested interest in the telling thereof.

Purpose

There are several reasons for creating a narrative of a schedule.

The narrative puts into words what a typical schedule is telling the reader/viewer. Lots of upper management and owners do not have enough experience reading schedules and don't know how to interpret what they are looking at if the schedule is in Gantt, PERT, or line of balance format. A narrative eliminates confusion.

The narrative helps to tell "the truth." A schedule means nothing if it does not relate the truth as the creator and owner of the schedule see it. If a schedule is manipulated to reflect what the creator wants to hide because of his own delays or problems with the project that are his responsibility, he is doing a disservice to the other team members, and the owner in particular. He puts himself at great financial risk in doing so. So a schedule must tell the truth. If the schedule reflects the truth, the narrative will also.

The contract dictates how often a project schedule needs to be updated and submitted to the owner. If a schedule is submitted without an accompanying narrative, the creator of the schedule is relying on the owner to interpret the results on his/her own. On one hand, one could think that is a good practice—let the owner figure out the state of his project. On the other hand, though, relying on the owner to do that puts the creator at risk of not understanding what is really happening, and that is not recommended either. Submitting a narrative along with an updated schedule puts the onus of its contents on the owner. Narratives become especially important to a project when they are relating and tracking delays to a project. It must also be pointed out at this time that, if a project is experiencing or about to experience a delay, that delay should be included in the schedule as soon as it becomes apparent. Even if the cause of or the fix for the delay is not known, it needs to be incorporated immediately so that all stakeholders are aware of it as soon as possible. Two examples follow.

If a project is suffering from a delay that is caused by the general contractor (GC) or one of his/her subcontractors, the schedule needs to reflect that delay and where it is occurring. The narrative will tell the owner what the delay is, the impact of the delay to the project, and how the GC plans to mitigate it in order to bring the project back on schedule, or at least minimize the impact.

If a project is being delayed by the owner, the schedule also needs to reflect that delay and its impact on the project. Owners sometimes do not want to admit that they are the cause of a delay because, if it is great enough to delay the completion of the project, it will usually cost the owner more money to complete it. By submitting a narrative describing the delay, the GC puts the owner on notice that he or she is delaying the project. The owner may choose not to read the narrative and understand the delay, but the delay is included in the narrative and that narrative is submitted per the contract. The owner can never come back and say he or she was unaware that he or she was impacting and delaying the project. This situation happens often, and the use of a narrative immediately cuts the owner off from using that excuse. Precedence suggests that narratives and their contents hold up in court if a project reaches that unfortunate point.

Default Condition

A narrative should be submitted with each official update of the schedule per the project contract. The only time a narrative is not needed is if the schedule is updated in between official updates, and these updates are not submitted to the subcontractors or owner. A narrative is not usually used as an in-house report, except when submitted along with the official schedule.

Best Practices

A schedule narrative should be used each time an official update of a project schedule is submitted to an owner per the contract.

Recommended Practice

A narrative should include any and all information derived from the schedule that needs to be relayed in written form to the stakeholders of a project. The narrative can be written in either sentence/paragraph format or bullet points, and it is up to the project team to decide. However it is presented, the narrative should include the following, at a minimum:

- Activities or scope of work started since the last update
- Activities or scope of work completed since the last update

- Activities or scope of work planned to start during the next reporting period
- The current critical path(s) of the project schedule to include near-critical
- The current state of schedule development or revisions to the schedule. If the project is using software such as Digger, which compares the current schedule to the last one and any changes that were made between the two, include that information if required by contract.
- Any and all issues and areas of concern that are or could impact the schedule, including suggestions and remedies for mitigating the impact of said issues

Advisories

Avoid at all costs writing, providing, and officially submitting, along with the monthly update, a narrative laying out the current condition of the schedule, and thus the project.

3.3 Scope Definition

The scheduler is not responsible for defining the scope of the project, but he or she must develop a robust project schedule at the appropriate level of detail consistent with the level of available scope definition.

Guidelines

Definitions

The relevant professional bodies define "scope definition" as described in Table 3-1:

PMI	"The process of developing a detailed project scope statement as the basis for future project decisions" (PMI, 2004, p. 375).
AACEI	"Division of the major deliverables into smaller, more manageable components to: 1) Improve the accuracy of cost, time, and resource estimates; 2) Define a baseline for performance measurement and control; and 3) Facilitate clear responsibility assignments"(AACEI, 2010a, p. 91).
APM	"Scope management is the process by which the deliverables and work to produce them are identified and defined. Identification and definition of the scope must describe what the project will include and what it will not include, i.e., what is in and out of scope"(APM, 2010, p. 34).

Table 3-1: Definitions for "scope definition"

Purpose

It is important to recognize that the scheduler is not responsible for defining the scope of the project. This is the job of the designers, customers, and other stakeholders, based on the project business case and requirements.

The role of the scheduler is to capture and interpret the available project scope definition and incorporate this effectively into project schedule development, such that the project schedule provides project management, stakeholders, and the project participants with a road map for how the project is to be executed. That is what happens when, how, and with what resources in order to meet the project objectives, including those from the business case which should underpin the scope definition.

Default Condition

A project typically begins in the eyes of a customer, owner, or operator as not much more than an idea, with very little in the way of scope definition.

As the project moves through its life cycle phases, such as consultancy, concept, feasibility, basic engineering, detailed engineering, procurement, and construction, the level of scope definition increases, which has a corresponding impact on the level and detail available for project schedule development.

Best Practices

The information available to enable the scheduler to review, capture, and interpret the project scope definition will be dependent on the phase the project has reached in its life cycle and the point at which the scheduler's organization becomes involved.

Typical information might include:

- Invitation to tender (ITT) or enquiry—technical information
- Project business case
- Scope statement (preliminary or detailed)
- Cost estimate (and classification)
- Work breakdown structure (WBS)
- Risk register
- Preliminary drawings and documents
- Detailed drawings and documents
- Installation quantities

In capturing and interpreting the scope definition, the scheduler must understand the roles and responsibilities of those involved in the project and know the right person(s) to speak to in order to resolve any ambiguities and anomalies, ask the right questions, and obtain the right answers.

Irrespective of the level of scope definition available, a WBS must be prepared as the framework within which the project schedule is developed. It will then be clear whether there is sufficient scope definition to develop the schedule in its entirety. If this is not the case, the "rolling wave technique" must be applied to schedule development.

The "rolling wave technique" is defined by PMI as:

> A form of progressive elaboration planning where the work to be accomplished in the near term is planned in detail at a lower level of the *work breakdown structure,* while the work far in the future is planned at a relatively high level of the work breakdown structure, but the detailed planning of the work to be performed within another one or t wo periods in the near future is done as the work is being completed during the current period. (PMI, 2004, p. 374)

In the context of an engineering, procurement, and construction (EPC) project, AACE recommends Level 3 detail for the project schedule, with the caveat (if full scope definition is not available for the entire project life cycle phases) that the rolling wave technique can be applied. This is where Level 3 may apply to the detailed engineering/design phase, with the later phases for procurement and construction detailed to Level 1 or 2—which will be further detailed as scope definition becomes available.

In addition to PMI and AACE, the rolling wave technique is also recognized as best practice by the Association for Project Management (APM) and Chartered Institute of Builders (CIOB) in the United Kingdom, with APM identifying the importance of the rolling wave technique to the schedule baseline and application of the earned value management process.

CIOB (2011) does not refer to the term "rolling wave" explicitly, but rather uses the term "schedule density" for the technique.

With the rolling wave method, the network detail varies according to the completeness of the prerequisite information and level of scope definition. Put simply, as the level of scope definition increases, the project schedule must be further detailed to incorporate the associated deliverables sufficiently in advance of performing the associated work. Typically, full scope definition should be available for at least the work taking place over the next three months or, better still, up to nine months, which can be planned in full detail.

Work planned to take place after this period should be scheduled in less detail, in accordance with the reduced level of scope definition.

The concept is illustrated in Figure 3-1.

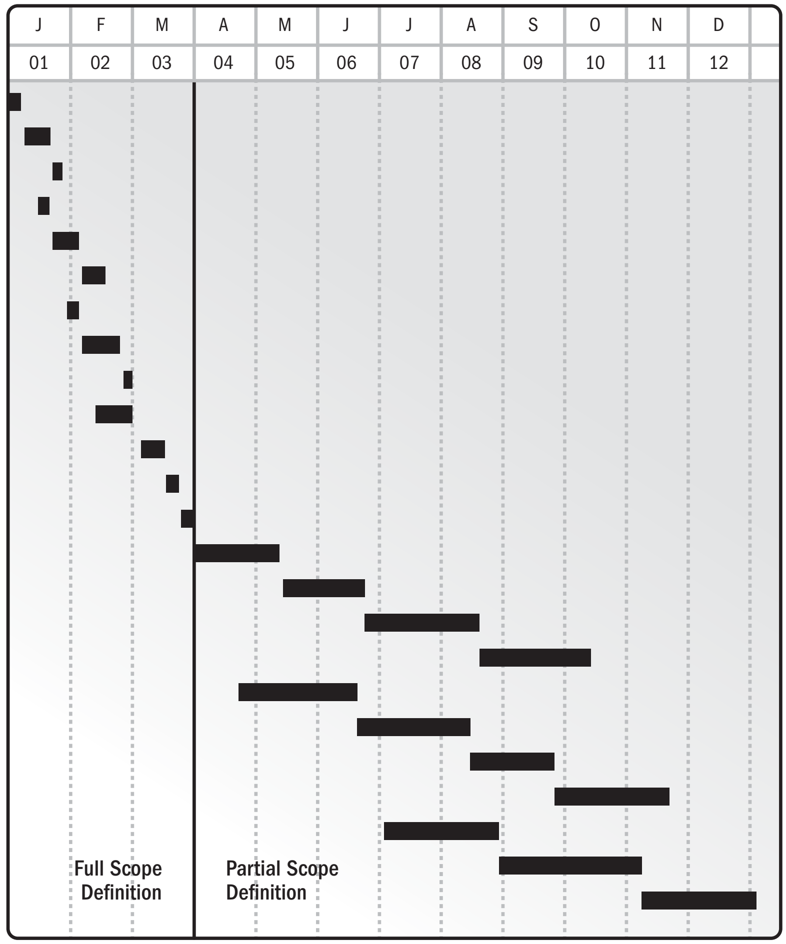


Figure 3-1: Rolling wave planning technique

Section 3.2 "Schedule Development Philosophy and Theory" of this *Best Practices and Guidelines* describes the use of a schedule narrative which must accompany the project schedule and, with respect to scope definition, clarify the current state, while identifying any remaining assumptions and anomalies as part of the schedule basis.

Advisories

Since the mid-1980s, the convenience of PC and modern project management software and the speed of data entry can easily lead the scheduler and project team into the temptation to develop the project network in more detail than the available scope definition and prerequisite information supports.

This must be avoided at all costs; otherwise, we have the following situation:

- A project schedule which is too detailed for many stakeholders, leading to lack of understanding
- Wasted time and effort in project schedule development, followed by major rework and high maintenance of the project schedule, continually removing and replacing large sections of data (activities, relationships, resources, assignments) as the scope definition becomes clearer.

So why is there a tendency for this to happen far too often?

In his book, *Computerized Project Control*, Drigani (1989) realized this in describing the early impact of the PC and associated applications as follows:

> It can be said that the introduction of project control software can create a situation of excessive output production. There are however particular reasons that lead to this situation, which have been discussed

> here. They all derive from the fact that the introduction to powerful software has offered project controllers and project managers the opportunity for obtaining what they could not have obtained before. From a situation in which project controllers could produce only limited information, we are now reaching the point at which it is necessary to carefully determine that which is really useful. As can be seen, this is again a management problem. (p. 149)

In addition to the convenience of the PC, aspects such as the personalities and human nature of those involved in project network development seem to influence the level of detail.

While some project team members or stakeholders may complain that there is too much detail, others find comfort and a false sense of security in excessive detail. They assume that more thought must have been put into the project network development, and that the detail provides more certainty as to the outcome. In reality, there is confusion in thinking that quantity is equal to quality.

These informal and subjective considerations sometimes manifest themselves in the specification of unrealistic customer requirements in the invitation to tender (ITT), with the customer often specifying the submission of a fully detailed project network six to eight weeks after contract award, for a major project of several years' duration.

3.4 Schedule Structure

Guidelines

Definitions

A schedule structure is the framework which consists of a set of elements or variables associated to each activity. The particular arrangement of these elements will define how the schedule is organized and presented. Organizational purpose may be for ongoing schedule development, status input facilitation, presentation of results, etc.

Some of the typical elements used are:

- Work breakdown structure (WBS)
- Organization breakdown structure (OBS)
- Resource breakdown structure (RBS)
- Code structure
- Phase
- Responsibility or split of work
- Location of work
- Plot area or elevation
- Engineering discipline or construction craft
- Type of effort

Purpose

The purpose of the schedule structure is to provide the framework upon which the schedule is built, in order to carry out the schedule development, status input, and, most importantly, communication with the project team.

The various elements which the scheduler decides to incorporate serve to organize the presentation of the activities for those who need to understand and use the schedule. For simple, or very summary-level schedules, the structure may be as straightforward as necessary to show only major phases.

For more complicated schedules, which may have thousands of activities, the structure becomes more crucial. Various elements may need to be combined in order to show a complicated program in a manner understandable by those who are the users of the schedule.

The schedule's structural elements are further used for the filtering and ordering of activities of complicated schedules with many activities. Selection of activities may be made for a specific purpose such as four-week look-ahead schedules, current activities within a particular update reporting cycle, or a subset of activities for an individual subcontractor or phase of work.

Default Condition

Some of the elements of the schedule structure are dictated by contract requirements. Many are defined by the nature or type of project or industry in which the schedule is to be deployed. As such, each organization will likely have a set of typical elements they customarily incorporate. Often these are determined by company procedures but will also be dependent on the experience and thought process of the individual scheduler.

Best Practices

Some of the considerations to keep in mind while structuring a schedule:

The structure should be thought out ahead of time so that as it is being developed, the structural elements are maintained. If these need to be incorporated or modified after the schedule is completed, it can be much more difficult to accomplish.

The end users must always be kept in mind, as schedules are for the benefit of the project stakeholders and as such should be a good communication tool. Output should be readily understandable in order to be effective in providing guidance, status, and forecast of project events.

Resulting organization of schedule activities should be a recognizable modeling of the execution plans of the project. For example, major industrial design and build projects may present a basic structure by phase, such as:

- Basic design
- Detailed engineering
- Procurement
- Construction
- Systems commissioning
- Operational startup

Key interfaces need to be considered with other project entities such as: joint venture partners, future incorporation of subcontractor detail schedules, and summaries of client project master schedules. This may include interfaces with other software, versions, or systems such as in the case of resources loaded from estimate budget or cost systems.

Recommended Practice

Consideration should be made of the primary purpose of the schedule. For example, it may be to monitor and forecast detailed activities, or for summary status reporting to clients, or some other primary intention.

It may be necessary to keep contract requirements present and incorporated to the structure.

Structure will likely be required to provide the basis for summary-level reporting based upon detailed activity levels. Caution should be taken to do this intelligently, so the summary information is meaningful.

Advisories

Precaution should be taken in cases where multiple successive schedulers work on the same schedule. The new scheduler should endeavor to use the existing structure to the extent practical in order to maintain continuity of understanding. In the event new structural elements may be needed, these should be incorporated in a manner as to not lose overall schedule integrity. All sections of the CPM network need to continue to work together. This should help record past activity and provide a good basis for forecasting future work completion.

3.4.1 Work Breakdown Structure

The work breakdown structure (WBS) is a tree structure, but can also be in an outline, which shows a decomposition of effort required to achieve an objective such as a program, project, or contract. In a project or contract, the WBS is developed by beginning with the end objective and successively decomposing it into manageable components in terms of size, duration, and responsibility (e.g., systems, subsystems, components, tasks, subtasks, and work packages), including all steps necessary to achieve 100% of the scope (the objective).

The solution to successful project scheduling is to decompose or break down the project objectives into tasks *before* considering delivery dates, resource constraints, required trades and other resources, or task dependencies. This helps to objectively identify all of the work necessary without mistakenly leaving out real work in order to fit date constraints.

The WBS step helps accomplish the following key objectives:

- Develops an objective, rational view of the amount of work required
- Helps the team grasp the skills and amount of resources required for the project
- Provides a clear framework for assigning a clear task definition to individuals and for delegating the responsibility for completion
- Lays a foundation for analyzing the task dependencies, and for isolating and managing risks
- Lays a foundation for developing a bottom-up estimate for the project schedule
- Allows tradeoffs to be made consciously and with the proper consensus involved

Guidelines

Definitions

WBS is defined in the *PMBOK® Guide* – Fifth Edition as "a hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables" (PMI, 2013, p. 126). Each hierarchical decomposition may be known as a breakdown element.

Purpose

To understand the WBS, consider this example:

A project exists which involves the development of an aircraft's guidance and navigation systems. A manager is responsible for two operations: *Write Software* and *Test Software.* In order to plan and manage the total workload, it would be useful to roll up these two operations so they can be seen as one.

To do this, one should create a work breakdown element, number it (say, GUIDE 1), and name it Guidance Software. The two network operations are linked via the element's number or breakdown code, as shown in Figure 3-2.

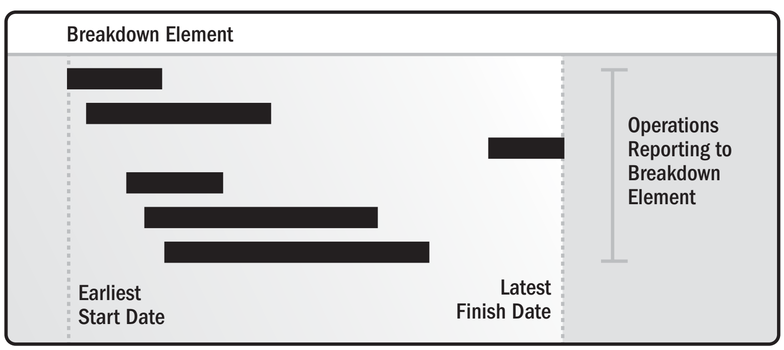


Figure 3-2: Work breakdown element

The breakdown element is not an operation, it does not have a duration of its own, and it cannot use resources or cost any money. However, it can have a description and organizational codes just like an operation, and it can be selected for reports. Each breakdown element can be used to group operations which may be scattered throughout the project plan into discrete packages of schedule and cost information.

Rolled Up Dates

When the plan is scheduled, the dates from the linked operations are *rolled up* into the breakdown element, where the *earliest* start date of all the operations becomes the start date for the breakdown element. The *latest* finish date of all operations becomes the finish date for the breakdown element.

Thus, if there are a number of operations rolling up into a breakdown element, it stretches to encompass the whole time span of all operations, as shown in Figure 3-3.

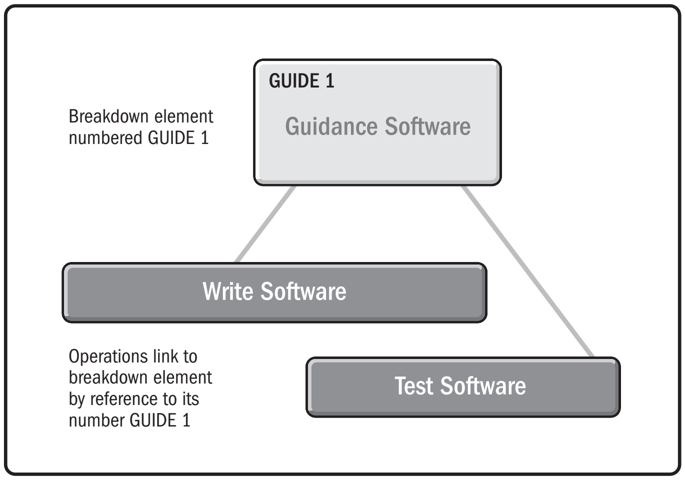


Figure 3-3: WBS hierarchy

In a similar way, when a resource analysis is carried out, the start and finish dates from that analysis are rolled up to form the resource analysis for the breakdown element.

This means that when a breakdown element is included on a report, such as a Gantt report, the scope of all the operations that roll up into it is included.

Rolled Up Costs

When cost analysis is carried out, the cost results will roll up into a breakdown element so that it contains the summed totals of the cost values for all operations reporting to it. These will be the same values carried by the operations themselves:

Estimated Cost	Earned Value
Actual Cost	Recoverable

Multiple Levels

So far, only a single work breakdown element where the costs have been rolled up has been considered. Now consider guidance and navigation software as part of a larger system.

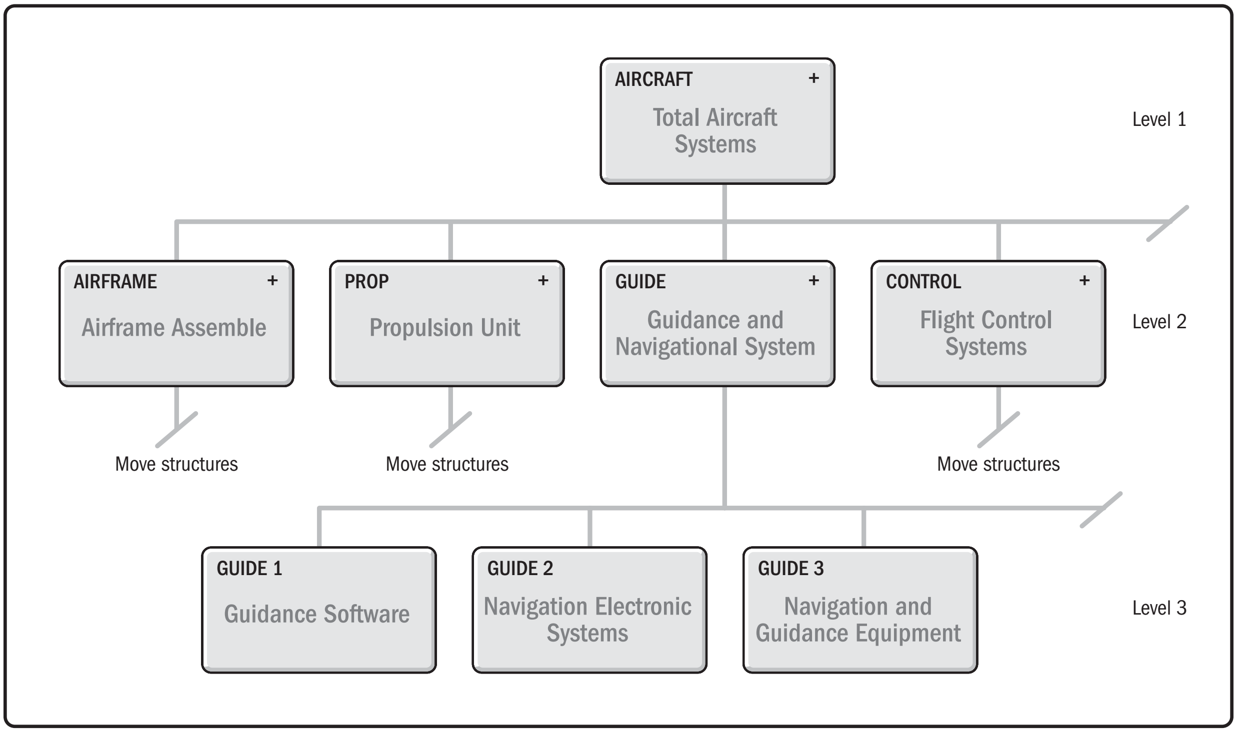


Figure 3-4: WBS level example

In Figure 3-4, the breakdown element GUIDE has been broken down into GUIDE1, GUIDE2, GUIDE3, etc. This is all part of the guidance and navigation system. Each one of these additional elements can have any number of network operations reporting to it—rolling up their dates and their cost results in the same way.

In the Figure 3-4, these elements are linked to a *parent* element—coded GUIDE—which represents the complete guidance and navigation system. The elements GUIDE1, GUIDE2, and GUIDE3 are all at the same level of the structure, and they are the children of GUIDE, which is at a higher level.

This means that the parent element GUIDE now has a start date which is the earliest of the start dates of all its children, meaning the earliest of all operations which relate to the whole guidance and navigation system. Similarly, the finish date shows when all operations in that system are complete. By the same token, all the cost information for the entire guidance and navigation system is rolled up into that single element.

Consider that the guidance and navigation system is itself a child of a larger system—the aircraft itself.

The aircraft itself may also be just one child within a larger system that incorporates a total program of development.

Figures 3-5, 3-6, and 3-7 illustrate how a tree structure can be constructed which allows the roll-up of information to higher and higher levels of command. In this example the overall cost values for the aircraft system are all available in the single element at the top of the tree. The values have been rolled up through the entire tree from all the operations within the structure.

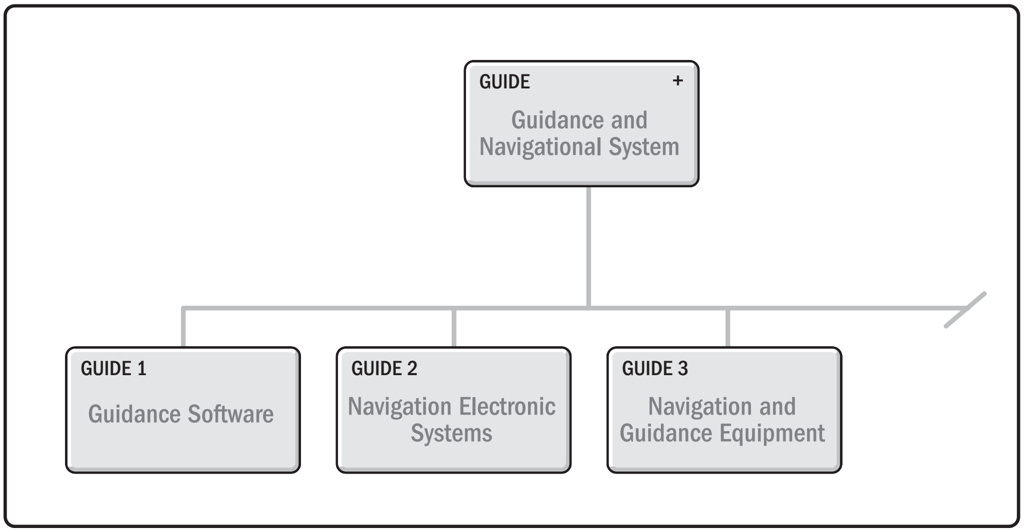


Figure 3-5: WBS tree structure

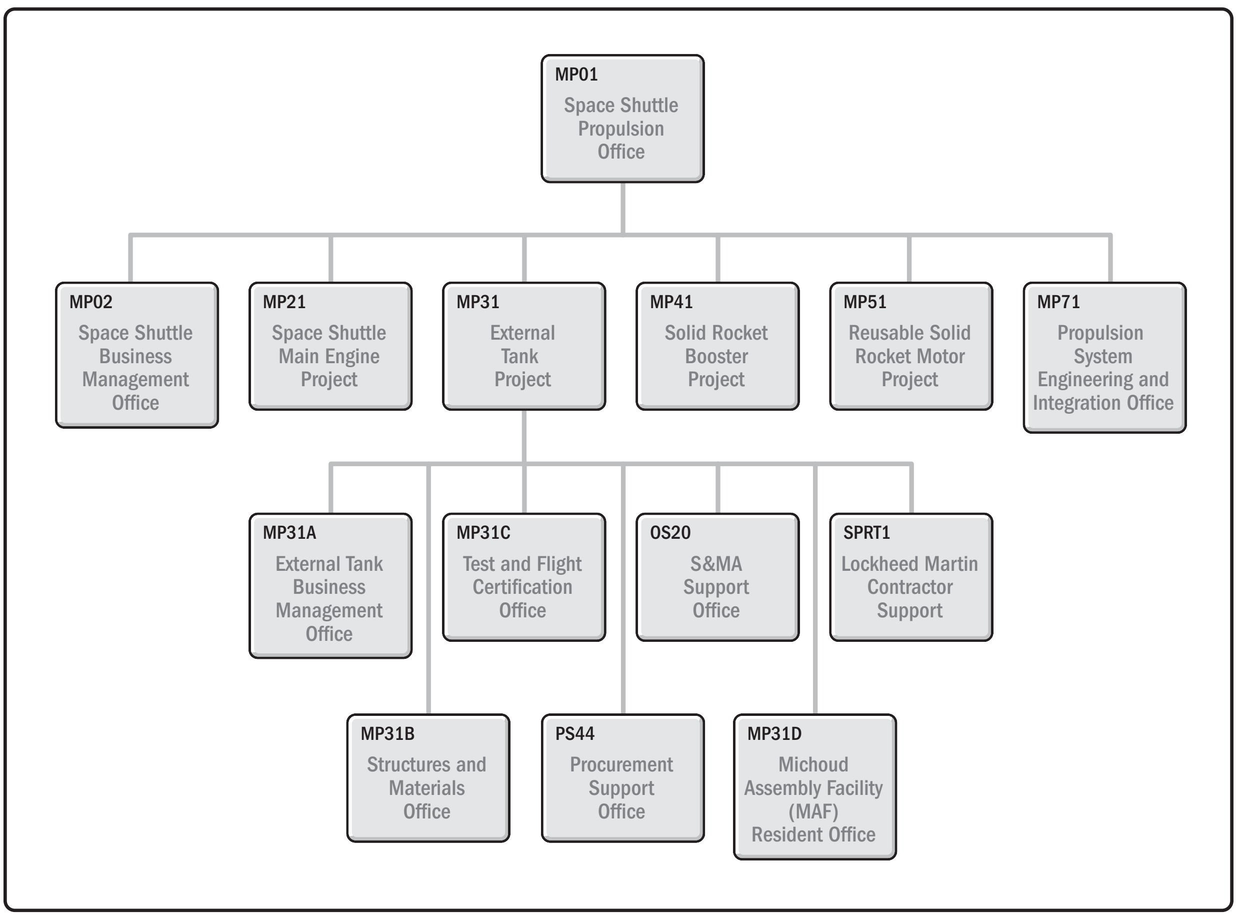
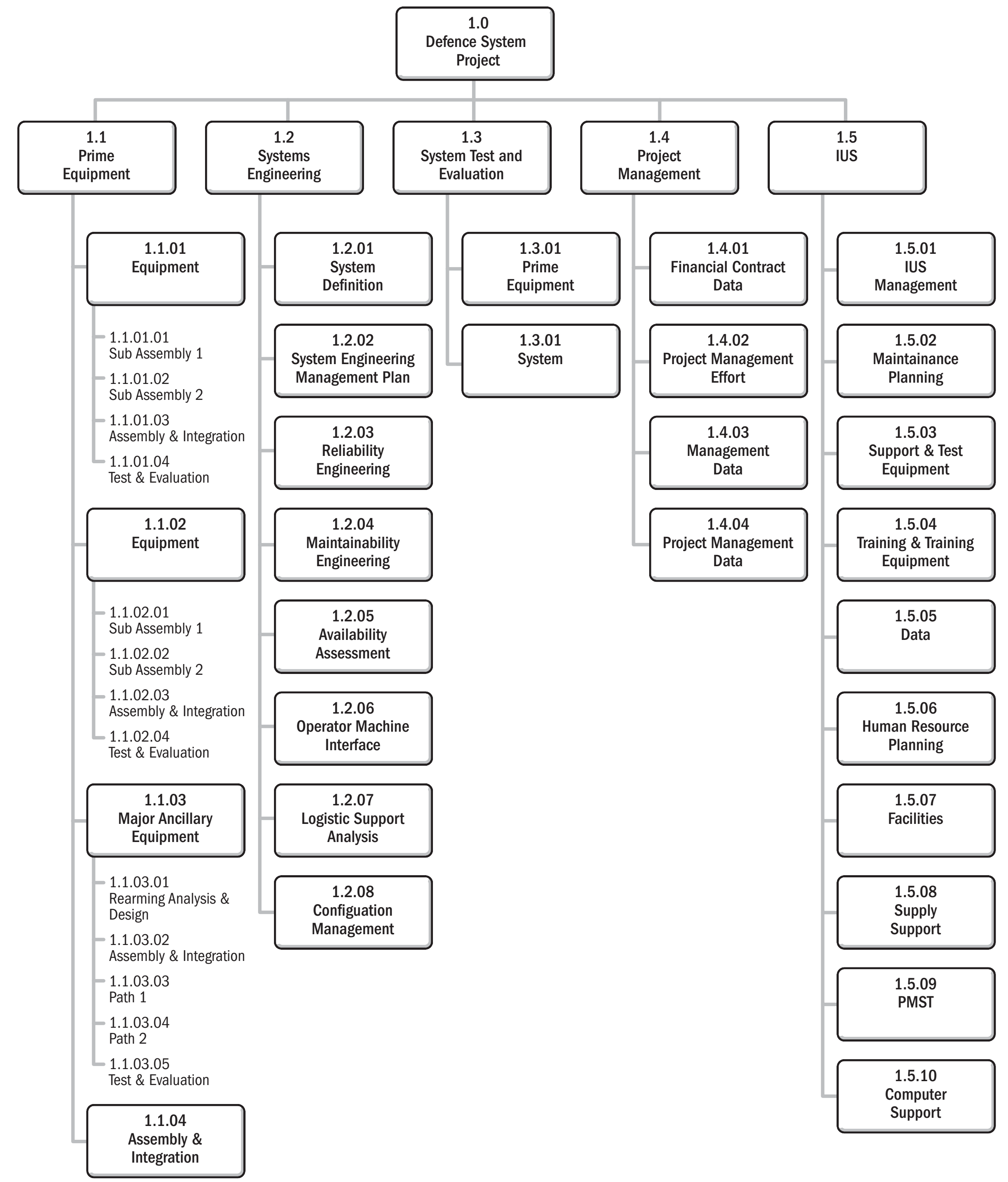


Figure 3-6: Tree structure



Source: DEF (AUST) 5664 Issue A

Figure 3-7: WBS tree structure

Work Breakdown Structure—Outlining

Another method for defining WBS is outlining. The outlining method requires each WBS element to be coded with a unique element identifier, which may be numeric or alphanumeric, in such a way that the identifier allocated to a child WBS element defines its relationship to its parent. Simple WBS identification schemes are recommended, and extraneous information should be avoided.

Level 1	Level 2	Level 3
Task 1	Sub task 1.1	Work package 1.1.1 Work package 1.1.2 Work package 1.1.3 Work package 1.1.4
	Sub task 1.2	Work package 1.2.1 Work package 1.2.2 Work package 1.2.3 Work package 1.2.4
Task 2	Sub task 2.1	Work package 2.1.1 Work package 2.1.2 Work package 2.1.3 Work package 2.1.4
	Sub task 2.2	Work package 2.2.1 Work package 2.2.2 Work package 2.2.3 Work package 2.2.4
	Sub task 2.3	Work package 2.3.1 Work package 2.3.2

Table 3-2: Example WBS outline

Work Breakdown Structure Coding Scheme

It is common, but not essential, for WBS elements to be numbered sequentially to reveal the hierarchical structure. For example, WBS "1.3.2 Rear Wheel" identifies this item as a Level 3 element, since there are three numbers separated by a decimal point. A coding scheme also helps WBS elements to be recognized in any written context.

A practical example of the WBS numeric coding scheme for part of a construction project is shown below.

1.1 Building Systems Integration
- *1.1.1 Requirements Definition*
- *1.1.2 Regulations*
- *1.1.3 Scheduling*
- *1.1.4 Monitoring & Control*
- *1.1.5 Procurement Management*
- *1.1.6 Closeout*

1.2 Design
- *1.2.1 Conceptual Design*
- *1.2.2 Preliminary Design*
- *1.2.3 Final Design*

Levels

Each stratum of the structure is called a "level." The top level of the tree is called Level 1, and this is usually only one element. However, there may be several Level 1 elements when running a multi-project schedule. The children of Level 1 elements are referred to as Level 2 elements, their children as Level 3, and so on.

The WBS is decomposed down to the work package level. A work package is the lowest level in the WBS, and it is the place where the cost and schedule for the work can be reliably estimated.

It is recommended that a WBS be decomposed to no more than five or six levels. An effective limit of WBS decomposition may be reached when it is no longer possible to define "planned outcomes," and the only details remaining are actions. A WBS can be expressed down to any level of interest, and the top three levels are as far as any program or contract needs to go, unless the items identified are high-cost or high-risk. Then, and only then, is it important to take the work breakdown structure to a lower level of definition.

Most Effective Level

The second level is considered the most important because it determines how the grouping of actual costs and scheduled data for future project costs and scheduling estimates is constructed. A project manager may find it useful to know how much it costs to design (a major work element) a product after it has been completed so that the data can be used for future and analogous estimating.

In other cases, the project manager may want to know how much a major part of the product actually costs after the project was completed.

General Requirements

The WBS element should satisfy the following considerations:

- A single-top WBS element covers the total scope of work.
- Every WBS element is a distinct product or enabling service, which is mutually exclusive from other products and enabling services.
- Every WBS element has either no children or multiple children.
- Every child WBS element has only one parent and is a descendant of the top WBS element.
- Every child WBS element is needed to deliver the parent.
- If all child WBS elements are complete, their parent is complete.
- The complete scope of work is captured in the WBS.

Default Condition

Best Practices

The 100% Rule

One of the most important WBS design principles is called the "100% rule." PMI's *Practice Standard for Work Breakdown Structures* – Second Edition (PMI, 2006) defines the 100% rule as follows:

> The 100% Rule ... states that the WBS includes 100% of the work defined by the project scope and captures ALL deliverables—internal, external, and interim—in terms of the work to be completed, including project management. The 100% Rule is one of the most important principles guiding the development, decomposition and evaluation of the WBS. The rule applies at all levels within the hierarchy: the sum of the work at the "child" level must equal 100% of the work represented by the "parent" and the WBS should not include any work that falls outside the actual scope of the project, that is, it cannot include more than 100% of the work. It is important to remember that the 100% rule also applies to the activity level. The work represented by the activities in each work package must add up to 100% of the work necessary to complete the work package. (p. 8)

Planned Outcomes, Not Planned Actions

If a WBS is built with too many action-oriented details, it is likely to include too many actions or too few actions. Too many actions will most likely exceed 100% of the parent's scope, and too few will fall short of 100% of the parent's scope.

The best way to maintain the 100% rule is to define the WBS elements in terms of outcomes.

The WBS is an extremely valuable tool to project planning and scheduling methodology. It creates the foundation for all project planning, and it can make or break a project. A well-structured WBS helps ensure that proper project baselines, estimating, resource use, scheduling, risk analysis, and procurement are achieved.

Contractor WBS

Recommended Practice

1. The WBS should be decomposed to the level necessary to plan and manage the work to satisfy the project objectives.
2. The WBS dictionary should also include the following information for each WBS element, where applicable:
   a. Reference to lower-level WBS elements
   b. Contract reference
   c. Entry and exit criteria, including acceptance requirements
   d. Performance measure
3. The WBS should be prepared with a tool that enables it to be contracted and expanded by WBS element, to facilitate review and ascertain completeness.
4. All internal products should be identified in the WBS.
5. The WBS should not be determined by organizational arrangements.

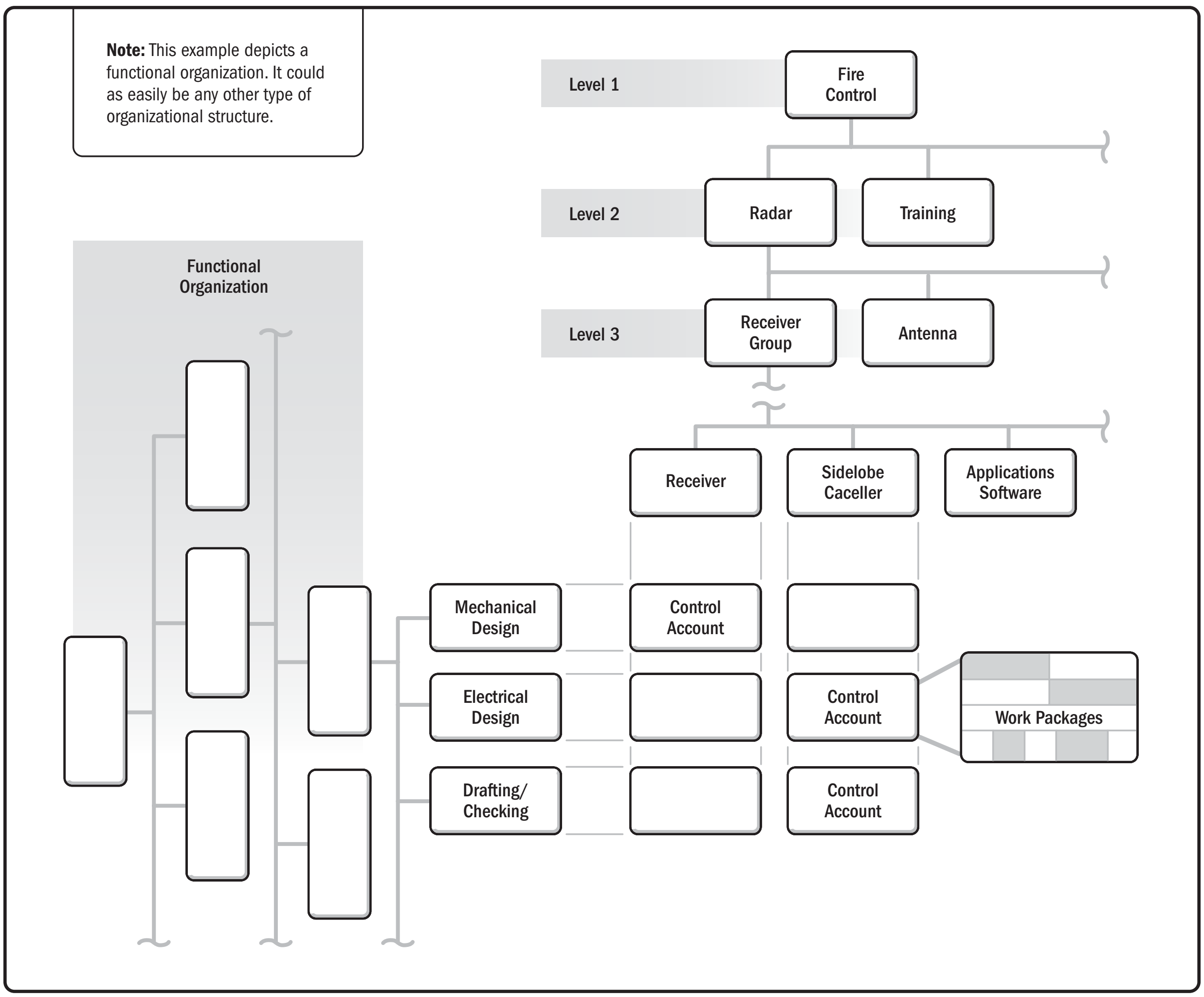


Figure 3-8: Organizational mapping to the WBS

The WBS should not influence or in any way affect the contractor's program organization. That is, a contractor can be organized in any way (e.g., by function, process, or integrated product team) and effectively use a valid, product-oriented WBS. As Figure 3-8 illustrates, at some level in an organization there is the point at which a control account (also referred to as a cost account) is managed. Likewise, the same point exists in any WBS. Therefore every part of a WBS is visible or accessible regardless of the contractor's organization. For example, the management information needed by the government to manage the development of a radar receiver is available from the control accounts that are part of that effort's WBS. So too, the information the contractor needs to manage the development is available from the same control accounts, which in this example are a part of the contractor's electrical design department.

Advisories

Avoid pitfalls in constructing a WBS. Some common pitfalls in creating a WBS are indicated below. By keeping these few possible issues in mind, the project team will be much more successful at creating a useful and accurate WBS.

A WBS is not a plan or schedule. The WBS cannot be used as a replacement for the project plan or schedule. A WBS is not required to be created in any type of order or sequence. It is simply a visual breakdown of deliverables.

A WBS is not an organizational hierarchy. The WBS and organizational hierarchy chart are not the same thing. Although often similar looking in appearance, these two documents are very different. The organizational hierarchy illustrates things like chain of command and lines of communication, but the WBS is restricted simply to a project and shows only the deliverables and 100% scope of that project.

Get the right level of Work Package detail. When determining how specific and detailed to create work packages, care must be taken to not get too detailed. Otherwise, this will cause the project manager to micromanage the project which will eventually slow down project progress. On the other hand, work packages whose details are too broad or too large become impossible for the project manager to manage as a whole.

Deliverables are not activities or tasks. The WBS must contain a list of decomposed deliverables. In other words, what the client/stakeholder will get when the project is complete. It is NOT a list of specific activities and tasks used to accomplish the deliverables. How the work is completed (tasks and activities) can vary and change throughout the project, but since deliverables cannot change without a change request, activities and tasks should not be listed in the WBS.

WBS updates require change control. The WBS is a formal project document, thus any changes to it will require the use of the project change control process. Any changes to the WBS also changes the deliverables and, therefore, the scope of the project. This is a most important point to help limit scope creep.

Avoid decomposing into too many levels. A common mistake is made when decomposition of the project goes too far down. Usually five to six levels is enough to define the work package.

A work package at the activity level is a task that:

- Can be realistically and confidently estimated;
- Makes no sense practically to break down any further;
- Can be completed in accordance with one of the heuristics defined above;
- Produces a deliverable which is measurable; and
- Forms a unique package of work which can be outsourced or contracted out.

Avoid overlapping scope between two elements. To avoid confusing similar work activities, it is important that there is no overlap in scope definition between two elements of a WBS.

Some additional pitfalls—A sound WBS clearly describes what the program manager wants to acquire. It has a logical structure and is tailored to a particular defense material item. It can tie the statement of work, contract line item number structure, and system description documents together. Remember that the WBS is product-oriented. It addresses the products required, NOT the functions or costs associated with those products.

Elements not to Include

The following expands the explanation of what should be excluded from the WBS elements.

Do not include elements which are not products.

A signal processor, for example, is clearly a product, as are mock-ups and computer software configuration items (CSCIs). On the other hand, things like design engineering, requirements analysis, test engineering, aluminum stock, and direct costs, are not products. The first three are all engineering functional efforts, aluminum is a material resource, and direct cost is an accounting classification. Thus, none of these are appropriate WBS elements.

Program phases (e.g., design, development, production, and types of funds, or research, test, and evaluation) are inappropriate as elements in a WBS.

Reworking, retesting, and refurbishing are not separate elements in a WBS. They should be treated as part of the appropriate WBS element affected.

Non-recurring and recurring classifications are not WBS elements. The reporting requirements of the CCDR will segregate each element into its recurring and non-recurring parts.

Cost-saving efforts such as total quality management initiatives, cost, and warranty are not part of the WBS. These efforts should be included in the cost of the item they affect, not captured separately.

Do not use the structure of the program office or the contractor's organization as the basis of a WBS.

As previously stated the WBS is a tree structure, but can also be in an outline structure, which shows a decomposition of effort required to achieve an objective such as a program, project, or contract.

Do not treat costs for meetings, travel, computer support, etc., as separate WBS elements. They are to be included with the WBS elements with which they are associated.

Use actual system names and nomenclature. Generic terms are inappropriate in a WBS.

The WBS elements should clearly indicate the character of the product, to avoid semantic confusion. For example, if the Level 1 system is fire control, then the Level 2 item (prime mission product) is fire control radar.

Treat tooling as a functional cost, not a WBS element.

Tooling (e.g., special test equipment, and factory support equipment like assembly tools, dies, jigs, fixtures, master forms, and handling equipment) should be included in the cost of the equipment being produced. If the tooling cannot be assigned to an identified subsystem or component, it should be included in the cost of integration, assembly, test, and checkout.

Include software costs in the cost of the equipment. For example, when a software development facility is created to support the development of software, the software effort should be included under integration, assembly, test, and checkout. Software developed to reside on specific equipment must be identified as a subset of that equipment.

Additional Considerations

When the WBS process is rigorously applied, there should be:

- A clean structure for the organization and management of the project;
- Clear accountabilities for project outcomes; and
- Minimization of the chance of work elements being missed.

3.4.2 Activity Id Coding

Guidelines

Definitions

Activity identification (ID) is an alphanumeric or numeric tag or reference which provides a unique identifier for each activity of a schedule. Activity ID coding is considered to exist when the assigned alphanumeric identifier follows a specific scheme that provides information about the nature of each schedule activity, such as work location, responsible party, WBS classification, and project phase.

Purpose

The primary reason for adding intelligence into the activity ID number is to provide organizational information to the database of the CPM network. This may be particularly useful for very large networks with hundreds or thousands of activities to indicate for each activity specific connotations, such as area location, phase of the project, type of work, responsibility, and WBS classification. This can help the schedulers by providing navigational or general information as to the nature of the activity.

Activity ID coding may also be beneficial to the end user by making it easier to identify their own activities as well as that of another group or division, the location of the work, etc. This is a way to provide information without having to include it in the activity description (albeit cryptic in nature).

In some instances, depending on the software being used, the activity ID coding may provide additional means of filtering, sorting, or summarizing the schedule activity database. Typically, however, it is complementary to the main activity coding or WBS structure used by the scheduler for these same purposes.

Default Condition

By default, CPM software usually allows for automatic numbering of activities. This is typically a sequential numbering system which may be controlled or altered by the user and does not relate any other information about the activity other than a sequential number and unique identifier.

When the scheduler considers it necessary to add intelligence to the identification of the activities, specific letter and number combinations may be set up to give information about the type of effort being represented by the schedule activities. This information may be about location, responsibility, WBS, project phase, type of work, or other details as deemed useful by the scheduler.

By default, the activity ID coding does not normally exist on its own, so it needs to consciously be created during schedule development. An exception to this is when schedule templates with predetermined coding schemes are used. In these cases adjustments may be needed to adapt to the specific circumstances of the project at hand.

Best Practices

Keep it short and simple (KISS). The selected coding should be very straightforward. For example, design activities would start with DES; permitting with PER; procurement with PRO; milestones with MIL, etc. Specific construction locations may be designated with a minimum of two characters, such as 1st floor 1F, 2nd floor 2F, etc.

Keep coding to a minimum. Preferably, do not use more than three sets of variables within any given activity ID coding scheme. Overly complicated activity ID coding may lead to complications in schedule CPM database maintenance and understanding. Define as an integral part of the schedule structure. Activity ID coding should be functionally complementary to the activity codes, applied WBS, applied organizational breakdown structure (OBS), etc.

Do not sacrifice the quality of activity description. Understanding of the activity should not rely on activity ID coding, but rather proper activity descriptions. This will facilitate comprehension and acceptance by those who are the project users of the schedule reports.

Decide activity ID coding conscientiously ahead of time. Prepare before starting to build the CPM schedule. The scheme should be applied consistently in order to be effective. Use a legend, because providing a coding ID breakdown to the end users to decipher the meaning of the alphanumeric combinations will be helpful for them to understand the schedule more easily.

Allowances should be made for characters which provide pure sequencing independent of the "intelligence" coding. This is necessary in order to have the flexibility to add activities wherever needed for proper scope identification without being restricted by a coding structure.

Recommended Practice

Activity ID coding can be very useful while building a repetitive project schedule, depending on the CPM software being used. A segment of the project can be set up, such as one floor, and then replicated to other areas, such as upper floors, by adding a prefix or suffix. For example: Activity ID 1005 is the first floor. By adding a suffix 1005F2 is the second floor, 1005F3 is the third floor, and so on. This approach can be even more useful if there are logic changes or corrections discovered after the pasting is done because one can filter out all the "1005"** activities and make common changes. In some circumstances, it may be useful to include known alphanumeric identifiers such as CSI division numbers or specification codes.

For adding activity relationships, one suggested approach is as follows. After initial development, print a report showing activities organized by selected characteristic, such as "trade." Then go through the schedule and add relationships as needed by quickly referencing the report and then typing in the predecessor or successor.

In some instances, ID coding reflects an incrementally advancing number for each added activity, such as in the case of a WBS. This may provide the flexibility to insert additional activities without having to renumber, or have a numbered activity out of sequence.

Advisories

The primary precaution when using activity ID coding is to avoid complicated coding which may make adding or correcting activities difficult.

When required to use predetermined codes such as a prescribed WBS coding or CSI specification code within an Activity ID (e.g., P115400-01) it should be understood that these may require several characters, leading to laborious efforts to incorporate and maintain. (One suggestion is to build the schedule first and add these later if the software used provides a practical way to do this.)

Very detailed ID coding will tend to force the use of drop-down boxes (depending on the software) to add an activity relationship, since it takes too long to type them in.

In some software (such as Suretrak), there are automatic renumbering features. Precautions should be taken to be sure that the ID coding structure is not overwritten by this feature.

3.4.3 Activity Coding

Guidelines

Activity codes enable the user of scheduling software to format, sort, and/or filter activities within the schedule and to isolate selected activities in a way that will better present them within the project schedule as related to each other. Activity codes can be defined in a limitless number of ways, depending on the needs of the project schedule. Activity codes can include such topics as responsibility, phase, area, building, room number, change order, specification, division, direction, lane number, mile marker, or any conceivable grouping by which activities can be coded. The following information from *CPM in Construction Management* highlights the importance of good coding.

> The usefulness of the schedule produced by the CPM software from the logic network will be determined to a large degree by two distinct factors: the validity of the input and the ability of the scheduler to fashion the output in the format that will be understood by management that will, in fact, assist those individuals charged with performance. The choice of appropriate codes at the outset of data acquisition is the key to both of these endeavors. (O'Brien & Plotnick, 2005, p. 207)

Definition

Activity codes are variables included in the database within the scheduling software that enable the schedule to be grouped, sorted, and/or filtered in a way that best presents a group of activities related to each other.

While calendars and WBS coding can be loosely defined as part of activity codes, they are separate within the scheduling software. Calendar coding within the scheduling software for each activity will tell the software what calendar to use when calculating early start or early finish. The scheduler can easily sort, format, and/or filter activities by which calendar they may be using (e.g., activities pertaining to a particular shutdown), but they cannot designate areas, phases, or responsibility.

Normal WBS coding can also sort, format, and/or filter the activities pertaining to a selection of work to be completed, and designate the subcontractor or responsibility of those activities. However, WBS coding (not to be confused with the WBS practice of WBS in project planning) is rigid in its ability to provide custom sort, filters, or formatting of scheduling activities.

Activity codes provide the freedom to sort, filter, and format a group of activities in limitless ways and can create custom ways to present the desired outcome.

Default Condition

As described in *CPM for Construction Management:*

> As the team develops the logic diagram and determines appropriate estimates of duration for each activity, a myriad of detail will be examined. If the scheduler does not know the details at the time they are first

> being determined, it is unlikely that any member of the team will be inclined to go back and trace the steps taken. Thus the first step to be taken, before asking "what comes after the notice to proceed," is to set aside an hour to discuss who will be using the CPM output and what these individuals would like to see. (O'Brien & Plotnick, 2005, p. 207)

Depending on the type of project, schedule activity codes can have default conditions as numerous as the types of industries in which scheduling is used. While a project schedule for manufacturing a large aircraft may have one set of default codes, a construction project would have several others. The construction of a school or hospital will have equally different default activity codes than the construction of a highway, bridge, or intersection.

Some default activity codes that may be seen in many types of industries can include responsibility, phase, and location. While others may include a drawing number, specification, or work order.

The determination of what activity codes to include in a project schedule should be defined at the earliest phase of creating the project schedule. These activity codes may be required as part of the contract documents, and still others required as part of company policy, while other activity codes addressed may be project-specific.

Recommended Practice

CPM for Construction Management aptly describes the following:

> Since a good part of the rationale for preparing the CPM is to assist the team members in the field to perform their specified portions of the works, it may be very helpful to provide additional coding so that you can filter or select portions of the total works. Thus, in addition to noting the responsible team member or subcontractor to perform a specified scope, it may be useful to note the location of the work in a large project by area. This may include area, sub-area, alternate breakdown of area, phase, stage, step, etc. in setting up appropriate codes for location, different team members need a varying degree of specificity, and thus, you may desire to have codes for both broad areas and more detailed subareas. You should code for both physical (e.g., second floor) and functional locations, such as "high pressures team system." (O'Brien & Plotnick, 2005, p. 212)

At the beginning of a project, during the creation of the project schedule, the project stakeholders should address the requirements of activity codes in order to define the areas of work which are to be scheduled. This will include addressing contract requirements, company requirements, and specific project needs and defining the codes within the activities. As the WBS is created and the project broken down into areas of responsibility, phases, areas of work, etc., activity coding is at that time completely defined with the ability to add additional codes as needed and define them at a later point in time.

While creating the activity lists, activity codes are selected for each area of work within the project, and activities are listed as part of the variables for each activity in order to enhance activity description. By completing these steps at the creation of the schedule activities, the scheduler will reduce the time needed later to wade through the entire project schedule searching for selected activities pertaining to a selected phase, area, responsibility, or any other variable in order to define the project scope.

However, the creation of new and additional activity codes may be needed during the maintenance of the schedule throughout the project's life. New activity codes for RFIs, change orders, delays, or issues should be defined and added to applicable activities during the course of the project.

Advisories

Be cognizant when defining the activity ID structure that you can get very detailed about what information is included in the codes and the breakdown of the ID. Not all activities need the same amount of information embedded in their respective unique identifier. A general condition activity does not need a location code or a CSI code versus say an install dry wall activity on the 20th floor of a high rise office tower.

While there is an endless number of descriptions of activity codes to use with the project schedule, not all activity codes are applicable to every activity.

However, activities that do have relevant values within the activity codes should be defined as completely and correctly as possible. That will enable the project scheduler, project manager, and other stakeholders the ability to identify, sort, and filter out the desired activities with the least amount of effort and time. By entering the values within the activity codes at the beginning of the project, valuable time in the middle or at the end of the project is saved by not having to sort through the entire schedule to find activities they may be looking for.

3.4.4 Schedule Levels

Guidelines

Project schedules need to become more detailed as the planning window changes over the life of the project. The interests of various project participants also differ and scheduling a project at different levels of detail helps provide the end user with the appropriate information at the right time.

Definitions

Schedule levels are hierarchies in the level of detail contained in a project schedule, based on the needs of the various project participants. Moving from a summary schedule to more detailed schedule levels, the interest of project stakeholders who will be using the schedule for different purposes dictates the appropriate schedule level. The number of activities in the schedule and the typical activity duration are the primary factors that determine the schedule level.

Schedule levels defined as Level 1 through Level 5 are recognized by several industry sources, such as AACE and the Chartered Institute of Building (CIOB).

These different industry sources tend to agree on the following definitions for Schedule Levels 1–5:

Level 1—Executive Schedule. Establishes contractual milestones, includes summary level activities, key procurement and commissioning sequences, often one page.

Level 2—Management Schedule. Based on project manager input, establishes critical path and key target dates, and includes constructability and some resource dependencies, often broken down by CSI divisions, mostly finish-to-start logic.

Level 3—Progress Schedule. Based on site superintendent or construction manager input; integrates vendor design, fabrication and delivery; may be resource and cost-loaded; often CSI divisions are further subdivided into areas, elevations or systems; this schedule drives the updating process.

Level 4—Working Schedule. Based on input from contractor field supervision, including subcontractors; often resource-loaded to detail crew movement, means and methods; grouped by CSI sections, as well as areas or elevations, detailed procurement and commissioning; developed before the start of a given phase or area (may be done on a rolling wave basis).

Level 5—Look-Ahead Schedule. Based on input from crew foremen, subdivides upcoming Level 3 or Level 4 activities into tasks for a two- to three-week look-ahead period; resource-loaded and reviewed on-site in progress meetings.

Purpose

The purpose of the different schedule levels is to recognize that schedules become more detailed as the planning window changes from the entire project to phases or stages of the project. Schedule levels also recognize that the various project stakeholders have different needs when it comes to schedules, and therefore provide a somewhat standard method of progressing through the level of detail in the schedule that is appropriate for the end user. Rigid definitions are less important than the concept of developing the appropriate level of schedule detail at the appropriate period in the life of a project, and the different level schedules are all related and serve their own specific purposes. The contract delivery method may also influence the timing of the different schedule levels over the life of the project. Turnkey, design-build, and integrated project delivery teams will engage general contractors, major trade subcontractors, vendors, and construction managers at earlier stages than traditional design-bid-build, allowing progression to more detailed schedule levels earlier in the process.

Default Condition

Level 1 schedules are simple executive summary schedules. Level 2 and Level 3 schedules can be used as forecasting tools, to evaluate performance, delay, and disruption. They can also serve as a source document for forensic modeling. A Level 4 schedule can be used for a time impact analysis. Level 5 look-ahead schedules serve as a day-to-day work plan for the field. Each lower-level (higher number) schedule should be derived from the next higher level schedule.

Best Practices

Develop each lower-level schedule from the next higher-level schedule. It is helpful to develop Level 2 and Level 3 schedules with a uniform activity duration range—this simplifies the creation of Level 4 rolling wave or phase schedules. The *Forensic Scheduling Body Of Knowledge (FSBOK)* (Ponce de Leon, Jenzen, & Fredlund, 2012) uses the term activity or schedule granularity to refer to schedules having uniform activity duration, while the CIOB Guide (2011) uses the term schedule density to refer to schedules that use varying activity durations.

Table 3-3 provides a guide to suggested typical activity durations for each schedule level, for mega projects (>$US500M) and major projects (<$US500M):

Level	Activity Duration (Mega)	Activity Duration (Major)
1	6 to 18 months	3 to 12 months
2	3 to 9 months	2 to 6 months
3	3 to 12 weeks	2 to 6 weeks
4	2 to 6 weeks	2 to 4 weeks
5	Days to 3 weeks	Days to 3 weeks

Table 3-3: Example activity duration based on schedule level

Develop each schedule level based on input from the appropriate sources, as listed above in the Definitions section. This will ensure that the schedule has the appropriate level of detail to serve its intended purpose for its intended end user.

Recommended Practice

Table 3-4 provides a summary of the *FSBOK* general intent, target end user, and scheduling objective of each schedule level:

Level	End User	General Intent	Scheduling Objective
1	Executives Senior managers	Snapshot of summary activities and logic	Conform to contract and key milestones
2	Senior managers Project managers	Establish critical path and key milestones	Show compliance with on-time performance and completion
3	CM, on-site staff	Detail for site management, staging deliveries	To execute, monitor, and control the work
4	Area supervisors	Working schedule for area or phase, for next 3 months	Trade coordination, crew movement, means/methods
5	Crew foremen	Detailed look-ahead schedule, for next 3 weeks	Assign work to crews, ensure proper workflow

Table 3-4: Schedule level matrix

Advisories

Avoid inconsistencies between schedule levels by deriving the lower-level schedule from its next higher level. Establish procedures for updating the various schedule levels, depending on how each level will continue to be used over the lifetime of the project. Resist the temptation to include too much detail in a higher schedule level. Level 1 executive and Level 2 management schedules serve a specific purpose for those project stakeholders who do not need to see or have the time to devote to the level of detail that Level 3 progress and Level 4 working schedules provide.

Level 4 working and Level 5 look-ahead schedules should be based on input from the level of supervision closest to those actually performing the work and who have the detailed knowledge of the means and methods to be used. Particularly for Level 5 look-ahead schedules, the crew foremen are in the best position to fully understand the workflow and the handoffs between crews or trades, and make accurate commitments to task durations. A detailed Level 4 or Level 5 schedule prepared by a project manager in the office, without experienced field input, will likely be completely reworked in the field to reflect reality.

3.4.5 Milestones

Guidelines

Definitions

Milestones are defined as a significant point or event in the project, such as an event restraining future work or marking the completion of a major deliverable. Milestones have zero duration.

There are two types of milestones: contractual and preferential. Contractual milestones are those that are mandated for a specific completion date or time in the contract documents, and often have liquidated damages associated with failure to meet the milestone requirements. Preferential milestones are those that are used for an arbitrary purpose, not mandated by contract, and may include useful points in the life cycle of the project, such as building dry-in, rough-ins complete, or other phase completions.

Milestones have no duration, but they can either be start milestones or finish milestones, depending on their use. If a milestone is a start milestone based on the description, it will appear as starting on the beginning of a day or however the calendar for the schedule is set up. Conversely, a finish milestone depicts an event that ends at the end of a day—again, depending on the calendar.

Determining whether a milestone is a start milestone or a finish milestone can be subjective. It depends on factors such as the project team's description and definition of the milestone. For example the milestone "blowdown" in the high tech construction market means that enough work has been completed that the project can no go "clean" and start building the clean room in a clean environment. There is a huge amount of work that had to be completed to represent blowdown as a finish milestone and then another load of work to continue on building once blowdown begins if it is a start milestone. That is where the subjectivity comes in.

Purpose

Milestones can add significant value to project scheduling by allowing project management to much more accurately determine whether or not the project is on schedule. In addition, by constraining the dates associated with interim milestones, the critical path can be determined for the work required to achieve those interim milestones in addition to the project completion.

Milestones should be included as part of the preliminary scope statement. As part of the planning process, they should be identified by the project team, included in the activity list and explained in the written narrative.

Milestones are particularly useful when filtered out into a milestone schedule, which is a high-level schedule showing only the milestones. The milestone schedule is a very effective report for senior management, allowing a quick review of project progress against the milestones.

Default Condition

Schedules should include at least two milestones, one for the project start date and the other for the project finish date. In addition, all contractually required milestones should be shown in the schedule.

Preferential milestones may also be used to monitor the progress of events such as notice to proceed, completion dates, owner activities, and often critical deliverables. For instance, "Ready to Advertise for Bids" is an important event. It represents an instant in time but has no duration of its own. To reach this particular event, all activities pertaining to the design and specifications for the project must first be completed. No action toward getting a contract can be taken until the logic flow has passed through the event (O'Brien & Plotnick, 2005, p. 52).

Best Practices

Establishing milestones as a contractual requirement helps the owner to control the project's progress, and it provides a definite area for controlling the performance of the contractor (O'Brien & Plotnick, 2005, p. 421).

Milestone lists identify all milestones and indicate whether they are mandatory (required by the contract) or optional (based upon project requirement or historical information). The milestone list is a component of the project management plan, and the milestones are used in the schedule model. The milestone list should be included in the written narrative, with explanations of the purpose of all milestones.

Milestone charts which identify the scheduled start or completion of major deliverables and key external interfaces can also be used as visual representation and to monitor specific milestones.

Contractual milestones should be included in the schedule with constraints applied so as to provide a mechanism to identify the critical path of each milestone. These constraints should be the "finish no later than" type, which allow the network logic to be used to calculate positive total float for early completion, and show negative total float when the schedule predicts late completion of any milestone.

Recommended Practice

Milestones are unique events with no duration that mark significant points in project execution. As part of the planning process, milestones should be identified by the project team, and included in the activity list (AACE, 2007).

Milestones should have no resources and should be depicted on the schedule as a diamond shape in order to stand out in the bar chart view.

All contractual milestones should be included in the schedule.

Advisories

Milestones are frequently used to monitor progress, but there are limitations to their effectiveness. Milestones should not be in the direct network path, but instead should be connected to the activities that drive the network logic. Milestones should not be loaded with costs or resources since the duration is zero, and they should not be driving the critical path.

The use of mandatory-type constraints, such as "finish on," should be avoided, since they may provide misleading float values by not allowing the network calculations to show any earlier completion than the constraint, even when the work predicts early completion.

3.5 Activities

This section will provide the definition of a schedule activity, the purpose and the various types of activities that are found and available to be used in the development of a project schedule. An activity may be defined as an element of work or action needed to produce a requirement (task) within a project and that may require a resource (people, material, or equipment) over a period of time.

Activities are used in a schedule to:

- Define an item of work, action, or amount of time required to achieve a project goal;
- Define or identify a portion of a project;
- Mark the beginning or end of a project; and
- Capture a resource(s) requirement for a defined period of time.

An activity will represent a unique element of work and be assigned a description that represents the work being performed. The element of work can require one or more resources to complete the requirement and, depending upon the type of activity, will be assigned a duration of time. The following sections will help define the use of the activities and the different activity types.

3.5.1 Activity Types

A project schedule contains various types of activities, each with a specific use and purpose.

Guidelines

Definitions

An activity is defined by the specific purpose it serves within a project schedule and by the current status of the activity as a schedule is updated. These activities and their definitions are as follows:

Start milestone–An activity with a zero duration (no time requirement) that designates a beginning. This beginning may be the start of a project, phase, or series of work efforts. A start milestone does not have a predecessor.

Finish milestone–An activity with a zero duration (no time requirement) that designates an end. This end may mark the end of a project, phase, or series of work efforts. A finish milestone does not have a successor.

Critical–An activity that exists along the longest path (sequence of activities, logic string) that determines the total duration of a project. This activity will have zero float or contain the lowest float value of activities within a schedule.

Near critical–A near critical activity is an activity that exists along the next longest path (sequence of activities, logic string) within a schedule. Note there can be multiple critical paths both critical and near critical. Usually it is the project team who decides the definition of near critical in terms of its float/slack.

Hammock–An activity which derives its duration based on the start and finish of a series of activities in a schedule. The duration of a hammock activity is dependent on the progress of the activities it spans. Note this term is software specific to Primavera. In other software it is defined as a summary activity.

Discontinuous–An activity in which the interval between its start and finish dates is allowed to exceed its assigned duration in order to satisfy start-to-start and finish-to-finish relationships with other activities.

Work–An activity that represents some effort needed to complete a requirement/deliverable defined by the project scope. Depending on the status of this activity and if it resides along the longest path within the schedule, this activity may be critical, near-critical, or non-critical.

Purpose

Activities are used in a schedule to:

- Define items of work or periods of time that are required to achieve the goal of the project;
- Define a portion of a project;
- Mark the beginning or end of a project, phase, or task;
- Identify a portion of a project (hammock);
- Provide a means to capture or accumulate a resource requirement; and
- Provide a means to capture a number of activities that are related to each other within the scope of the project and present a total duration requirement.

Default Condition

Reference to this section should be made before a project schedule is developed and at any time the project schedule may need to be revised to address a change in scope.

Best Practices

This topic should be distributed to the project team so that an understanding of what is being presented in the project schedule is understood. This topic should be referred to when a change in scope is required to be entered into the schedule so that activity type and use is consistent in the schedule.

Coordination between the scheduler and any other team member needs to be maintained when the schedule is used for more than tracking time, i.e., when schedule use extends to budgeting cost, assigning resources, etc.

Recommended Practice

A glossary of activity types and uses should be provided to all team members prior to the development of a project schedule. This distribution will facilitate an understanding of how the schedule needs to be prepared and what is being presented during updates.

The person or persons responsible for schedule development, progressing, and revisions should be completely familiar with the activity types and uses in the project.

Advisories

When more than one person has access to editing a project schedule, activity types should be verified on a periodic basis to ensure correct usage. The incorrect tagging of activities may lead to data being taken from the schedule resulting in false reports which in turn may lead to making incorrect project decision making.

When staff is added to the project team, distribution of the activity type definitions and use should be made so that any new team member can be made familiar with the ground rules set for the project schedule.

An activity type should not be confused with a constraint that may be assigned to an activity. The following are constraints that should not be interpreted as activity types:

- As soon as possible
- As late as possible
- Not earlier than
- Not later than

Each activity must have a description defining the scope of work that it represents. An activity description should contain a noun and a verb at minimum and ideally a location, unless a location is embedded in the activity ID code. For example, if an activity is describing the scope of work to install doors at Level 3 of a high-rise condominium, the activity should read something like "Install Doors–level 3." It should not just say "Doors." The word "install" implies an action, while "doors" is obviously the noun and the recipient of that action. Also, activity descriptions should only describe the scope of work of only one subcontractor. For example, many builders of schedules create concrete installation activities that are written thus—"F/R/P SOG"—which translates to "Form/Rebar/Pour Slab on Grade." The description breaks the first rule mentioned about a noun and a verb, and it includes the work of three separate contractors. One sub usually does the forming, another sub installs the rebar, and another pours the concrete (unless self-performed). The "F/R/P SOG" needs to be broken down into three separate activities—one for each sub.

To take the example one more step, there are actually five subcontractors involved in the activity "F/R/P SOG." Before the slab can be poured, the electrical and plumbing subcontractors need to do their work in the slab before the final layer of rebar is placed and the slab is poured. This is a good example of the level of detail one should include in the schedule. The original activity can mushroom into five activities (one for each subcontractor). If you are building a 40-story office building with the same five activities for each floor, the schedule increases by 160 activities which the scheduler now owns and has to track.

3.5.1.1 Tasks

A task is a component specified by a project scope of work and has a limited definition in respect to the project. A task may be a deliverable or work required to be performed, as defined by the project scope of work.

Guidelines

Definition

A task is a product that has a defined meaning specific to the project and its requirements that may differ from one project to another.

Purpose

A task is used within a project plan to define a deliverable or a required action that may require one or more activities. A task can be identified as a component of the project work breakdown structure. Therefore, it is used to group or summarize several activities into a single work requirement.

Default Condition

This topic should be referred to during the decomposition of a project to help define and describe grouping in the project plan and facilitate the planning process into an organized structure.

Best Practices

During the development of a project scope of work or the project schedule, the project should be decomposed into tasks that define an intermediate level above activities. These tasks then feed up into deliverables necessary to achieve the goal of the project.

Recommended Practice

In developing a project schedule, review the project scope of work and identify any work breakdown structure that may exist. If one is not apparent, develop a structure and decompose the elements into defined deliverables and any work necessary to achieve the deliverables. These work requirements should be used as tasks within the project.

Advisories

In decomposing a project, avoid reducing tasks into small work requirements. These work requirements are activities and should be treated and tagged as necessary following a defined activity type methodology. Tasks should be provided with unique descriptions that will facilitate ease of identification within the project work breakdown structure.

3.5.1.2 Independent Activity

An independent activity is a type of activity that accommodates a level of flexibility in determining its duration when resource availability is defined.

Guidelines

Definitions

An activity is considered independent when the duration to complete the required work is not fixed, in that the duration to complete the necessary work is a function of one or more resources that are assigned to the activity and their specific availability to perform the work required.

This activity may be considered resource-driven, or effort-driven.

Purpose

The purpose of an independent activity is to account for the:

- Various resources assigned to the activity
- Availability of the resources to perform the work
- Duration required to complete the defined work

This activity type will allow the total activity duration required to complete the necessary work to change. This change is a function of one or more resources available during the project life, and it facilitates changes to resource availability due to unforeseen conditions or events.

Default Condition

During the initial planning stage of a project schedule, the use of independent activity types is beneficial to facilitate the uncertainty of activity durations for resource-loaded/driven work.

During the execution of work, independent activity types will facilitate changes in resource availability and provide a more realistic forecasting of work and project outcome.

Best Practices

Minimal use of independent activities within a schedule will provide a good means of controlling the outcome of the project during planning. When a critical path is identified, the use of independent activities to assess the impact of resource availability will increase the confidence level of project outcome.

Independent activities should be identified to facilitate editing. The use of activity coding or other function within the scheduling software should be investigated and used to its fullest.

Recommended Practice

Once there is concurrence of the project schedule, the use of independent activities should be minimized, unless the intent is to continue using the availability of resources as a driving factor for project duration.

Advisories

Maintenance of resource availability is a critical component in the use of independent activities. Incorrect availability will result in incorrect project forecasting.

3.5.1.3 Hammock or Level of Effort (Summary) Activities

Guidelines

Definitions

Hammock Activity (summary activity)—Hammock activities in a project schedule group related activities over a segment of the project's life. Hammock activities can be filtered out in a separate report that will minimize the total number of activities displayed. Hammock activities report information that is time-dependent and lasts from the earliest start date to the latest finish date of the activities it encompasses. It is recommended that hammock activities be a start-to-start relationship with the first activity as a predecessor and a finish-to-finish relationship with the last activity as a successor.

Level of Effort (LoE)—LoE is a type of activity that reports on a fragnet of activities over a period of time. An LoE activity's duration is dependent on the time frame from its earliest predecessor and latest successor activities. The term level of effort is also known as effort activity or effort-driven activity.

Neither the level of effort nor hammock activities should have constraints assigned to them. Level of effort activities are not affected by resource leveling calculations. Level of effort activities should be used to report on a group of ongoing tasks.

Purpose

The purpose of using hammock activities is to provide summary level views of the networks within the project schedule. They are mostly used for anyone who wants to see what the summary of the project is without showing every detail needed to complete the project. They show how long one section of the project will take by using one activity instead of all the activities that encompass the section of the project. To cost load a hammock activity, the amount of costs for the hammock need to match the costs of all the activities encompassed by the hammock activity.

Default Condition

The default condition for using hammock activities is that they should have a start-to-start relationship with the earliest predecessors and a finish-to-finish relationship with the latest successor activities. Each hammock/LoE activity only reports on the fragnet of activities contained within the hammock/LoE. The hammock will represent the earliest start date and latest finish date of the logical sub network it encompasses.

Best Practices

Hammock/LoE activities should be used when a summary of the schedule is needed. Use of hammock/LoE activities can minimize the total number of activities displayed in a report by summarizing fragnets of activities.

Hammock/LoE activities can be filtered into a special summary schedule report to provide a high-level view of the project. This is useful for summarizing phases of the project such as foundations, structure, rough-in mechanical work, finishes, and others. They can also be used for phased construction reports.

A technique that can be used in cost loading a schedule is to load the total cost of the activities encompassed by the hammock/LoE into that activity. This can be useful in cost-loaded schedules that comprise processes such as a waste water treatment plant that needs to identify the total costs for specific processes.

It allows for quick cost loading, and since the hammock/LoE activity will show progress based on the progress of all activities contained within the hammock/LoE, the reported costs are accurate.

Recommended Practice

The recommended practice for using a hammock/LoE activity is to represent a group of related activities by a single activity. It is used to summarize the schedule and provides less specific detail needed to complete the schedule. The hammock/LoE activity needs to reflect the earliest planned start and latest planned finish date of the activities it is representing.

Advisories

Hammock/LoE activities should never have constraints or show up on the critical path because they are not activities directly associated with the work product.

Hammock/LoE activities should only be used if a summary of the schedule is needed. If costs are loaded in hammock/LoE activities, there is a risk that poor production will show reduced costs earned. If the activities reported by the hammock/LoE slip, the unit costs for the hammock are reduced and the schedule may show negative cost earnings that period. This often happens when field general conditions are cost-loaded into a hammock/LoE activity and the project is extended; the costs/day will be reduced, which could cause the earned value to be less than the previous period, resulting in a loss of revenue.

In some software, such as MS Project, hammock/LoE activities, called summary activities, are often generated automatically by the software while developing or managing the schedule. These activities should not be tied logically into the network because they are just reporting activities.

If the predecessor relationship is missing in a hammock/LoE activity it will report the earliest start date, and if the successor relationship is missing it will report the latest finish date.

3.5.1.4 Milestones

There are certain significant events on each project that are used to measure progress. These events are shown as milestones in the project schedule.

Guidelines

Definitions

A milestone is a zero duration activity or event that receives special attention, and is generally used to denote a particular point in time for reference or measurement. Milestones are often used for management summary reporting, and should be capable of validation by meeting all of the items prescribed in a defining checklist as agreed with the stakeholders.

Purpose

Milestones are used to represent significant points in time in a schedule for measurement of progress.

Default Condition

Most contract documents and specifications will require that significant events be reflected as milestones in the schedule.

Best Practices

The schedule must, at a minimum, include the milestones required by the contract and/or specification documents. A start milestone should represent the start of an activity or set of activities. A finish milestone should represent the completion of an activity or a set of activities.

Recommended Practice

The schedule must include all contractually mandated milestones. Typical contractually required milestones include contract award, notice to proceed (NTP), substantial completion, and final completion. The contract may require certain milestones be shown for payment purposes.

The schedule should include milestones for any interim work start or completion as required by contract.

Other milestones that could be shown are structural completion, building dry-in, mechanical completion, and electrical completion.

A start milestone should represent the start of an activity or multiple activities. Start milestones include NTP and start construction.

A finish milestone should represent the completion of an activity or multiple activities. Finish milestones include substantial completion and final completion.

Key meetings may be shown as milestones in a schedule in lieu of showing them as one-day tasks. Meetings may include pre-installation meetings for specific scopes of work, user group meetings, and design review meetings.

Decision points as required by the contract and scope of the project may also be shown as milestones and may highlight go/no–go decisions.

Advisories

All stakeholders must agree to what milestones are to be shown in the schedule and understand what the milestones represent. It is important to use the correct type of milestone, either start milestone or finish milestone, to represent the key event.

Milestones must have a calendar assigned; some specifications will require that milestones be shown on a seven-day, 365-day-per-year calendar. The use of multiple calendars can create issues when analyzing the schedule's critical path.

Some contracts may require that certain milestones have a date constraint assigned. It is important to understand what type of constraint, if any, should be assigned, as the use of constraints in a schedule will impact the schedule calculations. Constraints in a schedule should be limited to those required by contract.

The scheduler must ensure that all logic ties to and from the milestones are correct.

Milestone activities must be properly updated during the schedule update process.

3.5.2 Activity Coverage

Guidelines

Definitions

Activity coverage: (1) the scope of work of an individual schedule activity, (2) the sum of the scopes of the list of activities; ideally, these are equivalent to the project scope of work.

As a component of the overall project, each activity must cover a defined scope of work that is a subset of the overall project scope. AACE's definition of activity considers the concept of activity coverage, indicating that "individual activities have relationships and may have other attributes, such as cost and resource loading and constraints" (AACE, 2013, p. 29).

The concept of activity coverage establishes the relationship between an activity in a CPM schedule and the actual scope of work that the activity models. Activity coverage may be defined differently for administrative activities than for work activities.

Activity coverage can be regarded as complete on either an individual activity or an entire project level, which is the basis for the two definitions given. In either case, activity coverage is complete when the scope of work is covered comprehensively, clearly, and with sufficient detail for the input and output needs of the schedule users.

Purpose

The purpose of clearly and comprehensively defining activity coverage is so that project participants can understand and properly use the schedule. Clear activity descriptions and limits facilitate proper planning, complete coverage of the scope of work, and proper updating through all phases of the project. The identification of schedule activities will take place during the planning phase. The purpose of well-defined activity coverage during the planning phase is to ensure that the complete scope of work is modeled in the schedule and that the scope of work of each activity is understood by all stakeholders. Detailed understanding of the scope of work modeled is particularly important for those who will be responsible for the execution of each activity.

During the execution phase of the project, as the schedule is managed and maintained, accurate and detailed descriptions of each activity will assist those responsible for executing the work with reporting progress and will assist project controls personnel with maintaining accurate schedule updates.

Default Condition

Complete coverage of the project scope and unambiguous definition of each individual activity is the default condition for activity coverage in a CPM schedule. However, completeness of coverage is open to subjectivity due to the fact that any task can be parsed to further and further levels of detail. For example, constructing a foundation can be divided into excavating, forming, placing reinforcement, placing concrete, curing, stripping forms, backfilling, and the associated inspections for each of those tasks. Most of those tasks could be further divided by section (for large foundations) or even divided into sub-tasks. For example, forming could be divided into staging, erecting, bracing, tying, and coating forms with release agent.

Each project will require its own unique considerations, and individual practitioners have preferences for the level of detail deemed appropriate depending on the project type and complexity. For the purpose of defining the default condition for activity coverage, it can be said to be complete when each activity is defined to the level that it can be adequately measured and controlled, and the activities in the schedule fully define the scope of work for the project.

Best Practices

The range of practices regarding the level of detail necessary for each activity makes assessment of the specific project and the needs of the stakeholders an important consideration in activity coverage. Determining the right number of activities is not developed purely by instinct or some mysterious process, but rather by understanding the unique attributes to the project. One must consider the overall project cost, the contractual requirements, and how the schedule will be used by the team to manage the scope when determiing the level of detail and the number of activities required to develop your schedule.

Of course, the scope of work covered by individual activities will be broader for summary-level schedules. Schedules prepared during the initial phase of a project and those used for management presentations will have individual activity coverage far broader than that used for detailed project execution schedules. The activity coverage in the summary schedules is not poor or improper, per se. The schedules should instead be regarded with the purpose for which they were prepared in mind.

The level of detail in a schedule may be based on a numbering system, such as those described by AACE's *Recommended Practice No. 37R-06* (AACE, 2008). Referencing the overall schedule level to a published practice can assist stakeholders in understanding that the scope of individual activities can be read more broadly. Not every detail of the project execution plan will be included in the summary schedule.

For execution-level schedules, AACE recommends that an activity's essential attributes should include a descriptive title and initial duration reflecting the intended scope of work (AACE, 2007). AACE further notes that the activity title should be clear and succinct without being vague, stating that "the activity description and initial activity duration should unambiguously communicate the scope of the work" (p. 2).

The quality of activity coverage in a CPM schedule can be compared to the quality of a project specification, in that both schedules and specifications attempt to define a scope of work at an appropriate level of detail for execution, and that they be clear, complete, concise, and correct. Similar criteria can be applied to the definition of schedule activities. For work activities, the activity should cover the scope of work:

- Clearly;
- Comprehensively;
- Consistently (whether by area, system, trade, or project);
- With sufficient detail to manage;
- With sufficient detail to support updating and reporting requirements;
- Facilitating clear relationships between activities;
- Facilitating clear starts and finishes of activities; and
- Providing sufficient detail to support understanding and monitoring outside activities that could potentially delay the work activities.

Coverage of administrative activities in CPM schedules is open to a broader range of practice than that of work activities. However, when defining administrative activities, similar guidelines can be applied, especially considering that activities regarded as administrative in one industry may be regarded as work activities in another. For example, some industries may consider preparation and execution of client presentations as key work activities because completion of the presentation may be a key milestone or gateway to the next phase of a project. Other industries may consider similar presentations as an ongoing administrative task that takes place in parallel with the execution of the project. The construction industry tends to limit work activities to those that physically take place in the field, while offsite fabrication may be classified as a procurement activity and tracked in a manner similar to other administrative activities, despite the fact that the activity represents physical work.

Contractual requirements and project reporting needs should be considered in determining which activities are defined as administrative or work activities, or whether a distinction is even necessary. It is less important to distinguish administrative activities from work activities than it is to ensure that both types of activities are adequately modeled and controlled during project execution. For example, subcontract buy-out activities are not often modeled in detail in construction schedules, but can drive the overall project schedule, if not completed, to support timely mobilization of critical subcontract work.

The specific coverage of work activities in the field may depend on how closely it is necessary to monitor the work. Activities defined with durations ranging from one to two weeks work reasonably well in project management structures that require weekly reporting. Personnel at the execution level will benefit from activity coverage that allows for "look-ahead" schedules, showing one to three weeks of work in a convenient, easy-to-read format.

In some applications, activity coverage may be defined at the daily or hourly level of detail. In fact, management at that level is common in scheduling for outages in the power and process industries. However, management at that level of detail may be regarded as micro-management and looked upon negatively if attempted in another application or industry. Therefore, the culture of the industry and workforce is also a consideration in refining the level of activity coverage in a schedule.

Some project controls systems allow for the division of activities into steps or tasks to provide a more detailed breakdown of what each activity covers. That level of detail can be useful for describing the work to be executed for specific stakeholders that will perform the activity without cluttering schedule layouts with details that may not be necessary for those not engaged in the direct execution of a specific activity.

The available organizational project controls resources are another consideration in determining the level of detail that is appropriate for each activity. Coordinating the level of activity definition with the organization's ability to manage and update the schedule is important to the overall accuracy of the schedule and reporting during the execution phase.

In summary, there are a range of practices regarding activity coverage, particularly with regard to administrative activity coverage. In defining the activities in a schedule, a balance is sought between creating a level of detail appropriate to define the work activities and crafting a schedule that is a useful management tool. The best schedules have activities that are clearly defined, produce reporting useful for both execution and management decision-making, and allow for some flexibility at the detailed execution level.

Recommended Practice

Based on a review of the available best practices, the following are recommended for activity coverage:

- Define each activity in a manner that clearly identifies the scope modeled and indicates where the activity starts and ends.
- Define activities sufficiently such that the cumulative scope of the activities is equivalent to the project scope, without gaps or duplication.

If the scope of each activity is clear to those who must execute and manage the activity, and the sum of the activity scopes is equivalent to the overall project scope, activity coverage will be complete. Clear definition of the start and end points for each activity will facilitate logic definition between activities, and the list of schedule activities identified will facilitate complete definition of network logic.

Advisories

In the ideal schedule, the defined activities completely cover the project scope of work, without any overlaps. Thus, there are two primary issues that occur when defining activities, which result in either incomplete or redundant activity coverage due to:

- Neglecting portions of the scope of work from the scope of the defined activities
- Defining activities that include overlaps in the scope of work between activities

Gaps and overlaps in the scope of work modeled can also occur due to differing interpretations of the scope of work covered by individual activities. Defining activities according to the recommended practices will minimize confusion due to different interpretations of activity scope by different stakeholders. During the project planning phase, discussion of the types of activities to be modeled in the schedule and the level of detail to be used will further limit potential gaps in understanding. Inadequate attention to the design of the schedule is often the root cause of inadequate activity coverage.

3.5.2.1 Work Activities

This topic provides the definition of a work activity and how it is used in scheduling.

Guidelines

Definitions

Work is an action or series of actions performed by a resource or person to produce or accomplish something. Within the schedule, a work activity is the task with a duration and resource for the effort to be completed.

Purpose

A work activity provides a means, a placeholder, to represent a required duration of effort in a schedule. This activity also allows the assignment of resources (people, equipment, material, and budget) to identify when a resource is needed and for what length of time.

Default Condition

A work activity represents a duration of effort and not a duration of inactivity e.g., a winter shutdown for a construction project, or a delay due to an unforeseen condition or event.

Best Practices

During the course of developing project activities, work activities are identified by resource requirements, where a physical effort is required.

Recommended Practice

Use consistency and clarity in activity identification throughout the life of the project; do not mix or cross-identify activities in the schedule. Remember that an activity or work description is the only way to convey to others—the stakeholders—what the schedule is all about and what it means.

Advisories

Do not place multiple scopes of work into a single activity of work. Each description of work should only contain the scope of work for one subcontractor and the resources that the sub will need to perform that one scope of work.

3.5.2.2 Administrative Activities

The administrative activities topic will define what administrative activities are, and what they represent within the project schedule and plan.

Guidelines

Definitions

An administrative activity is an activity type used specifically related to the effort necessary to manage the daily operations of a project or organization.

Purpose

The purpose of the administrative activity is to capture effort that is dedicated to the oversight of a project's operations, not limited to the following types of work:

- Planning
- Organizing
- Staffing
- Accounting
- Procuring
- Preparing bid packages, documents, and drawings

Default Condition

Activities specific to administrative work span the entire duration of the project, actually beginning prior to the physical start of the project and ending with the project closeout work.

Best Practices

Activities specific to the project's administrative work should be separated from the project's specific work activities, since administrative work is continuous even during a delay in the physical work of the project. This is due in part to the fact that certain overhead expenses continue while physical work is suspended.

Recommended Practice

Administrative activities should be unique. This separation of work and administrative work can be accommodated by the use of unique activity identification numbers or a coding structure. A structures methodology should be used and consistent from one project to another.

Advisories

The client should be questioned regarding the procedures to be used for administrative activities. Any existing procedures should be investigated before a project methodology is put into action.

The methodology used for the project should be documented within the project execution plan.

3.5.2.3 Coordination Activities

This topic will define what coordination activities are and what they represent within the project schedule and plan.

Guidelines

Definitions

A coordination activity is one that represents the integrated effort of a group of stakeholders or team members focused on a defined purpose and goal.

Purpose

The purpose of a coordination activity is to capture various project activities that may not have a specific occurrence within the life of a project or that may reoccur at specific intervals, and which are specific to a particular stakeholder, team, or agency in a single activity that spans an extended period of time. The use of coordination activities will reduce the number of activities within a schedule and lead to simplification of the project schedule. An example of a coordination activity may be a project staff meeting.

Default Condition

A coordination activity will appear only one time within a project schedule which will have a single purpose relative to a specific function within the project's scope of work.

Best Practices

For schedule effectiveness, a single coordinating activity should be used relative to a single function. Multiple coordinating activities may be included in a project schedule, but each activity should be associated to a single purpose.

Recommended Practice

One coordination activity should be created to summarize numerous meetings or general activities. For example, during the design process of a roadway, coordination needs to be conducted with respect to existing utility lines above and below grade. This coordination will involve numerous meetings with the utility owners. For scheduling simplicity, each utility owner should be assigned its own coordination activity that summarize the various meetings that will be required. Combining all the utility concerns into a single coordination activity will yield simplicity, but progress reporting will not be effective.

Advisories

A single coordination activity should occur in the schedule of each identified concern. Work that may result or be connected to the coordination activity should not be included in the coordination activity, but inserted in the schedule as a work activity.

During a project cycle, if a new stakeholder is identified and requires a level of coordination then a new coordination activity should be added to the schedule to accommodate the new stakeholder. The new stakeholder should not be included in any coordination activity already existing in the schedule.

3.6 Durations

Guidelines

Activity durations, along with logic, are the basic building blocks of any schedule. The scheduler should be aware of the methods available to estimate activity durations, and how the method used will influence the accuracy of the schedule over the life of the project.

Definitions

Durations are simply estimates of the period of time to perform the work assigned to each schedule activity, typically measured in days. At higher level summary schedules, durations can be measured in weeks or even months. At the other end of the spectrum, a very detailed schedule to control a relatively short project or specific phase of a project could measure durations in hours. But use of days to measure durations is by far the most common planning unit.

Most scheduling software will use, calculate, and display an activity's original duration and remaining duration. The original duration is the number of days (or other unit of measure) initially assigned to a given activity. Once an activity has started, and the start date has been actualized in the schedule, the remaining duration will be displayed as the number of days (or other unit of measure) remaining to finish that activity. The remaining duration will either be manually entered during the schedule update, or calculated if the percentage complete is linked to remaining duration and entered during the schedule update (software dependent). See the section on earned value for further considerations regarding this issue.

From a risk management perspective, durations carry a certain amount of uncertainty in their values, so durations would more appropriately be modeled on probability distributions. This is related to the range of production rates that could be assigned to tasks based on individual talents, project conditions, climate, and a number of other considerations. Traditionally, outside of CPM scheduling, there are several methods used to deal with this concern and produce probabilistic calculations of durations. In a CPM schedule, durations are typically deterministic, using a single value.

One of the reasons that deterministic schedule methods seem to work reasonably well is the self-correcting nature of the project controls effort. If there is a good analytical process in place during the routine schedule updates, any stacking of pessimistic durations will be identified in the update analysis, and corrective actions will be taken to bring the project back onto schedule

Purpose

What is a schedule, but a collection of activities with durations, connected by logic? The duration of the overall schedule is the combined result of the individual activity durations and the logic links between activities. Duration estimates represent a tool for the project team to use to help prioritize resources to accomplish tasks and achieve successful on-time project completion. Schedule durations distribute requirements and resources necessary to implement the project plan. Careful duration establishment helps the project team members understand what they are expected to do and how long they have to do it. Durations are intended to adequately demonstrate the intended plan to complete the project on time.

Therefore, the accuracy of the activity durations has a significant impact on the accuracy and reliability of the overall schedule. As schedules are initially developed, the individual activity durations will be estimates, based on a number of factors, including:

- The past experience of the person creating the schedule;
- The knowledge of the person creating the schedule, as it relates to the specific project;
- Quantities and production rates derived from the project cost estimate;
- Assumptions as to the available resources for labor, materials, and equipment;
- Mandatory project milestone dates or completion dates provided by the client that drive overall and/or activity durations; and
- Constraints such as project entitlements, permits, and approvals that dictate certain start or finish milestones.

Default Condition

Estimating activity durations is a most basic component of developing a project schedule. The recognized methods for estimating durations are presented below in the Best Practices section.

Best Practices

Estimating project activity durations requires the scheduler to start with basic information—a general understanding of the scope of work and the required resources to perform the work (labor, materials, and equipment). If more detailed information regarding the quantities of work to be completed and of available resources is provided, this information can be used to more accurately calculate activity durations.

The *PMBOK® Guide* recognizes three methods for estimating deterministic schedule activity durations, useful for progressively elaborated schedules such as those developed early in the project and updated as design is advanced. The methods are:

- **Expert judgment.** Relies on knowledge of prior similar project durations to inform estimates for the current project, more of a "gut check" on durations that may be estimated or validated by other methods that follow.
- **Analogous estimating.** When detailed information about a project is limited, using parameters from previous similar projects can be used to estimate the current project durations; some schedulers will derive "rules of thumb" or other guidelines for common activity durations based on past performance, not as accurate as other methods and typically used in earlier phases of a project.
- **Parametric estimating.** A more quantitative approach that yields more accurate durations, by using known quantities and historical production rates to calculate durations; general contractors with history in self-performed work and records of trade subcontractor past performance often use this method, but it still requires assumptions or data on available resources to apply the production rates to the project quantities.

As the project definition or design progresses, and the amount of detailed information available to the scheduler increases, the appropriate method for more accurately estimating activity durations can be used to improve overall schedule accuracy and reliability.

Recommended Practice No. 32R-04, "Determining Activity Duration" (AACE International, 2012) suggests that there are three phases to determining durations: determining unconstrained activity durations, adjusting activity duration based on constraint impact, and revising activity original durations to meet project requirements. These phases are described in detail in the Recommended Practice, and the concept is very useful as an approach to deterministic duration estimating.

This estimating of durations for the official project schedule, the baseline or as-planned, becomes more detailed, requiring reasonable calculations. Once production rates and quantities are established to calculate the durations, it is important to ensure that the production rates are based on available resources and spaces. Without taking into account available resources to perform the activities, and without consideration of the available spaces in which to work, estimates of durations are not appropriate and may not be reasonable.

Recommended Practice

The Best Practices section above lists the generally accepted methods to use for estimating activity durations. Additional considerations regarding activity durations include:

- Maintaining uniform activity durations during early stages of project schedule development can simplify the process as the schedule is expanded in level of detail.
- A good guide for the maximum duration of an activity is to limit it to half or the full reporting period between schedule updates. Frequently, updates are required on a monthly basis, which would indicate a maximum activity duration of about 10 to 20 working days.
- Feedback from trade or project supervision that is closest to those actually performing the work is excellent input to schedule productivity, in this case to estimate activity durations, based on their detailed trade-specific knowledge and past experience. Use of experienced general contractor and trade subcontractor superintendents and foremen can improve the accuracy of schedule duration estimates.
- Once the durations are estimated in compliance with best practices, the individual activity durations should be reasonable and appropriate. However, this does not guarantee a reasonable and appropriate schedule because it only addresses the use of resources on each activity, not necessarily all activities planned to perform at the same time. It is vital to examine the issue of concurrent activities because the durations of each activity will require concurrent resource use. This is also true for spaces; each trade individual needs a certain amount of space for materials storage, tool storage, and work. The available spaces for work will limit the number of individuals, as well as the number of trades that can work at the same time in each space.
- As a result of this issue, trade and space stacking are common causes or symptoms of inappropriate or unreasonable schedules, so the quality control verification for the baseline or as-planned schedule should include a review of available resources of concurrent activities. Review of the total number of crews and individual resources in the early and late date sorts of the schedule will help improve the reasonableness of the plan.

Advisories

All schedules are plans based on estimated activity durations, and the accuracy of the activity durations will be directly reflected in the overall accuracy of the schedule. Despite the best efforts of the scheduler in preparing the schedule, and the management of the project to meet the schedule in the field, issues will come up that impact the schedule and require reworking the schedule—by revising activity durations, revising schedule logic, or more likely a combination of the two. A strategy should be developed early in preparation of the schedule with regard to maintenance of it. Documenting the methods and assumptions for estimating durations is important to aid in decisions required during the maintenance phase (See Section 4, Schedule Maintenance).

There have been projects where the durations of activities or the project are stipulated by the owner or project constraints. This is similar to other project constraints, and requires the same review of the duration estimate and evaluation of the concurrent work opportunities and challenges. Once the schedule has been accepted, each stakeholder, from general contractor to subcontractor, is responsible for meeting their estimated durations. Section 5, Schedule Maintenance, provides insight into monitoring the performance of each of the stakeholders.

During the schedule usage phase, review of the as-built durations is monitored to determine if they are reasonable as the project progresses. If and when durations no longer appear to be reasonable, the original assumptions for estimating those durations or the concurrent work strategy should be reviewed. If the original assumptions no longer represent reasonable assumptions, steps should be taken to mitigate the problems related to the reasonableness of the contemporaneous schedule. This could include adjusting future durations to match the as-built durations, so any negative impacts of trending of missed durations can be mitigated.

3.6.1 Durations versus Update Frequency

Guidelines

Projects require a schedule as part of the project management process. For the schedule to be a valuable tool, it needs to be updated on a meaningful frequency. While there is agreement regarding the durations and update frequency, it can be difficult to determine the appropriate periods for the project schedule. A number of factors could potentially affect the schedule and potentially limit its usefulness to track progress through the updates if the duration sizes are not correlated with the update frequencies.

Definitions

Update frequency is defined by the number of updates received or required over a time frame, such as a month or a year. In many projects, an update is provided on a monthly basis, often to align with the invoice cycle. However, for projects where the schedule is used extensively for management, daily or weekly updates are sometimes and often necessary.

Purpose

The purpose of the frequency of updates is to provide the project team with an accurate detail of progress performed, in some stipulated window. The update frequency affects the level of detail in the schedule (see Section 2, Schedule Design). The durations of the activities in the schedule are generally also determined by the level of detail in the schedule. The amount of information needed by those who will be using the schedule generally influences its development, and determines the scope of the individual activities, and thus their estimated durations. Formal planning of the project before initiation is needed to assess the level of detail that is appropriate and will allow for a meaningful update.

Generally, smaller update windows allow for a more accurate level of detail about the progress made. The less often the schedule is updated, the harder it will be to analyze, and the more likely that detailed analysis of impacts to the schedule can be performed.

The frequency of an update is usually specified in the schedule specifications and/or the contract. Larger update windows provide a less accurate update, as more activities are required to be progressed and could reduce the ability to segregate problem areas of the project.

Durations and frequencies may depend on the information needed at a particular stage during the project life cycle. Durations and their frequencies may need to be adjusted, depending on status. For example, with a project that has fallen behind, mitigation or acceleration may be necessary to bring it back on schedule. Therefore, after planning and consideration, durations may need to be reduced to accommodate the new efforts. Similarly, the frequency of updates may be increased in order to create smaller update windows to track the progress of any acceleration efforts.

Durations for construction activities are dependent on the planning unit/s. If resources need to be monitored on a daily basis, there should be a greater level of detail when planning for durations. This will help to determine which, if any, resources are shared between contractors and which may run the risk of overlapping.

Default Condition

Usually, maximum duration limits are established within the contract specifications. Typically, an estimated duration for an activity should not be greater, but also not limited by, an update window (frequency).

The level of detail is decided based on a number of factors:

- Contract specifications;
- Uniqueness, size, and complexity of the project;

- Expertise and availability of project controls staff;
- Resources available to perform the work;
- Management need of visibility on the project;
- Project completion;
- Number of contractors and interface points;
- Status of in-progress project;
- Resource calendars;
- Environmental factors; and
- Existing conditions.

Early planning is essential to identify concerns intended to necessitate duration and reporting requirements. This will influence the amount of detail needed for development of activity durations.

Best Practices

Activity durations and frequency of updates are related to each other; however, they are not dependent. When determining durations, it is important to remember a number of factors that play an important role, such as end-user needs, who will manage the schedule, or how often the schedule will be updated.

Typically, in planning, no activity should be longer than a specific number of days or relationship to the update window (such as 20 workdays) unless specified or approved. There are exceptions for certain types of activities, such as procurement or submittals. By focusing on duration breakdown smaller than or equal to the update window, the project team is encouraged to consider resource logic to get the work completed and communicated.

Alternatively, the activity duration typically should be no longer than an update cycle, not counting procurement durations with naturally occurring long durations. This helps the decision for how often an update will be performed, if not specified in the contract.

One fact to keep in mind is whether the schedule is to be used to manage workers on a weekly/daily basis. The detail of the activities needs to be more developed to match this small window. Similarly, updates would normally be expected to be done weekly or every two weeks, likewise for durations. This allows for closer monitoring of progress and does not consist of many activities progressing beyond an update window.

Recommended Practice

The *PMBOK® Guide* – Fifth Edition provides guidance on this topic. The process of estimating durations needs to be well-thought-out and documented so that project team members use the same set of guidelines. Estimating activity durations is defined in the *PMBOK® Guide* as:

> Estimating activity durations uses information on activity scope of work, required resource types, estimated quantities and resource calendars. The inputs of the estimates of activity duration originate from the person or group on the project team who is most familiar with the nature of the specific work activity. (PMI, 2013, p. 167)

When the project team is estimating durations, the schedule should not be so intricate and detailed that it becomes time-consuming to maintain. By having too much detail, a scheduler runs the risk of not updating progress accurately, with so many activities to update in each window. However, on a daily or weekly updated schedule, smaller durations are imperative to track progress.

It is important when developing durations to consider the frequency of updates to be produced. This forces the project team to develop the durations with detail that coincides with the frequency of updates. The schedule loses its ability to be a meaningful analysis tool if durations are significantly longer than the frequency of updates. The project scheduler should not come up with durations independently without consultation with the project team. Through meetings during the planning process, the scheduler should gain the information he or she needs from the project team in order to estimate accurate durations.

Advisories

Large update windows limit the need to update and, therefore, limit the accuracy of each update. Large update windows also limit the usefulness of the schedule if in a dispute situation, and a more costly approach is then required for the forensic analysis.

Too much detail may cause resistance from the users and can limit the usefulness of the schedule if the users cannot manage and understand it.

Too little detail may result in an unreasonable schedule and inappropriate duration estimates. Appropriate duration sizes and update frequency helps to minimize potential analysis problems in a disputed situation.

Resources that are not segregated will reduce the accuracy of duration calculations. If, for example, the schedule has mechanical, electrical, and plumbing trades lumped together as one activity, the duration estimating likely did not take into account the sequencing of the three trades. This may be acceptable for a summary level schedule, but should be avoided for a more detailed schedule. Each of these trades is separate and should have its own activities and durations.

3.6.2 Estimating and Duration Verification

Guidelines

The ability to forecast time on the job and plan criticality of the sequencing of work is integral to a contractor's successful fulfillment of contract obligations and to make money on any given project. Concurrently, an owner or stakeholder in a project can utilize simple steps to ensure that the durations planned are appropriate and reasonable, as well as progressing in an optimal manner during updates. Finally, correctly and transparently tracked durations, in a planned versus actual manner, can help to demonstrate impacts on a project.

Definitions

The definition of activity duration in a schedule is the time associated with any discreet scope of work enumerated in a single activity on a schedule. The activity duration is estimated by the unit quantity multiplied by the production rate (time/unit) for the scope included in the activity description.

The durations assigned to activities are crucial and important components of scheduling. The time component of activity scheduling, along with assigned logic, ultimately results in the calculation of the criticality of the activity fragnet in the produced schedule.

In deterministic CPM scheduling, each activity duration is achieved by a single quantity and production rate for that activity scope of work. There are risks in duration estimating that are based on the uncertainty of achieving the planned production rates, and when considered significant, those risks are managed by replacing the deterministic calculations by probabilistic modeling through the use of a Monte Carlo simulation tool. (See Section 3.12, Risk Management Implementation.)

Purpose

The purpose of activity durations is to allocate time to planned activities. This time can be tracked in the planning unit, generally activity-hours or -days (amount of total single person hours or days that it takes to finish an activity) or crew-hours or -days (amount of multiple person crew hours or days to finish an activity). Durations are calculated by dividing the total hours or days required to finish a scoped activity by the assigned resource daily output.

Default Condition

Assigning and verifying activity durations during the course of a project can be split into three time periods. Each of these time periods requires separate sets of inputs to successfully accomplish the goals of the procedures.

Pre-Construction—the utilizing of historical achieved data to plan future performance on like-scoped activity durations.

Pre-Construction and In-Progress Construction—the checking of data against project records or national clearinghouse information for validation of planned durations.

In-Progress and Post-Construction—the use of comparisons such as actual durations versus original durations to evaluate the sufficiency of assigned planned durations compared to actual progress on the project.

Best Practices

During the pre-construction and planning phases of a project, the assignment of durations to activities that comprise the planned schedule of performance should be based on the best information available. Frequently, this information should be culled from the historical record of like-scoped performance on past projects. When utilizing past production rates, it is important to note any impacts that might have been present on the project that could have affected the achieved productions rates. Weather, owner-mandated construction limitations (security, time of day, and year restrictions, etc.), and experience learning curves for unfamiliar types of construction all can affect the results. Once comfortable with capturing the information present in the historical project information, it should be applied to planned individual- or crew-hours of performance.

During pre-construction or actual construction on a project, the need to verify durations may arise. Company-specific historical productivity records to compare current planned durations might not exist. Specialty scopes of work that are inherent in a project might not have prior performance records. In these cases the scheduler or estimator can consult the myriad of national clearinghouse information for similar scope productivity. Resources like R. S. Means, Building Construction Cost Data, or Richardson Construction Estimating Standards, to name a few, show expected productivity rates for specific work scopes. This information is usually presented in both man-hours and crew-hours. When utilizing this information, it is important to factor in the suggested crew sizes that are assigned to the productivity rates. While it is known throughout the construction industry that the pricing information predicted in these reference materials might not be the best indicator of regional or current influences, the prescribed productivity rates are a strong and stable reference point. This is evidenced by the relatively static nature of these rates over the last 20 years of publishing resources.

Finally, during the post-construction period, influences or factors that drove actual performance should be identified and categorized for the sake of planning future projects. Scheduling diagnostics can be run in order to find scopes of work that were prosecuted much more aggressively or passively compared to the original planned duration. These diagnostics can also be run during the course of the project to help explain the degree to which impacts are hampering efforts. One valuable diagnostic tool that can be run on durations is a comparison called the Time Performance Ratio (TPR). The TPR is a simple mathematical equation that divides the actual performance time by the planned duration. Activities with TPRs of over one have had their actual performance lag compared to plan, while those with TPRs of less than one have actually proceeded quicker than planned. All activities can then be categorized by the TPR values, and the worst performing activities, in terms of actual time compared to plan, can be investigated for impact causation.

Recommended Practice

When estimating and verifying durations of activities on a planned or executed sequence of work, it is important to keep clear and concise notes that explain any assumptions that have been made in order to arrive at final productivity numbers. Outside of helping to explain thought processes that might be revisited as the project progresses and after completion, it will also serve to communicate assumptions in the case of conflict. In construction conflicts, the original bid is often considered during the analysis of delays and disruptions, although the analysis will rely upon actual achieved production rates much more than planned rates in the bid estimate, which could be optimistic or faulty.

For this reason, it is always in the best interest of the scheduler and estimator to enumerate and record all reasoning behind components used to develop and calculate the schedule network.

When assigning durations to projects, it is best to utilize past performance productivity on similar projects. When this information is not present, national clearinghouse resource productivities can be modified and utilized to estimate planned durations of activity performance. These clearinghouses may also include suggested impacts percentages to productivity for known impacts ahead of time. The best case scenario for a scheduler or estimator is to take a conservative approach to assigning productivity and durations. Assumptions used in the calculation of productivity rates should not be too optimistic.

Admonitions and Advisories

Time Performance Ratio (TPR) values do not identify any causation, only the results of performance, so they cannot indicate responsibility for delays or disruption that might have resulted in poor TPR values.

TPR values are as accurate as the actual duration records, so if non-workdays are not maintained in the activity calendars, the actual durations could be overstated. Software that allows suspending and resuming of work can help support more accurate TPR values if the activities were interrupted.

3.6.3 Participation In Duration Review

Estimating activity durations is an extremely important task in project scheduling which has implications that affect the schedule, budget, and perhaps other areas of project objectives. Although it is usually performed by the scheduler, it requires input and review from all parties involved in the process.

Guidelines

Definitions—Participation in duration review is a collective effort by the project management team members for the purpose of determining and verifying the durations of the activities constituting the project schedule. This effort is managed by the project scheduler under the supervision of the project manager. The scheduler coordinates and finalizes this effort, with the final outcome to be approved by the project manager and project team members, and then adopted in the baseline schedule.

Purpose—Participation in duration review is important because activities that compose the project are to be performed by different teams often belonging to different entities. So the input from all team members and their approval of the final durations are essential for producing a baseline schedule that constitutes a reference for project monitoring and control during the execution of the project.

Default Condition—Unless otherwise agreed upon, it is usually the responsibility of the general contractor (GC) to prepare a schedule for the project that meets contractual requirements such as the project's completion date. The scheduler prepares the schedule using estimates derived from previous experience, input from the project management team, stakeholders, and third-party references. Thus, the GC will be responsible for the activities' durations in the schedule, as well as the schedule logic and other attributes that collectively lead to the establishment of a project's predicted completion date and other important interim milestones.

Best Practices

Ensuring participation in duration review should be the responsibility of the scheduler, who is responsible for preparing the project's schedule. Project team members are generally of two types: those who are under the authority and supervision of the general contractor (such as self-performing crews and subcontractors), and those who are not (such as the owner, construction manager, owner's representative, engineering leads, design consultant, and project management consultant). For more appropriate and reasonable schedules, the scheduler needs active participation from both groups. The scheduler creates the draft project schedule using tentative durations estimated as noted earlier, in Section 3.6.2, Estimating and Duration Verification. The scheduler then meets with stakeholders to discuss relevant activities and agree on reasonable durations. After the completion of these meetings with all team leaders, the scheduler updates the schedule with these durations and recalculates the project milestones, such as substantial or final completion.

There may be a need to adjust some durations or sequencing. The scheduler would then hold a meeting with team leaders for the relevant activities, discuss adjustments, and come up with final durations that are acceptable to all parties. Then the scheduler finalizes the schedule and sends copies to all team members to ensure agreement. Once the scheduler has the consent of all team members, and all quality control checks have been completed, it is submitted to the owner for approval. Once approved, the schedule officially becomes the baseline or as-planned schedule used for the purpose of monitoring and control.

Recommended Practice

The scheduler would conduct the duration review meetings and could incorporate use of a duration factor or duration constraint checklist. This list includes factors that may influence the durations of activities. These factors can be grouped under major categories such as weather, soil, work location/height, type of management (QA/QC program), equipment, labor skill, job site condition, and others. The group labeled "weather" could include temperature, humidity, precipitation, wind, lightning, and visibility (fog, smog, sand storms). This checklist could be used to help ensure that constraints that might affect durations are considered during the estimate and verification.

The adjustment and fine-tuning of activities durations in the schedule may take a few iterations and some negotiations between the scheduler and other team members in order to arrive at durations acceptable to all parties and to the contractual obligations. In some cases, the durations supplied by team members may be reasonable but will not result in a timely completion of the project. The scheduler then would review the areas where the draft schedule does not comply with contractual requirements and project needs, and adjust the schedule with input from team members by fast-tracking or compressing relevant activities. The draft will need team approval before finalization.

There are other important factors the scheduler must take into consideration:

- Every duration change will likely result in the change of the timing of other succeeding activities. There can be a domino effect any time an activity's duration is changed. The impact must be assessed, and relevant team leaders informed, prior to finalization of the schedule.
- When an activity is shifted in time, even if its own duration is not changed, it may have an impact on the work plan and budget. When such shifting is significant, it can change the conditions under which the activity is performed. For example, weather conditions may change, the rain season may start, or daylight hours may increase or decrease. This emphasizes the need for appropriate weather planning (see Section 2.6.5, Planning for Adverse Weather). Shifts may also affect the work plan of the team leader and the allocation of subcontractor resources.
- When the scheduler feels that the duration of an activity is unreasonably large or has a high level of uncertainty, it is recommended that such activity be broken down into several activities that allow more control and more certainty in determining their duration.
- When determining durations, the team should not be too optimistic or pessimistic. The chosen durations should reflect the best information available at the time of schedule development.

The objective is to produce a schedule that contains appropriate and realistic durations that are acceptable to all project team members and leads to a satisfactory fulfillment of contractual obligations. The scheduler should encourage the active participation of all team members in suggestions that not only allow the achievement of such objective, but also optimize the approach.

Advisories

The scheduler should avoid:

- Determining activity durations for work performed by other team members without consultation.
- Ignoring factors that may influence activity durations (the checklist mentioned above).
- Ignoring the cost impact of changing activity durations and/or timing.
- Failing to assess and take into consideration the domino effect of a change to activity durations on other activities.
- Failing to solicit input and feedback from team members and team leaders for suggestions to achieve the objective.
- Failing to communicate and document this process clearly and properly.

3.7 Sequencing and Logic

Guidelines

Definitions

The PMI *Practice Standard for Scheduling* – Second Edition (2011b) defines logical relationship as: "a dependency between two project activities, or between a project activity and a schedule milestone. The four possible types of logical relationships are: Finish-to-Start; Finish-to-Finish; Start-to-Start; and Start-to-Finish" (p. 122).

The AACE International, in *Recommended Practice No. 24R-03,* "Developing Activity Logic," defines relationships as:

> a recommended practice of AACE International, development of activity logic (also called network logic) in planning and scheduling provides guidelines for the sequencing of activities in a logical way generally before duration estimating can be performed. Logic is generally determined before durations are considered. Logic development methods include precedence diagramming, or arrow diagramming methods. Logic is the set of activities and dependency relationships between them. Logic dictates the planned sequencing of activities. A network diagram is often used to illustrate the logic. (AACE, 2004, p. 2)

The *PMBOK® Guide* – Fifth Edition defines activity sequencing as:

> The process of identifying and documenting dependencies among schedule activities. It is the process by which activities are linked to each other with discrete (Hard) and discretionary (Soft) ties. Those ties are known as relationships and are further defined as Start-Start (SS), Finish-Finish (FF), Start-Finish (SF), and Finish-Start (FS). This process is typically done prior to establishing durations for the activities but should be validated after durations are established and applied. (PMI, p. 153)

Purpose

The process of applying logical sequences to the various schedule activities is needed to define the sequence in which the various activities must be completed, and their relationships to other activities which must be completed within the project schedule.

These are all necessary preliminary steps in defining a schedule which will allow the project team to successfully accomplish the project deliverables. The logical sequences allow the chosen project tool to establish project completion time frames and the project critical path. The activity sequencing, along with the durations of activities, define the time periods for the earliest and latest dates that work can be accomplished.

Initially, sequencing is done to establish a logical order of progression for a list of previously unrelated activities. Only after durations are applied can a preliminary critical path method (CPM) be established. Re-sequencing may be required once durations are applied, typically to meet an imposed constraint.

Default Condition

The default condition for sequencing of activities is the utilization of a finish-to-start (FS) relationship between activities, with all activities having at least one predecessor and successor, except the first and last activities. There should be no other activities missing a predecessor or successor, commonly called open-ended activities, in the schedule.

In addition to FS relationships, activities may also be linked by utilizing start-to-start (SS), finish-to-finish (FF), and start-to-finish (SF) relationships.

In these situations the relationships define the conditions which control the successors' start or finish. Schedule logic and establishing the sequencing between project activities is a vital step in developing effective project schedules.

Best Practices

Activity sequencing defines the relationships that exist between the activities that must be performed within the project. To develop accurate activity logic, a thorough understanding of the project scope, as well as how the work is to be performed are required. By detailing out the work breakdown structure (WBS) and its relationship to its other elements, the activity logic and sequence can be established.

The sequence of activities should be defined such that the start of every activity has a logic relationship to a predecessor, and the completion of each activity has a logic relationship to a successor. The majority of all activities are logically defined using a finish-to-start relationship, unless work performance must occur in conjunction with another activity that is concurrent or overlapping.

FS, FF, SS, and even SF relationships each have their place in properly modeling the project execution being scheduled. While trying to use FS as much as possible for simplicity, realistically, overlaps will occur among activities, depending upon the level of detail in the schedule. This is particularly true for engineering and construction.

The strategy for selecting the best relationship to employ is based on which best represents the actual circumstances of the activities in play. If the start of an activity in general tends to follow the start of the predecessor, then SS should be used. Keeping in mind that the SS relationship generally schedules the successor to start immediately upon start of the predecessor, or after satisfying the lag value in the SS relationship, it is important to note that progress in the predecessor is not required for the successor to start.

If the completion of the successor is more likely defined by the completion of the predecessor, then FF should be used.

Careful review of status during the next update is then needed to determine the situation of the successor, given that the predecessor is underway.

Best practice is to use that relationship (FS, FF, or SS) which best represented the governing circumstances of how the activities are most likely to take place.

The SF relationship—though not recommended for frequent use—is best used when scheduling just in time activities, and a short delay may be required for administrative and other purposes.

All the relationships have an important role, including the use of negative lags under certain circumstances.

Recommended Practice

It is recommended that, once the scope has been drilled down to the lowest level of detail (the activity level), the sequence of work performance is then defined, resulting in relational logic which contains no open-ended activities (other than the start and completion of the project), and where the majority of the activities within the project network are logically tied with finish to start relationships when at all possible.

Prior to sequencing a list of activities, consensus should be reached with the project team, or the "experts" who will be responsible for implementing and managing the successful completion of the project.

"Expert knowledge" is very valuable in developing a schedule/tool that the project team will rely on and use.

AACE recommended practice for developing logic is:

> Development of activity logic is a pure planning step where relationships are established regardless of the dates on which activities fall. The next step in the planning and scheduling process is to consider other factors such as time, resources, and milestones to achieve project objectives. (AACE, 2012, p. 2)

Advisories

- Avoid creating artificial or incorrect activity relationships by developing initial activity sequencing independent of resource availability. In other words do not hook up activity logic when it makes no sense.
- All activities/milestones should be logically tied to a predecessor and successor to avoid open-ended activities, except the first and last.
- Avoid using relationship types other than finish-to-start, whenever possible.
- Avoid forcing all activities/tasks to start at one start point and finish at one point. There are quite often various stages or phases in a project which would require multiple starts and finishes.
- All sequencing and logic should represent the reality of the project and should not be driven by schedule dates, but rather by logic.
- Avoid clogging up the schedule with discretionary logic. At the time of sequencing, an activity may acquire more relationships than it will actually need to function properly in a CPM schedule. (Since we don't know what relationships are discrete and discretionary at the sequencing stage, we perform due diligence by including the most likely ones. It is recommended that we scrub the relationships that lose their relevance once the durations have been assigned. This simplifies the schedule.)

3.7.1 Relationship Types

Guidelines

Definitions

PMI's *Practice Standard for Scheduling* (2011b) defines four possible types of logical relationships:

Finish-to-Start (FS)—Logical relationship where the initiation of work of the successor activity is dependent upon the completion of the work of the predecessor activity.
Finish-to-Finish (FF)—Logical relationship where the completion of work of the successor activity is dependent upon completion of the predecessor activity.
Start-to-Start (SS)—Logical relationship where initiation of the work of the successor activity is dependent upon the initiation of the predecessor activity.
Start-to-Finish (SF)—Logical relationship where completion of the successor activity is dependent upon the initiation of the predecessor activity.

Purpose

The purpose of developing logic relationships is to establish the sequence of work performance, which when combined with the duration of the activities defines the time frame for the project and shows the ability to accomplish the project. It develops the plan for performing the work and the framework to monitor and track project progress and impacts.

Default Condition

The default relationship type should be FS, with a minimal usage of SS and FF relationship types, and a rare usage of the SF relationship type.

Best Practices

The preferred application of project logic development is the usage of FS relationships between activities, when at all possible, and the adherence to only allowing two open-ended activities: on the start and completion activities/milestones.

Recommended Practice

Though the preferred application of project logic development is the usage of FS relationships between activities, it is also recognized that this is not always a realistic option. The goal is to use FS relationships as much as possible and minimize use of the other relationships (SS, SF, and FF), within the constraints of the schedule design.

Advisories

- Minimize use of finish-to-finish and start-to-start relationship types.
- Rarely, if at all, utilize the start-to-finish relationship type.
- Be careful with the use of SS relationships because the predecessor is in control of all the SS successors. If the predecessor SS activity is actualized out of sequence, it will allow all other SS successors to start immediately, whether or not it is reasonable. Be careful to review the predecessors to any activity that will have SS successors to ensure that the relationships should not more appropriately be FS from the predecessor.
- See Section 3.7.3, Use of Lags, for more information.

3.7.2 Driving Relationships

Guidelines

Definitions

A driving relationship is one that controls the start or finish of a successor activity. Every activity must have at least one driving relationship. It also must be accurately reflected in the schedule at all times.

Purpose

Driving relationships control the start of the successor activities and are relevant in determining the critical path.

Default Condition

All activities, except the first, must have at least one driving relationship.

Advisories

Relationships that utilize SS or FF relationships or FS ties with negative lags may not result in effective driving relationships. (See Section 3.7.3, Use of Lags, for further information.)

3.7.3 Use of Lags

Guidelines

The term "lag" is most often used in construction scheduling but the term "lead" is also used. They are interchangeable. Below is a list of definitions from various construction documents and sources for both terms.

Definitions

Lag—Time that an activity follows, or is delayed from the start or finish of its predecessor(s); sometimes called an offset. A lag may have a negative value tied to the finish of a previous activity, reflecting a fast track approach. However, the use of negative lags when building baseline schedule models is poor technique and often prohibited by specification (AACE, 2004, p. 59).

Lead—Time that an activity precedes the start of its successor(s). Lead is the opposite of Lag (AACE, 2004, p. 59).

Purpose

Lags can represent a naturally occurring span of time that does not need to be monitored, is not generally a work activity, and is not generally tracked.

Default Condition

Lags/Leads can provide sequencing between activities that are not detailed enough to allow for the use of finish-to-start relationships.

Lags can be used for non-work time or mobilization time between activities.

Best Practices

Define activities, not lags/leads.

Apply lags/leads sparingly.

Each activity with a lag must contain another relationship that prevents it from resulting in an open-ended activity during updates.

Every lag/lead should be defined with a purpose and reported in a narrative.

Review lags/leads periodically to ensure usefulness, relevance, and that they are not creating float sequestering.

Recommended Practice

Use lags only when necessary to accurately schedule construction. Examples:

Laying pipeline—Excavate, then begin laying pipe a day or two later. The time between excavating and laying pipe could be to mobilize the pipe-laying crew, or to allow the ditches to dry sufficiently for pipe.

Concrete—Excavate for footer, but prior to the completion of footing excavation, start formwork. The lag would represent the amount of time that the excavation crew needed to advance ahead of the formwork crew, to allow the formwork crew to start work and progress efficiently.

Do not use a lag for something like cure time; use an activity instead.

Advisories

Lags should not be used when:

- The lag time needs to be monitored. (There is no good mechanism to monitor lags, as they are relatively invisible in schedules.)
- The lag represents a work activity that may not be 100% complete at update time. (Lags disappear when the starting condition is fulfilled.)
- The lag time is likely to be critical. (When the predecessor is actualized to the start of the lag, the successor ES time is not driven by the lag time after the data date.)
- The schedule needs to have sufficient detail to remove the need for lags.
- A lag should be used:
  - To drive completion dates of activities.
  - To sequester float for the benefit of one party.
  - To represent non-work time, which simply creates gaps in the network.

Negative lags can hamper risk analysis in some software. Negative lags may prevent the project team from being aware of the underlying "logic" being used to represent the activities, as it is counterintuitive. Negative lags, when used in preliminary schedules, carry a high risk of forcing the successor to start earlier than the predecessor during schedule duration adjustments.

Positive lags can allow the successor to be scheduled simply by the calendar rather than any amount of progress of the predecessor. Once the predecessor starts, an SS lag will automatically schedule start of the successor once the lag value is reached in calendar time, so the modeling will not provide the logic needed to force some amount of progress on the predecessor prior to starting the successor.

Some software packages allow lags using some percentage of completion of the predecessor, which is very useful and eliminates the risks of both negative and positive lags.

Lags/Leads will amplify or reduce the effects of delay when the path includes activities on multiple calendars. (See Section 3.8.1, Use of Calendars.)

3.7.4 Open-Ended Activities

Guidelines

The development of a project schedule requires defining the activities and their logical sequencing. Appropriate activity sequencing needs logical relationships between activities. The absence of open-ended activities, except project start and completion, determines the scope, logic network, start, and completion of the project.

Definitions

An open-ended activity is one without a predecessor, successor, or both, or an activity where the start or the completion of that activity is not tied into the network. In general, there shall not be any open-ended activities in any project schedule except the project start and project completion activities or milestones. Open-ended activities are usually caused by missing relationships between the activities, or insufficient relationships between activities that will become open ended during updates. Such is the case in relationships of the start-to-start, finish-to-finish, and finish-to-start types, with or without lags.

There are exceptions, such as the situation where an activity may require a start no earlier than date constraint (appropriately applied) that sufficiently starts a path for which there is no logical predecessor. This can occur when the scope of the activity may be owned by someone outside of the schedule author and is thereby included for informational and computational purposes only, such as for a vendor-provided material delivery date.

The Association for the Advancement of Cost Engineering (AACE International, 2004) definition in RP24R-03 states, "Before beginning schedule analysis the logic network diagram should have a single start node [milestone] or point, and a single finish point or node. Every activity between the overall start and finish must have both a start and a finish relationship" (p. 3).

Purpose

The absence of open-ended activities in a project schedule will establish integrity of activity sequence, logic network, and the workflow between start and completion of the project. Every activity must be linked to at least one predecessor and one successor activity, except for project start and completion milestones. The logical relationships between the activities and milestones are the basis for any legible project schedule. Further, they provide the base for proper planning, execution, monitoring, and communicating the delivery of the project scope to the stakeholders. Also, the purpose of not leaving the open-ended activities in a schedule is to prevent the CPM from calculating incorrectly.

Limiting open-ended to only the project start and project completion (with few exceptions), is to create reliability of all critical path method computations, to include early dates, late dates, total float and, as a result, path delineations, including the critical path. This provides the ability to more accurately calculate the critical path, as well as ensuring that the CPM network contains complete logic between all activities.

Default Condition

The CPM schedule should be a closed network of all activities that constitute the work, where the project start and finish should be, in most cases, the only milestones or activities without a predecessor and a successor.

Best Practices

The best practice for a project schedule is to link every activity with at least one predecessor and one successor activity, except the project start and completion milestones. This practice also eliminates any occurrence of dangling activities in the schedule, which breaks the flow of activity sequence and logic network from start to completion, and calculates false duration of the project.

Recommended Practice

The biggest problem with having open-ended and dangling activities in a project schedule is that they break the continuous flow of sequence of activities, or the project's logic network, and thus the duration of the project is wrongly calculated because the full scope of work is not included in the logic network. This also shows false interruptions in the closed network of the schedule between the start and completion milestones.

The number of activities with no predecessors should be one, or the project start, and the number of activities with no successors should be one, or the project completion milestone.

Many leave open-ended activities in a schedule, as they do not have any logical successors or scope within the project. The recommended practice to eliminate them is to tie them to a "dummy" finish milestone, and then tie the dummy finish milestones to project completion.

The practice explains to the team that they are aware of the open-ended activity.

Another good practice for checking and limiting open-ended and dangling activities in a project schedule is to verify the number of relationships under each activity. Every activity should have at least two relationships: at least one predecessor relationship which controls the start of the activity, and at least one successor relationship which controls the finish of that activity. However, the project start and the completion should not have a predecessor and successor relationship respectively.

Advisories

All the project schedules should be limited to *only* two open-ended activities and *no* dangling activities in between. In achieving this good practice in every baseline schedule and update, one has to implement the following advisories:

1. Any dangling activities should be reviewed and linked to at least one corresponding appropriate activity in the network logic.
2. Any dangling activities which are not within the scope of the project should be tied to a "dummy" finish milestone, and then the dummy finish milestones should be tied to project completion.
3. A thorough review is required on open-ended listings and errors/warnings of the schedule report before analyzing a schedule.

4. One should check the activity sequence and project's logic, while limiting the open-ended activities to two. This can be done with a careful review of relationships from milestone to milestone and/or between start and completion of the project.

Scheduling software does not necessitate a closing logic tie when employing start-to-start relationships, resulting in activities with start but no closing logic. If utilizing start-to-start relationships, be sure to identify closing logic for the predecessor activity when at all possible.

When start-to-start and finish-to-finish relationships are employed, the closing or balancing logic can be eliminated as the logic is revised in an update and the original driving relationship is satisfied. If utilizing start-to-start, finish-to-finish or finish-to-start relationships, be sure to identify closing logic for the activity when at all possible.

The use of lags can also create open-ended activities such that once the lag is fulfilled the relationship anchor dissolves, thereby creating an open end. Schedule conditions can and will change over time. As the schedule is progressed and relationships fulfilled, open ends can be created. Users need to understand and assess the conditions of the schedule as a normal course of schedule analysis.

3.7.5 Overlapping of Activities

Guidelines

Definitions

The presence of overlapping activities means there are concurrent scopes of work going on at the same time in a project schedule. There are two ways this occurs. The first is in a series or chain of activities that represent the scope of work that it takes to achieve a milestone or just some common activity, such as above-ceiling inspections which require the predecessors of installation of overhead electrical and low voltage wiring.

Overlapping scopes of work in this instance would mean that there are different scopes of work going on at the same time in the same location. These are likely to be small overlaps, such as a wall formwork activity of 10 days, while an activity for installing block-outs for openings takes two days and starts after five days of formwork has been installed. These activities have to be overlapped, but the logic still needs to be connected; the block-out installation is dependent on the wall formwork and needs to be done no later than the completion of that wall formwork. This type of overlapping is generally modeled with SS activities with a positive lag, or FS activities with a negative lag.

Overlapping also occurs where there are multiple paths of events, independent fragnets, that lead to a milestone. One of those fragnets will be on the critical path, but the others do not necessarily have to be—although one or more of them could. When there are multiple paths to a milestone, there will be overlapping scopes of work, or work going on at the same time but usually in different locations of the project.

In this instance, the independent fragnets are not as likely to need lags to schedule the work as is generally necessary in the first instance.

Purpose

The purpose of having overlapping activities is to avoid breaking the activities down into more detail such that the more detailed activity fragnet would include one activity that could be completed before the concurrent activity starts. So in the first example above, the wall formwork activity of 10 days' duration would be broken down into two activities of five days each. Then the first wall formwork activity could be tied with an FS relationship to the block-out installation activity.

Overlapping activities occur due to the degree of detail in the schedule and the logic relationships used along with the lags. If a schedule were built with enough detail to allow using only finish-to-start relationships, there would be no overlapping in any given fragnet of activities.

Best Practices

It is not wrong to have overlapping activities or overlapping scopes of work in a schedule. It just depends on the level of detail and the logic used in building the schedule to the parameters dictated by the schedule specifications and the agreement of the stakeholders.

There are those who believe that the only relationship to use is a finish-to-start for all activity logic. Building a schedule to those parameters precludes there ever being overlapping activities in any given chain.

However, if the schedule uses start-to-start or finish-to-finish relationships with lags, there will be an overlap of activities and scopes of work.

Recommended Practice

As noted earlier, it is best to minimize the use of lags, so limiting the use of overlapping activities is recommended. However, most schedules will require some use of overlapping activities due to the level of detail, and this is considered good practice. As noted, it depends on the schedule specifications requirements, as well as level of detail.

Advisories

If a schedule is built such that activities do overlap in any given chain of activities, make sure that the overlap makes sense. Most importantly, make sure there is enough physical space for two different scopes of work to occur at the same time, and that there are sufficient resources to perform the scheduled work.

Concurrent work should always be examined carefully to ensure there is no stacking of trade resources or spaces.

3.7.6 Critical Path

Guidelines

If the project schedule is well developed and meets the quality control requirements as outlined in this *Best Practice and Guidelines* volume, the network will be reasonable and appropriate, and there will be no inappropriately large float values. With this schedule and good schedule maintenance, as work is progressed and reported, the critical and near-critical paths will be reasonable and reflect the appropriate activities that need to be completed to keep the project on schedule. There will be early warning of work needs due to float dissipating on the non-critical path work activities such that they will move on to the near-critical path category, and then to the critical path category, as the work is not completed early. With this practice, monitoring of the critical and near-critical paths would be enough to ensure on-time completion.

However, if the network is not developed sufficiently to provide that early monitoring, or if the network is weakened during schedule updates, the critical and near-critical path analysis will need to be supported by non-critical path analysis of the activities that have sufficient float to prevent them from showing on the critical and near-critical path. (See Section 5.2, Routine Schedule Analysis.)

Definitions

The AACE International *Recommended Practice No. 10S-90,* "Cost Engineering Terminology" (2010), defines the critical path as:

> The longest continuous chain of activities (may be more than one path) which establishes the minimum overall project duration. A slippage or delay in completion of any activity by one time period will extend final completion correspondingly. The critical path by definition has no float. (p. 31)

The AACE International *Recommended Practice No. 10S-90,* "Cost Engineering Terminology" (2010), also defines the longest path as the:

> Longest continuous path of activities through a project, which controls project early completion. It is possible for otherwise defined critical path activities to not be on the longest path and longest path activities to not show calculated critical float. The longest path analysis is unaffected by activity calendars. The longest path is determined by the string of activities, relationships, and lags that push the project to its latest, early finish date. The longest path is calculated by first performing a CPM "forward pass" to determine driving relationships and the project's latest, early finish date. The activity (or activities) with the latest, early finish dates are then identified and all predecessor driving relationships traced back to the project start date. These activities constitute the project's longest path. The longest path depends upon relationships driving the timing of activity starts, thus use of constraints and resource leveling can interrupt

> and invalidate longest path analysis. Use of interruptible activities can also result in false longest path indications. For complete accuracy, longest path analysis should take place absent of constraints, resource leveling, and/or interruptible activities. (p. 63)

Critical path is the path that determines the duration of the project. It is generally the longest path through the project, yet other activities can become critical if imposed date constraints are used. A delay in any of the activities on the critical path will create a delay in the project end date.

The critical path drives the project completion based on interrelationships and durations of the schedule activities.

A good definition is that the critical path is the longest path of activities running through the schedule, affected by calendars, constraints, and activity logic such that a delay to any of the activities on the critical path will prolong contractual project milestones, such as project completion.

So the critical path and the longest path may contain different activities due to the software components, and each must be analyzed separately if they are different.

Purpose

The critical path identifies the sequence of activities that must be accomplished on time to meet project deliverables. It is a tool or mechanism for the project team to use to prioritize the work and resources necessary to accomplish deliverables and achieve successful project completion. The critical path can also be utilized to identify potential delays in meeting project deliverables, and as a tool to identify alternative paths for project recovery from delays. Use of the critical path in analysis also allows any time saved on the critical and/or near-critical paths to be captured as project float, providing some contingency to the project.

Default Condition

The default condition requires a schedule that reflects the full project scope through activity definition, established in a logical sequence and utilizing productivity based duration estimates, that results in no open-ended activities other than the beginning and end of the project. This includes no hidden open ends resulting from SS, FF, and FS lagged relationships leaving the successor completion in limbo. It also incorporates resource availability in the durations and relationships, as well as other project constraints.

Best Practices

Using the project critical path provides a valuable project planning and management tool for: (a) time management, (b) monitoring on-going progress of activities that can delay a project, and (c) providing project information for early problem detection and decision making.

The best practices for utilizing the critical path to assure project success and address any project delays, are:

- Validation through the planning process of the:
  - Inclusion in the schedule of the full scope of work (see Section 3.4.1, Work Breakdown Structure);
  - Identification of all activities requiring time and resources to meet deliverables;
  - Reasonable and appropriate logical sequencing of these activities, taking into account available and concurrent resource needs. With all activities (other than the start and completion) containing appropriate logical relationships, there should be no open-ended activities.
  - Estimated activity durations are based on productivity that represents the available resources, as well as concurrent resource needs.
  - Schedule is calculated using both forward and backward passes, to identify the sequence of activities that cannot be delayed without impacting the project end date and the critical path (Note: There may be multiple critical paths.); and
  - Review and concurrence of critical path activities with the project team.
- Continuous review and monitoring of critical and near-critical path needs, to be performed on an established periodicity (usually the status period), since as activities are initiated, completed, or delayed the critical path can change.
- Monitoring of non-critical path work to ensure that missing logic will not allow stacking of work that does not appear on the critical or near-critical path early enough.

- Constant monitoring of predictions of achievement of milestone completions. If slippage to project or contract commitments occurs, the scheduler should work with the project team to identify potential recovery and efficiencies that can be implemented.
- Project critical path reporting mechanisms need to be clearly defined, understood, and consistent.

To establish a meaningful critical path, it is necessary to develop logical and well-defined activity relationships with empirically derived durations for executing all project activity in a practical manner. There must not be any open ends other than the project start and end. Constraints must be minimized and restricted to only those that represent external or internal events which cannot be effectively addressed with activity logic, and calendar changes as well as lags with relationships should be minimized.

Recommended Practice

It is recommended that the project controls personnel create the model of the activities and relationships, perform the analysis of the model to determine what is critical, and work with the project stakeholders and other key participants to attain agreement on what the model shows (to check the reasonableness of the model).

When a periodic update of project status is performed, the project controls personnel should look into the impacts from the as-built condition of the schedule, analyze the as-planned condition of the schedule, perform the trending and completion prediction analysis, and determine what has changed on the critical path and notify the appropriate project personnel. Tasks which fall on the critical path should receive attention by both the project manager and the personnel assigned to them, to prevent delaying the project.

Where there are internal project commitments that must also be monitored, the critical path to each milestone must be monitored during each update cycle as well.

Advisories

The critical path is one of the primary tools of project scheduling for planning and monitoring the accomplishment of project commitments. As such, the following advisories identify potential pitfalls in using the critical path most efficiently:

- Always define the use of the term critical path so everyone understands the meaning.
- Minimize the use of constraints and apply only where true ones exist.
- Minimize the use of multiple milestones; however, when utilized, monitor the critical path for each milestone for slippage.
- Too few relationships in the network logic could mean that the schedule is probably underdeveloped or missing logic.
- Too many relationships in the network logic could also mean that the schedule is more than likely over-developed or may include heavy resource linkage, or an attempt to sequester float by inappropriate relationships.
- The only activity that should have no predecessor is the project start milestone. Likewise, the only activity to have no successor is the project completion milestone.

3.8 Calendars

Calendars provide information on working and non-working days in a project. It is momentous to identify during planning for schedule development how many calendars we will have for a project and why. Each project has a global and at least one base calendar. A global calendar usually specifies non-work periods, exceptions, and holidays for the entire project, along with the project's resources, and provides information about when these resources are assigned on a timeline and when they are idle.

While defining the calendars, there are some areas we should remember to explore. For example, all engineering activities in a project are usually carried out at the home office (HO) or head office of a company, so the calendar defined for such activities should incorporate working days accordingly. Similarly, if a procurement team is also stationed in HO it will have the same calendar. However, activities like delivery of material (long lead items) usually require another type of calendar with a seven-day work week. For construction, it is important to identify and mark all holidays declared by the government of the country where the project is being undertaken. This does not need to be an exhaustive description, but the idea is to call attention to and explore each phase of a project while defining a calendar. In some cases, the contract also specifies working days for each phase; hence, that information is also to be considered while identifying and defining. Explanation about usage and types of calendars will be provided in the next topic sections.

3.8.1 Use of Calendars
3.8.2 Planning Unit
3.8.3 Global Calendar
3.8.4 Workweek Calendars
3.8.5 Weather Calendars
3.8.6 Holiday Calendars
3.8.7 Resource Calendars

3.8.1 Use of Calendars

Guidelines

Project schedules require calendars as part of the project management process. This is defined in Section 6 of the *PMBOK® Guide* – Fifth Edition, "Project Time Management." While there is agreement regarding the need for calendars, it can be challenging to determine the appropriate use of calendars for the project schedule. A number of factors impact the need for calendar use, and these will be discussed in this section.

Definitions

The simplest definition for a calendar would be any of various systems of reckoning time in which the beginning, length, and divisions of a year are defined. The Glossary in the *PMBOK® Guide* – Fifth Edition defines a project calendar as: "A calendar that identifies working days and shifts available for scheduled activities" (p. 553).

How many calendars and what type of calendars is determined by the amount of clarity regarding predicted events is needed by those who will be using the schedule. If a schedule is a preliminary or summary level schedule, then the use of calendars will be limited to describing generic historical events such as holidays or weekends. If the schedule is a baseline schedule, then it will contain multiple calendars, each describing events that will affect the associated work for an activity. When using calendars correctly, historical events and phenomenon can be predicted and accounted for in the schedule to avoid project delay. Formal planning of the project before initiation is needed to assess the appropriate calendars and their use. Development of the project calendars for a new project is discussed in Section 6 of the *PMBOK® Guide* – Fifth Edition.

Purpose

The purpose of using calendars is to disseminate easily understandable events and phenomenon to the project team. This will then make it easy for persons involved in a project to understand when delays and accelerations will occur and why. Calendars are intended to adequately illustrate and document these events and indicate how they impact associated work. Complex problems and systems may, and usually do, require more calendar detail than simple ones. Projects with a large contingent of human resources or subcontractors will require more calendars and calendar detail than projects with few resources.

The use of calendars is also dependent on what the output from the schedule needs to be, both in data and in accuracy of data. The use of calendars depends on the information needed at that stage in the project life cycle. For example, if the project is located in a hurricane-prone area, weather delays may be incorporated into the calendars associated with outdoor work. These delays might be estimated from historical data through various organizations such as the National Oceanic and Atmospheric Administration. On the other hand, if it is an interior office remodel of a government facility then a calendar representing weekends and government holidays would suffice for all work on the project. This would require fewer calendars and less detail in each calendar than a large project would.

Calendars are also dependent on the planning unit need. If resources need to be monitored on a daily/hourly/minute basis, there must be calendars associated and dedicated to a particular resource so that out-of-sequence activity work will not artificially distort resource reporting. This is especially true if resources are shared in order to perform out-of-sequence activities, which is a fairly common problem.

Default Condition

The amount and type of calendars needed is decided based on a number of factors:

- Geographical area of the project;
- Uniqueness, size, and complexity of the project;
- Risks inherent in the project;
- Expertise and availability of project controls staff;
- Knowledge and expertise of project management staff;
- Management need of visibility on the project;
- Stakeholder needs; and
- Number of contractors and interface points.

The amount of detail available for a calendar in a project schedule depends on the completeness of project scope definition. Very early in a project, when scope is still being defined, it is only possible to produce basic calendars as the activities they are associated with are not clearly defined. As the scope is defined more completely, it is possible to increase the amount and type of calendars. This does not mean that the amount of calendars must be increased, just that they can be increased and further detailed as more information becomes available. Likewise, in a large, multi-year project, it may only be possible to define generic calendars that encompass event basics (possibly holidays and weekends). As the timeline of the project progresses, calendars may be added or updated according to lessons learned on that particular project. Nevertheless, there should be a plan very early in the project planning phase concerning the intended use of calendars in the schedule and the ultimate planning requirements. This will greatly influence the amount of detail needed for later project calendars.

Best Practices

The type and amount of calendars in a schedule should be determined during the schedule design, well before activities are created during schedule development. This is one of the decisions that has to be made based on a number of factors, such as geographical position, who will manage the schedule and calendars, who will read the schedule and calendars, type of work, and what the purpose of the calendars are as they pertain to the scheduled work.

One rule of thumb used in planning is that no calendar can be used in the schedule without historical proof of events and/or specific approval. There will be exceptions for certain types of calendars, such as weather calendars that use historical data to make a best guess at events but can never be 100% accurate. This will force more thought by the project team members regarding the logic and detail required to get the calendars as accurate as possible and communicated for action and controls.

Alternatively, another rule of thumb states that calendars may be used for excusable delay. By incorporating delay into a calendar, the party being delayed is no longer showing slow performance, as the actual duration of the work is not increased due to non-work periods.

Use of calendars is also very dependent on whether the work to be scheduled is going to be performed by the contractor building the schedule. The schedule owner is going to be more inclined to include calendar detail that pertains to his or her own agenda, as communication is not always perfect in a project. This concept of awareness could potentially hinder parties that are not concerned with every detail of the project plan, including the calendars in the schedule pertaining to their own work.

If most work is similar on the project, there is less need for a variation in calendars and more need for a less detailed calendar system. Still, if the schedule is to be a management tool, used by the staff on-site, the calendars need sufficient detail in naming, activity association, and event description. If the schedule is more of an overview with little detail, then one generic calendar is probably acceptable.

Another recommendation is that tasks that are interrupted should be evaluated for delay causal as using calendars is not always the best way to define a non-work period. One mistake that is sometimes made is to define an absolute requirement in a schedule specification whereby a limit is placed on calendar detail based on the amount of calendars or association with certain scope. When used as an initial guide, this is acceptable. However, when it is made an absolute requirement, contractors are forced to use other methods to display events that may not make sense. One common example is placing activities into the schedule to represent delay which are not associated with a particular task but are affecting various portions of different project scopes. These activities clutter the schedule with varying degrees of durations and attributes, when the event could have been recorded in the appropriate calendars and not affected the schedule network logic at all.

Recommended Practice

A resource calendar needs to be developed and documented so that project team members are using a consistent set of guidelines. A resource calendar is defined in the Glossary of the *PMBOK® Guide* – Fifth Edition as: "A calendar that identifies the working days and shifts on which a specific resource is available" (p. 558).

The calendars required for an effective schedule will vary from project to project. However, there are certain considerations that should enter into the decision regarding the calendars to be used. The major considerations include size of project, complexity, duration, and associated risk. Fewer and less detailed calendars are required for small projects, simple projects, short duration projects, and low-risk projects. As any of these variables increase, the need for more numerous and more complex calendars arises. The combination of a long duration, complex, risky, and large project will certainly require the greatest amount of calendars and greatest calendar complexity. This discussion assumes that the level of calendar detail and number of calendars used is to be determined by the scheduler in concert with users. However, these recommendations can be overruled by owner direction. If calendars are only required to detail basic events, and/or the schedule is not considered a management tool and is treated as an idea of the project, then basic calendars may be adequate.

One obvious rule of thumb is that the calendar usage cannot be so large and complex that it takes all of the scheduling staff's time to maintain all the calendars with no time left for managing the schedule itself. Calendar usage is too heavy when nearly all of the scheduling staff's efforts are directed at detailing calendars with little regard for the schedule logic.

An important question is, "Who is responsible for setting the calendar specifications of a project schedule?" The client ultimately specifies the required calendars that will define events not related to the project itself. However, the contractor may need a greater level of detail in the calendars in order to manage daily activities. The project scheduler, or possibly project controls manager, needs to provide some guidance concerning the calendar development or an unusable calendar may result. Leaving out critical events for all organizations may result in an erroneous critical path. This must be balanced against the danger of too much detail in the calendars, since that means more time and resources required in the development of the initial schedule and maintenance of it throughout the life of the project. Unfortunately, not all users understand scheduling or the use of calendars, so their requirements may not be appropriate. A good suggestion is to have a "meeting of the minds" between the users and a scheduling "consultant" who can make useful recommendations. The project scheduler should facilitate (but also guide) the schedule development process. At the end of the day, it has to be the project team's schedule and they should own it. The project scheduler should not come up with a schedule using different calendars independently without consultation with the project team. This is all the more reason why a schedule management plan is necessary so that it is a collaborative environment.

This reinforces the importance of the first and major step being that of schedule design, and all the reasons for the calendars being discussed then. This includes explaining the benefits of more varied and highly detailed calendars, as well as the accompanying disadvantages, and a similar approach for the use of more basic calendars. This decision has to be made and agreed upon by the schedule development team before the first activity is drawn in the network or the first computer is engaged.

At the end of the day, the project scheduler is primarily a facilitator, formatting the team's plan into a cohesive, organized document. Schedulers prepare the project schedule for the project team's use, not their own. This suggests that the scheduler must provide what the client (team) wants, even if the scheduler thinks she/he knows better.

Advisories

The *PMBOK® Guide* – Fifth Edition indicates that calendars from a previous project may serve as a useful template for creating new project calendars and are major inputs to the activity duration estimating and schedule development processes. This has the advantage of saving time by using a calendar that was previously "debugged." The caution regarding this is that project calendars should not be boiler plates. Each project has unique requirements, risks, and interfaces that must be addressed on a project-specific basis. While a template can be a great timesaving option for the initial creation of a new schedule and calendars, it should not stand as is without being adjusted for the current project's specific scope and event requirements.

Never require more detail than is requested or needed. Excessive detail in the use of calendars causes friction with the users and can render the schedule useless if the user cannot manage and understand it.

On the other hand, too little detail may result in an erroneous schedule. Specifically, elimination of essential calendars or events from calendars can easily result in an erroneous critical path. The concern is that the problems with having weak calendars typically do not show up until either the project starts slipping and the schedule is of little help or the project encounters a claims situation.

If a calendar is to be used for resource planning, then compounded calendars should be avoided. For example, the schedule may have a single calendar incorporating mechanical, electrical, and plumbing events. This is often done for expediency, or to keep the schedule simple. The problem is that these are three separate trades, and typically represented by at least two but more often three separate subcontractors. Each should have their own separate calendars, or resource planning will be confused.

It is useful to insist on having separate calendars for each resource, as well as for every point in the project where there is a change in responsibility. When multiple calendars are combined in a single calendar, it is difficult or impossible to establish who or what is responsible for the event delaying the schedule. Likewise, if any events are missing, such as non-work periods during the winter for installing asphalt, it is possible that the critical path is inaccurate.

Avoid duplications and redundant entries. During initial creation of a schedule, it may appear that the calendars or events might have similar descriptions. Each calendar should be evaluated independently on its own merit of event duration/value/relevance. If calendars are in an exact and identical pattern for sequenced events, field values or relationships can vary slightly to produce different scheduling results. If calendar structure is modified for any reason, the true events assigned to each calendar must reflect what is anticipated or expected to occur for that specific activity in the field. This is another way of saying that boilerplate schedules and calendars must not be used.

3.8.2 Planning Unit—Hour/Day/Week

Guidelines

Definitions

The planning unit is the measuring gauge for duration, and it can be hours, days, weeks, or months. Activity durations, floats, lags, etc. are expressed in these planning units.

Purpose

The purpose of defining a planning unit is to have a basis for estimating project activities duration, their float, and lags between each activity. It also contributes to defining how detailed the schedule will be. For example, if a planning unit is measured in hours, it means having a detailed schedule on an hourly basis. On the contrary, if the planning unit is months, then it is assumed to be a higher-level schedule.

Default Condition

While planning for schedule development, the project controls team has to decide in line with feedback and requirements from all stakeholders on what the planning unit of the project should be. There can be a case when two planning units are also required. The client usually requests the main schedule to be on a daily basis and also requires having a summarized monthly schedule for higher management. Hence, all these cases are to be identified earlier in the development of a schedule.

Best Practices

"Estimate Activity Durations," Section 6.5 in the *PMBOK® Guide* – Fifth Edition, requires identifying a planning unit to enable the estimating process to begin. It is pertinent in planning for schedule development to define what the project planning unit will be. Also, in some software (e.g., Primavera), it is mandatory to define the planning unit as one of the first steps in the development of a schedule, even before defining activities. To define this, it is recommended to get feedback from major stakeholders of the project (e.g., the client, senior management of the company, the end user, etc.) as to what level they expect the plan to be and on what basis they expect project duration to be measured. This is significant, since information like total and free float will also be based on the same planning unit. Hence, it also contributes to attributes of critical path.

Commonly used planning units are hours, days, weeks, and months. Hours are mostly used in maintenance projects, which include shutdowns, turnarounds, balancing, modernization, and revamp (BMR) of process plants. In such short-duration projects, usually from 14 days to two months, it is required to monitor progress on an hourly basis. Hence, all planning activities (activity duration, lags, leads, floats, etc.) are calculated in hours.

The "day" planning unit is mostly used in long duration projects (e.g., construction of fertilizer plants), which may last from two to three years. In the same projects a separate higher level schedule is also sometimes required by the client. Such higher level schedules require monitoring on a monthly or bi-monthly basis and include planning units of "weeks" or even "months." So it varies from project to project and client to client. But what is important is to set the requirements as early as possible to allow all other processes of schedule development to go smoothly.

Recommended Practice

Identifying the planning unit(s) earlier in the project is strongly recommended by getting feedback from all key members. Communicate updates to all key members once they are finalized. The planning team can proceed with development of the schedule as soon as the unit is decided. Keeping the client in the loop will eliminate any rework and facilitate both parties.

Advisories

The only advisory is to make sure that the planning units are defined and agreed upon by all team members prior to schedule development. If a need arises to change the planning units, for example, from days to hours, for some detailed scope of work then a separate schedule can be developed to track that work rather than change the planning unit of the whole schedule. Hence, the planner has to repeat the work just because requirements were not identified earlier.

3.8.3 Global Calendar

Guidelines

Definitions

Scheduling software providers typically include a "global calendar" in their software package as a default calendar. The global calendar is then used as a template to create the project calendar or any other calendars that may be used by the project during its life cycle. The global calendar is used to create the workweek calendar (typically either a five-day or six-day per week calendar). The global calendar typically already reflects a five-day workweek with no holidays or non-work periods defined.

Purpose

The purpose of a global calendar was as the template used when creating all calendars within the project schedule. However, as scheduling software has evolved in recent years, global calendars are now being used by all when creating schedules.

Default Condition

The global calendar is a standard calendar that might show all days indicated as workdays. This includes all weekends and holidays. All other calendars, including the workweek and calendar day calendars, can be created from this calendar where non-workdays can be added.

Best Practices

Create project-specific calendars based upon the software's global calendars, using a global calendar when it can be set as a standard for a single location and organization (i.e., design office).

Recommended Practice

It is recommended that all days be considered as workdays in the global calendar. Once the global calendar has been cleared of all non-workdays, then the workweek and other project specific calendars can be created.

Advisories

Some software packages default to a global calendar, which allows all projects to access it unless specified otherwise. This may impact the calculations on totally different schedules, allowing any calendars created within the schedule databases to carry those non-workdays, causing an adverse impact to the schedule date calculations.

3.8.4 Workweek Calendars

Guidelines

Definitions

A workweek calendar defines for an organizations' resources:

- The working days per week;
- The working hours per day; and
- Could include start and finish times that an organizations' resources work.

An organizations' resources could be represented by crews, teams, equipment, contractors or people.

Purpose

The purpose of a workweek calendar is for an organization to:

- Plan their resources' work;
- Calculate the durations of activities based on crew sizing and an estimate of the amount of work required to complete the work;
- Evaluate the resource demand and compare the demand to the resource availability;
- Optimize resource demand to the available resources; and
- Inform resources of when they are required to work.

Default Condition

A default workweek calendar would typically be 5 days per week and 8 hours per day.

Some projects require calendars of 10 or 12 hours per day and 4, 5, or 6 days per week.

Workdays would be made into non-work to represent public/religious holidays and annual holidays/leave or other non-workdays.

Non-workdays could be made into workdays to represent when work is planned over weeks for overtime or other weekend work such as maintenance.

Best Practices

Ensure that all calendars are designed, agreed to, and approved by the project management team before the schedule is built.

Ensure all contractors who are creating schedules that are to be integrated into the master schedule are aware of the project calendars.

Recommended Practice

Hours Per Day

There are several work periods per day to consider when creating calendars and each project has different drivers and reporting requirements.

Estimating software usually handles unproductive time while scheduling software usually does not. Consider the following parameters when deciding what number of hours per day to plan with:

- Actual work hours per day. This is how many productive hours per day a resource works.
- Available work hours per day. This is how many hours a resource may work.
- Paid work hours per day. This is the number of hours that a person is paid. There may be travel time to the work place; this is often incurred in mine site and high security locations.

Unproductive time may be considered as either:

- Available work hours per day less actual work hours per day; or
- Paid work hours per day less actual work hours per day.

Therefore consider the reporting and management requirements before setting up calendars.

Calculation of the Duration of a Day

Most scheduling software converts the working hours per day into days by a single factor and these packages do not handle calendars easily with different hours per day. Therefore it is recommended to set up all calendars with the same number of hours per day for planning purposes, even if the resources do not work the same number of hours per day. For example, a crew that works 10 hours from Monday to Thursday, 8 hours on Friday, and 6 hours on Saturday may be better planned using 9 hours per day 6 days per week, giving the same number of hours per week.

Multiple Calendars with Different Non-Workdays

Calendars may have different non-workdays. For example:

- The office calendar may be 5 days per week including all holidays; and
- The site calendar may be 7 days per week with 4 weeks working and one non-workweek.

In this situation a critical path of zero days float may disappear or the total float value may change when an activity on one calendar follows an activity on another calendar.

Some software packages have functions available to handle these situations and the scheduler must be aware of this issue and the functions available in the software he or she is using to handle the display of the critical path.

Calendars with Different Hours per Day

The office calendar may be 8 hours per day, for example from, 08:00 hours to 16:00 hours. The site calendar may be 10 hours per day, for example from 07:00 hours to 17:00 hours. When a site activity follows an office activity, the site activity will have one hour schedule on the same day as the office activity and 9 hours scheduled on the last day of the site activity. Thus a 5-day site activity will span 6 days.

There are several techniques available to manage this issue:

- Use a software package that has a start on a new day function, or
- Ensure all calendars finish at the same time. For example, make the office calendar work from 09:00 hours to 17:00 hours, or from 08:00 hours to 17:00 hours with a one-hour lunch break.

Advisories

Do not change the calendars halfway through the project, as it may make considerable difference to your program.

3.8.5 Weather Calendars

Guidelines

A significant number of construction projects contain activities whose progress will be affected by adverse weather conditions. Weather calendars should be created and applied to the appropriate activities in an attempt to predict weather conditions and their effect on project completion.

Definitions

A weather calendar is a project-specific calendar within the scheduling software created to reflect the influence of anticipated weather during the project on weather sensitive activities in the CPM schedule.

Purpose

This recommended practice (RP) is intended to provide a guideline, not to establish a standard for creating and applying weather calendars for project activities whose durations are anticipated to be affected by typical weather events in the geographical location of the project.

This RP is written and intended primarily for use on construction projects by the project team members and stakeholders involved in the planning and scheduling of the project work activities, and it will assist them in anticipating the number of days each month during the life of the project that will be affected by weather events.

This RP guideline may be applicable to many different types of projects, but it is primarily concerned with projects where activities are subjected to adverse weather conditions.

Weather calendars add value to the project baseline schedule, which serves as the time management tool to guide the project team toward successful project completion.

Default Condition

Weather calendars should be used when weather conditions in and around the jobsite will affect the productivity of the activity or restrict its progress. A typical example would be the effect of rain on earthmoving activities. If a particular location has historically experienced three days of rain in the month of March, the weather calendar should be created with three days blocked out for the anticipated bad weather.

Best Practices

The calendar is generally created with the standard work calendar as its base, with days removed each month in anticipation of weather events. These can be rain days, wind days, or any other weather event that would curtail operations of activities affected by the event. The number of weather events for each month should be established using a reliable source such as the National Oceanic and Atmospheric Administration (NOAA) in the United States, using an average over the last five years.

Recommended Practice

Weather calendars should be created and applied to weather sensitive activities in an attempt to reasonably predict the restriction of the planned progress of those activities during those event days.

Advisories

Constraints—This RP discourages the use of activity constraints to simulate weather events. Constraints cannot handle shifts in network times due to changes in the project's plan.

Use of multiple calendars—This RP highly discourages the use of an excessive number of calendars on any given project.

Rain days and recovery days—This RP encourages including recovery days for rain events on projects with soil conditions that require drying time prior to the continuation of work.

3.8.6 Holiday Calendars

Guidelines

Construction projects contain activities whose progress will be directly affected by the observance of holidays. Holiday calendars should be created and applied to the appropriate activities to quantify the effect of holidays on project completion.

Definitions

A holiday calendar is a project-specific calendar within the scheduling software created to reflect the influence of anticipated holidays during the project on the execution of activities in the CPM schedule.

Purpose

This recommended practice is intended to provide a guideline, not to establish a standard for creating and applying holiday calendars for project activities whose durations are anticipated to be affected by holidays specific to the project.

This RP is written and intended primarily for use on construction projects by the project team members and stakeholders involved in the planning and scheduling of the project work activities and will assist them in anticipating the number of days during the life of the project that will be affected by holidays.

Holiday calendars add value to the project baseline schedule, which serves as the time management tool to guide the project team toward successful project completion.

Default Condition

Holiday calendars should be used when work on the project is suspended due to the observance of a recognized holiday. A typical example would be the suspension of work on a project in the United States on July 4th in observance of Independence Day.

Best Practices

Holiday calendars are generally created with the standard work calendar as their base, with days designated as "non-work" for recognized holidays. Holiday calendars are widely recognized by clients and owners, and in most cases listed in the specifications or general conditions of the contract. When recognized holidays fall on the weekends, the clients and owners generally specify alternate days to observe them.

Recommended Practice

Holiday calendars should be created and applied to all activities requiring resources to be expended during that time period.

Advisories

Constraints—This RP discourages the use of activity constraints to account for recognized holidays. Constraints cannot handle shifts in network times due to changes in the project's plan.

Calendar day activities—This RP recognizes that a number of activities are based on calendar days and holidays should not be interjected into calendar day calendars.

Use of multiple calendars—This RP highly discourages the use of an excessive number of calendars on any given project.

3.8.7 Resource Calendars

Guidelines

Utilize resource calendars to ensure that scheduling tool calculations consider the availability and non-availability of resources in the project throughout its duration.

Definitions

Resource calendar is a calendar of working days and non-working days that determines those dates on which each specific resource is idle or can be active. It typically defines resource-specific holidays and resource availability periods (PMI, 2011b).

Purpose

The purpose of having a resource calendar is to allow for the correct calculation of task durations and allocation of work by the scheduling software by providing it with the particular dates, recurring days, and load availability any particular resource is able (and not able) to do work. The main uses of resource calendars are to show periods of unavailability, for example, holiday/leave periods, part-time work (ie. 3 days/week), beginning of work (i.e. zero availability until day of start), ending of work (ie. zero availability after resource leaves the project) and below full-time load capacity/availability.

Default Condition

If there is no resource calendar, the software will assume that the resource is available to do work full time with 100% availability for the duration of the project, as per default number of hours/day defined in the base or project calendar.

Best Practices

Resource calendars are properly defined for both known resources as well as generic resources. For resources that do not work for the project, i.e. external or third-party teams, utilize the same resource calendars they use for their own companies. In this way, when you copy/import their tasks from their external schedules, the resulting start and finish dates are the same as calculated in the schedule.

Recommended Practice

Resource calendars are properly defined for all known resources. The calendars are routinely updated in synch with updates to project team calendars, human resource leave, and training calendars.

Advisories

Make sure to keep resource calendars in synch with the formal HR processes that cover the resource sick leave, holiday leave, and training calendar.

Do not include public holidays in the resource calendars as these dates should be part of the project calendar.

An alternative to using resource calendars is to use the Max % Units when assigning resources to tasks, i.e. specifying a resource is 50% across the duration of the task is the same as creating a resource calendar where the resource works only half of the day for the same period. Be careful when using both techniques together. It is best to use one or the other.

If using an Enterprise Project Management (EPM) tool, create, maintain, and use only the resource calendar in the EPM tool. Do not define/use local resource calendars where there is a definition already available in the EPM tool.

3.9 Constraints

A feature used in the development of project schedules is the constraint. Basically, a constraint in a schedule is a restriction on the activity that affects its timing, regardless of schedule logic. This section will provide some guidance in the following categories:

- 3.9.1 Use of Constraints
- 3.9.2 Mandatory Constraints
- 3.9.3 Early Constraints
- 3.9.4 Late Constraints
- 3.9.5 Other Constraints

3.9.1 Use of Constraints

Guidelines

Definitions

Constraint: A restriction imposed on the start or finish dates of an activity that modifies or overrides the activity's logic relationships. Constrained dates are sometimes referred to as "imposed" dates.

Mandatory Start: A restriction imposed on the start date of an activity that modifies or overrides the activity's logic relationships and sets the early start date equal to a specified date, generally making it a zero float event thereby forcing it onto the critical path, no matter what the rest of the network calculations determine—also called a "Must Start On" or MSO.

Mandatory Finish: A restriction imposed on the finish date of an activity that modifies or overrides the activity's logic relationships and sets the early finish date equal to a specified date, generally making it a zero float event thereby forcing it onto the critical path, no matter what the rest of the network calculations determine—also called a "Must Finish On" or MFO.

Early Start Constraint: A restriction imposed on an activity or task that limits the earliest time that it can start. This type of constraint does not allow the schedule to show a planned start date earlier than the constraint, no matter what the network calculations determine. The planned early date of the constrained activity will show the constraint date, even if the activity could, by logic, start earlier than the constraint. Also called a "Start No Earlier Than" or SNET.

Early Finish Constraint: A restriction imposed on an activity or task that limits the latest time that it can finish. This type of constraint does not allow the schedule to show a planned early finish date earlier than the constraint, no matter what the network calculations determine. Also called a "Finish No Earlier Than" or FNET.

Late Start Constraint: A restriction imposed on the late start date of an activity that modifies or overrides the activity's logic relationships and does not allow the constrained activity to show a planned late start date any later than the constraint date—also called a "Start No Later Than" or SNLT.

Late Finish Constraint: A restriction imposed on the finish date of an activity that modifies or overrides the activity's logic relationships so that the activity will have negative float if the calculated date is past the constrained date. Also called a "Finish No Later Than" or FNLT.

Purpose

The primary purpose of a constraint is to lock down a known date within a schedule that can start or finish at no other time. An example of this would be the start of a shutdown, the kickoff of a project, or a contractual milestone such as "project completion."

Default Condition

Preferably, a project should only have two constraints within the schedule: the project start and project finish dates. All other activities should be driven by logic. The use of constraints in a schedule alters intent and logic unless specifically outlined by narrative as to the nature and intent of the constraint.

Best Practices

The best practice regarding the use of constraints is to keep the number of constraints in a schedule to a minimum, using normal predecessor and successor logic links and lags for each activity, avoiding open ends. The scheduler must also be familiar with the software used to prepare the schedule, as not all software packages treat constraints in the same manner, nor do they use the same nomenclature.

Recommended Practice

It is difficult not to use some constraints in a schedule, so use them sparingly and correctly. Limit the number of constraints used within a schedule, only using constraints on dates that drive the success of the project. This will allow one to see the negative float faster and take corrective actions early.

Constraints are generally necessary to represent logic external to the project. Contractual dates represented by milestones are a good example of this kind of external logic, as are delivery dates which may also represent contractual agreements. One may find it helpful to place constraints only on milestones and use each milestone to describe the external relationship represented.

Constraints should only be used (and must be used) where the "real world" interferes with schedule logic and you cannot achieve the preferred dates through relationships and durations.

During the development of the schedule, identify the constraints used, make a copy of the schedule, and then run it without constraints to see how the constraints affect the schedule. Constraints should be used as a monitoring tool, not a scheduling tool to benchmark critical milestones within the project. Minimize the use of constraints and let logic drive the schedule, which is the basic premise of CPM scheduling.

Advisories

Constraints vary from software package to software package, so the scheduler must be aware of all the features within the scheduling software packages, as the constraint has the most power to distort a schedule. It is one of the most misused features within schedules today.

Whenever possible, avoid using constrained dates for tasks unless it is absolutely required, as you are signifying that a certain task must happen on a specific date regardless of the completion of tasks before or after it. If you do use a constraint, make sure it is reviewed at each update to validate that it is still valid and not artificially impacting other activities. If a constraint must be used, it would be best to use either a "start" or "finish no earlier than," or an "expected start or finish" constraint because using constraints may artificially alter the critical path logic, and ultimately the project completion date. Therefore, a true rendering of the intent and the flow of progress and the true critical path should be tracked, identified, and discussed with team members before constraints are inserted. It is very important for the scheduler, and the stakeholders of the schedule, to understand where constraints are being used, as well as how they affect float in the schedule, so they do not end up with an unpleasant surprise when least expected!

3.9.2 Mandatory Constraints

Guidelines

Definitions

Mandatory Start: A restriction imposed on the start date of an activity that modifies or overrides the activity's logic relationships and sets the early start date equal to a specified date, making it a zero float event thereby forcing it onto the critical path—also known as "Must Start On," or MSO.

Mandatory Finish: The mandatory finish constraint sets the early finish date equal to a specified date. Any imposed mandatory finish constraint sets the early date for all paths leading to that activity, making it a zero float event thereby forcing it onto the critical path—also known as "Must Finish On," or MFO.

Purpose

The primary purpose of a mandatory constraint is to lock down a known date within a schedule that can start or finish at no other time. An example of this would be the start of a shutdown, the kickoff of a project, or a contractual milestone.

Default Condition

A mandatory constraint will ignore all logic and fix the date within the schedule, placing that activity into a zero float condition.

Best Practices

The best practice regarding the use of mandatory constraints is not to use them except when absolutely necessary, such as a start or completion date of a project or significant event.

Recommended Practice

Limit the number of mandatory constraints used within a schedule to two: "project start" and "project completion."

Advisories

Using mandatory constraints artificially alters the logic and ultimately the project critical path and interim activity dates; therefore, they will not reflect a realistic schedule and they are not reliable in reviewing critical path. Total float (TF) is always reported to show zero float when using mandatory constraints. When a predecessor slips and impacts the (mandatory constraint) activity, the predecessor reports negative float. The mandatory constraint will not report any impact or negative float because most software tools, such as Primavera, calculates the mandatory's float as zero TF. If a constraint must be used, it would be best to use either a "start" or "finish no earlier than," or an "expected start or finish" constraint.

3.9.3 Early Constraints

Guidelines

Definitions

Early Start Constraint: A restriction imposed on an activity or task that limits the earliest time that it can start before the next activity—also called a "Start No Earlier Than," or SNET.

Early Finish Constraint: A restriction imposed on an activity or task that limits the latest time that an activity can finish before the next activity can begin—also called a "Finish No Earlier Than," or FNET.

Purpose

The "Start No Earlier Than" or "Finish No Earlier Than" constraints are used in place of mandatory constraints, generally applied to a milestone activity, to allow measurement of float to analyze the impact on other activities within that logic string.

Default Condition

During schedule calculation, the early start or early finish constraint will only affect the early dates during the forward path calculation. The calculated start date will move to the right only when the constrained date is later than the calculated late finish date. Total float will most likely be reduced during the calculation. The early start or finish constraint is used to ensure the task will start or finish no earlier than a specific date. Note: If the constraint is in a non-work period, it will move to the first available work period after the constraint date. The early start constraint has no effect on the schedule calculation once an actual start is applied.

Best Practices

Recommended Practice

The early start and finish constraints are the two most commonly used by schedulers. Use one of these two constraints when a constrained date is required.

Advisories

If you do use a constraint, make sure it is reviewed at each update to validate that it is still valid and not artificially impacting other activities.

3.9.4 Late Constraints

Guidelines

Definitions

Late Start Constraint: A restriction imposed on the start date of an activity that modifies or overrides the activity's logic relationships so that the activity will have negative float if the calculated date is past the constrained date—also called a "Start No Later Than," or SNLT.

Late Finish Constraint: A restriction imposed on the finish date of an activity that modifies or overrides the activity's logic relationships so that the activity will have negative float if the calculated date is past the constrained date—also called a "Finish No Later Than," or FNLT.

Purpose

The start or finish no later than constraints are used in place of mandatory constraints, to allow measurement of float to analyze the impact on other activities within the logic string.

Default Condition

During schedule calculation, the late start or finish constraint will only affect the late dates during the backwards pass calculation. The calculated start date will move to the right only when the constrained date is later than the calculated late start or finish date. Total float will most likely be reduced during the calculation. The late start or finish constraint is used to ensure the task will start or finish no later than a specific date. Note: if the constraint is in a non-work period, it will move to the first available work period after the constraint date. The constraint has no effect on the schedule calculation once an actual start is applied.

Recommended Practice

Late start and late finish dates are more restrictive than early finish constraints when calculating critical path. These constraints should be used judiciously.

Advisories

If you do use a constraint, make sure it is reviewed at each update to validate that it is still valid and not artificially impacting other activities.

3.9.5 Other Constraints

Guidelines

Definitions

Start On Constraint: A restriction imposed on the early and late start dates of an activity that modifies or overrides the activity's logic relationships so that the activity will have negative float if the calculated date is past the constrained date.

Finish On Constraint: A restriction imposed on the early and late finish dates of an activity that modifies or overrides the activity's logic relationships so that the activity will have negative float if the calculated date is past the constrained date.

Purpose

The start or finish no later than constraints are used in place of mandatory constraints, to allow measurement of float to analyze the impact on other activities within the logic string.

Default Condition

During schedule calculation, the "start or finish on" constraint will only affect the early dates during the forward path calculation. The calculated start date will move to the right only when the constraint is later than the calculated late finish date. Total float will most likely be reduced during the calculation. The start or finish on constraint is used to ensure that a task will start or finish on a specific date. Note: if the constraint is in a non-work period, it will move to the first available work period after the constraint date. This constraint has no effect on the schedule calculation once an actual start is applied.

Recommended Practice

Use a start on or finish on constraint in place of a must start on or must finish on constraint whenever practical. This will improve the ability of the software to calculate a realistic critical path.

Advisories

If you do use a constraint, make sure it is reviewed at each update to validate that it is still valid and not artificially impacting other activities.

3.10 Software Considerations

Today's scheduling software can perform other calculations that have an impact on the project's float that will have an impact on the quality of the schedule is not fully understood. This section will provide some guidance into the following categories:

3.10.1 Zero Free Float
3.10.2 Zero Total Float
3.10.3 Retained Logic vs. Project Override
3.10.4 Start Float vs. Finish Float vs. Most Critical Float

3.10.1 Zero Free Float

The use of constraints in the critical path method of scheduling is discussed in Section 3.9. However, most modern scheduling software allows imposition of additional constraints that affect CPM calculation for available float. Zero free float constraint is one such additional constraint that can be applied to alter the free float available to an activity, mostly for resource considerations.

Guidelines

Definitions

Free float is the amount of time a scheduled activity can be delayed without delaying the early start of immediately following (successor) activities. Free float is uniquely available to an activity and its utilization does not impact the total float available to the activity or its path.

Most software allows only complete suppression of available free float, also defined as a zero free float constraint. It is also known as the "as late as possible" constraint.

Purpose

A zero free float constraint enforces the activity to start as late as possible without affecting the early start of the succeeding activity. Note that doing so does not affect the succeeding early start and, hence, is not necessarily the same as the late start of the activity.

In Figure 3-9, only Activity F has one day of free float, even though path A-E-F-G has a total float of three days.

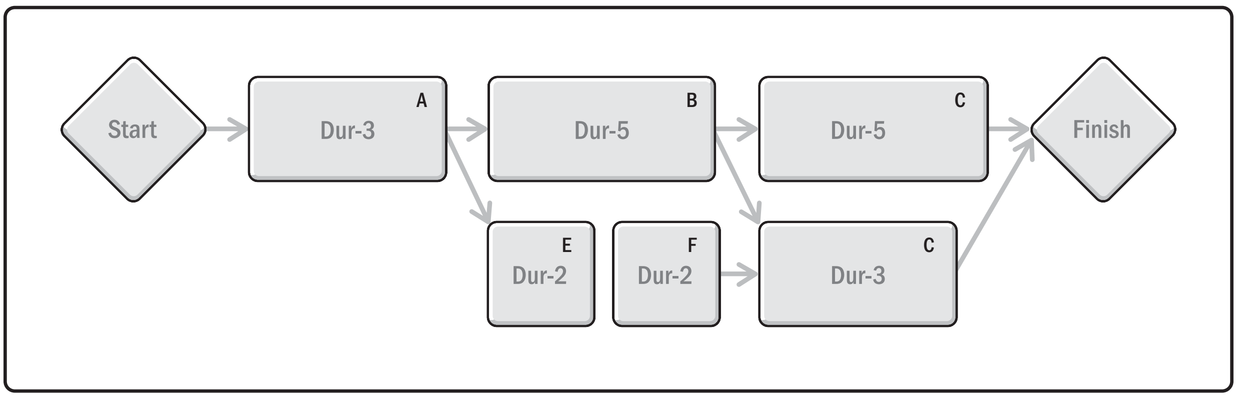


Figure 3-9: Precedence diagram showing free float

A zero free float constraint on Activity F would now enforce an early start for a day later to finish in time and still keep Activity G unaffected. However, note that now free float has been transferred to Activity E.

Zero free float constraints are used for various reasons, mostly related to resources. Resource leveling algorithms typically prefer utilization of free floats to move activities before total float is considered, because moving such activities would have the least impact on early planning. But applying a zero free float constraint only allows it to be leveled with available total float. Other applications of zero float constraint is for tracking material deliveries. Zero free float constraints allow delivery activities to be scheduled as "just-in-time." This kind of application is often used for scheduling conveniences, such as meeting requirements of accurate spending projections.

Default Condition

The default software settings for zero free float constraints are typically turned off.

Best Practices

Use of zero free float constraint is generally not recommended. Some contract conditions even disallow the use of these constraints as float suppression techniques. The best alternate practice recommended is use of lags or defined activities with durations that make the intent transparent to the project team.

Recommended Practice

The recommended practice of zero float constraint, where absolutely necessary, is to limit it for resource leveling purposes in very complex networks only. A preferred alternative is use of defined "dummy" activities to act as lags that make such assumptions transparent in the planning process, and during maintenance of the networked schedule. However, since dummy activities affect reports, use of lag is also a better practice where allowed and accepted by validation.

Advisories

A zero free float constraint does not enforce late dates as early dates for the activity. It is sometimes a mistaken conception to use zero free float constraints to produce late graphs. It is important to remember that zero free floats only delay the activity without delaying the *early* start of the succeeding activity.

3.10.2 Zero Total Float

Most projects have finish requirements and intermediate time constraints for schedules as a function of scope and contract requirements. However, constraints also come as objectives and outputs from planning phase or organizational requirements. These priorities may be a business decision to optimize a specialized subcontractor performance in manufacturing, or simply a customer service goal as an outcome of sensitive community engagement. These constraints are sometimes adopted as high priorities without a date constraint. Zero total float constraint is one that is employed to alter the total float available to the activity, and hence the critical path to meet such priorities.

Guidelines

Definitions

Total float is the total amount of time that a schedule activity may be delayed from its early start date without delaying the project finish date. It is calculated using the critical path technique and by determining the difference between the early finish and late finish dates.

A zero total float constraint imposes the early dates of an activity to equate its late dates.

Purpose

A zero total float constraint is mostly used to enforce a priority or make a certain task critical without imposing a date constraint. A zero total float constraint not only makes the early and late dates the same for the activity, but also causes driving predecessor activities to have zero total float, thus making a path critical. A zero total float constraint is also occasionally used to prioritize resources due to resource planning considerations.

Default Condition

The default software settings for zero total float constraints are typically turned off. To apply them, the last activity which is usually a milestone or a flag is assigned a zero total float constraint.

Best Practices

Use of zero total float constraint is generally not recommended. Some contract conditions, validation guidelines, and organizational best practices disallow the use of this constraint as a float suppression technique. When using zero total float constraints, it is best to tag these activities to ensure that the constraint is monitored, slippages are noticed, and its impact assessed in project performance.

Recommended Practice

The best alternate practice recommended is to use date constraints and identify it in project plans as secondary milestones.

Advisories

A zero total float constraint enforces a critical path without requiring a completion date constraint. The term "critical path" here is used in the most commonly accepted method of recognizing activities with float of zero or less. Careful network review is recommended while determining critical path(s) or longest paths of projects if the CPM network has open ends or other intermediate date constraints. With zero float constraints, slippages to late dates may go unnoticed in the absence of a careful audit process.

As a result of the critical path(s) generated by use of zero total float constraint, resources compete in a resource-driven schedule. Care is recommended in resource-leveled schedules.

3.10.3 Retained Logic versus Progress Override

Guidelines

Definitions

Retained logic instructs the scheduling software to continue enforcing the logic in the schedule when the successor activity starts prior to fulfilling the logical relationship of the predecessor, extending the early finish date of the out-of-sequence activity until its predecessor is complete. Progress override instructs the software to ignore the logic leading into the out-of-sequence activity.

"Out-of-sequence progress" is defined as the start of a successor to an activity before the logical relationships driving the activity in question have been satisfied.

Both retained logic and progress override are settings within scheduling software that tell the software how to handle out-of-sequence progress during the course of a project when using a CPM schedule.

Purpose

The choice between retained logic and progress override specifies the method the scheduling software uses to process the logic relating to activities that have been worked out of sequence. Progress override allows the scheduler to mitigate the effects of out-of-sequence progress without physically modifying the previously established logic. Retained logic protects the scheduler against out-of-sequence activities, allowing improper logic to drive network calculations. Given significant out-of-sequence progress, out-of-sequence progress on the critical path or a combination of the two, there can be important differences in the latest calculated early finish date and critical and near critical paths, depending upon which setting is used to calculate the schedule.

Default Condition

The settings become important only when there is out-of-sequence work that does not match the original logic programmed in the network, and even then only when that out-of-sequence work affects the critical path. The use of the setting for retained logic versus progress override often depends on the scheduling specification of the governing contract. Most construction scheduling specifications require the use of retained logic; however, there are still many contracts that do not address the issue. Therefore, it is always a good idea to check which setting is being used when reviewing a schedule, or series of schedules. The "physical" location in the Primavera software for making a selection between the two options is under the schedule button and then the options button.

Best Practices

Using retained logic is preferable to progress override. Retained logic may give a pessimistic view of the project completion date, as it does not account for completed work between an unfinished predecessor and an incomplete successor, but it is a great indicator of where changes in the logic need to be made to reflect the reality of the project. Progress override ignores logic related to out-of-sequence work and can leave unstated activities out of the network calculations because a successor was started prior to the predecessor's actual start. These unstated activities calculate float values equal to the remaining duration of the project because project override ignores the established logical link, effectively making the unstated activities perform as open-ended activities. It is easy to miss these activities, as they do not show up on critical or near-critical paths and "ride" the data date. For this reason, progress override tends to give an overly optimistic view of the project completion date.

Correcting the logic of out-of-sequence activities to reflect the actual plan in the field for completing the project is the best way to solve the problem. Otherwise, it is important to use a consistent setting throughout the series of schedules because changing the settings in a series of schedules can impart significant changes in milestone completion predictions and the identification of the critical path.

Recommended Practice

The preferred method is to use retained logic as a default setting, as it protects the scheduler against out-of-sequence activities, allowing improper logic to drive network calculations. Correcting the logic of out-of-sequence activities negates the question of which is better because neither setting affects the schedule if there is no out-of-sequence progress. Best practices in general suggest correcting out-of-sequence logic so that it matches the plan for means and methods of construction.

Advisories

The two settings will likely have a significant effect on the critical path, with progress override showing a very optimistic prediction of completion. With the use of progress override, activity logic that has been ignored due to this setting will change the network calculations such that float values for those activities will not be dependable.

Changing the settings in between schedule updates can artificially show delay or mitigation gains, changing from retained logic to progress override can improve completion predictions, and changing from progress override to retained logic can show a delay to milestone completion.

A temporary use of the settings provides a diagnostic tool to assess how out-of-sequence work is affecting the job. The settings should be changed temporarily to see what happens. The total float values should be analyzed to ensure that work is not being ignored and riding the data date with an abnormally large total float value. Consult with field personnel to correct out-of-sequence progress and ensure the schedule accurately reflects the plan to complete the project.

If the schedule suffers from excessive out-of-sequence work, progress override may lessen the effects of the remaining incomplete work, driving other work that can or does start. If that out-of-sequence work contains critical path work, changing the settings may show variances to help flag the presence of that critical path work that needs to be analyzed.

3.10.4 Start Float versus Finish Float versus Most Critical Float

Guidelines

Definitions

An activity's "start float" is the amount of excess time it has between its early start and late start dates (AACE, Cost Engineering Terminology, 2010, p. 104).

The "finish float" is the amount of excess time an activity has between its early finish and late finish dates. This may be referred to as "slack time" (AACE, Cost Engineering Terminology, 2014, p. 107).

The "most critical float" on a project is the float value which is least positive. This is generally associated with the most critical activity (or sequence of activities) on a project. It can also be understood as the smallest total float value.

Purpose

Start float can be used to understand the amount of time an activity has before further delay would result in the activity beginning after its late start date, thereby impacting project completion.

Finish float can act as a measure of the amount of time an activity's finish can be delayed prior to it impacting any succeeding activities. More simply, finish float is basically understood as the time between the scheduled finish of one activity and the start of the next. Consuming an activity's entire finish float will result in impacting project completion.

Start and finish float can also be referred to as total float, depending on the context in which they are being used.

Most critical float can be used to determine the most critical activity or sequence of activities on a project. In the event that the most critical float is positive, this means that early completion of the project is scheduled to finish prior to project completion.

Default Condition

Start float will be used in those cases where it is desired to know how long the project can hold off on starting an activity without delaying project completion.

Finish float will be used to determine how much time the activity has to complete before it impacts project completion.

Most critical float will be vital in determining which activity or sequence of activities is most important to finishing the project, qua to project completion.

Best Practices

The use of these float concepts requires a correctly constructed and validated CPM schedule, with no open-ended activities, a complete network, forward and backward pass calculations, etc.

The correct formulas for calculating these are:

$$\text{Start Float} = LS_{i,j} - ES_{i,j}$$
$$\text{Finish Float} = LF_{i,j} - EF_{i,j}$$
$$\text{Most Critical Float} = \min(TF)$$

Recommended Practice

It is recommended that all of these concepts be utilized in an effort to understand what time a project has available to it both before and during the project. They can also be utilized to understand the status of a project. Further, these concepts should be used to understand where individual activities stand, relative to where they were planned to be at a given time. They should be used to determine where the project stands relative to its project completion date.

Advisories

These float values may not provide the desired information in the event that there are project milestones or activities with restrictive constraints (physical or schedule-based).

They will also be less valuable in those cases where the schedule has not been properly built, i.e., if there are a lot of open-ended activities or sequences.

3.11 Resource-Loading

Projects are the interaction of humans, machines, and materials to produce an intended result. To the extent that we can manage time, we do so indirectly through a schedule to coordinate the actions of the humans, machines, and materials (resources). It is well understood that, to have a realistic schedule, the project's constituent resources must be accounted for in some manner. The many and varied means used to account for those resources can be described as "resource-loading." It is important to note that whatever process and assumptions are used to load resources in the schedule should be explained in detail in the written narrative accompanying the schedule update. (See Section 4.7, Documentation Purposes/Requirements.)

Guidelines

Definitions:

Resource-Loading—Recalling that schedule applications implement the schedule as a relational database and resources are entered in the database as attributes of an activity, there is one exception, the "resource or crew tie," which will be discussed further under Section 3.11.1, Resource Leveling. How that attribute is defined and used in calculations will depend on the intent of the executing organization. Resource loading may be employed as a bridge to an earned value system to estimate resource requirements and resolve conflicts.

Types of Resources—In the physical world, resources can take many and varied forms. Resources are commonly associated with people with a defined skill set, i.e., building trades, engineers or software architects and coders. Inanimate objects such as heavy equipment, test devices, or space to work, can also be treated as resources. Further, resources can incur cost in different ways (fixed price versus prorated). Some resources are consumed as the activity is completed, and others typically endure to be employed again. All these types and attributes have to be mapped in the available fields of a software database application. Table 3-5 summarizes the "types" of resources supported in three popularly used project management software applications: Primavera P6®, Microsoft Project® and Asta's Powerproject®.

Type	Primavera P6	MS Project	Powerproject
Labor/work	X	X	X
Non-labor	X		X
Material	X	X	X
Consumable			X

Table 3-5: Software considerations for resource loading

For each resource additional attributes may be defined such as the unit, cost per unit, availability, work calendar, or roles. These additional attributes can determine how the resource is portrayed or accommodated in the schedule. They may also determine whether, in accounting for the resource, the schedule can be changed, such as "leveling" or extending the duration of an individual activity.

Purpose

The coordination and allocation of resources is of interest to every level of project management. The level performed will determine the information that will be useful from the resource loading effort. Subcontractors may want to know when to show up, and how many crews they will need. The owner may be tracking total manpower and comparing it to the resource-loaded schedule to determine if the job is being sufficiently manned. Project managers may be looking for resource conflicts to resolve. All these questions can be answered using the work products of the resource loading effort.

Default Condition

Resources are allocated to activities. For each activity resource assignment there are three variables: the assigned units, duration, and budgeted quantity. Multiplying the assigned units by the duration yields the budgeted quantity. In some instances the activity is "effort driven." In this instance the duration can be increased or decreased by manipulating the assigned units. Other activities will consume resources at a uniform rate, causing the budgeted quantity to change proportionally to the duration. A generally optional value is the resource availability, or the number of units available for assignment over a given period. This value comes into play when "leveling" algorithms are employed, or the scheduler permits the application to change the duration based on the available resources.

Best Practices

Resource Histograms: As a default, the applications referenced above distribute the budgeted value uniformly over the activities' durations. In the vast majority of instances, this is a satisfactory approximation. In some instances an attribute may be assigned that causes the budget quantity to be allocated in a skewed manner. The budgeted value may be front-loaded, back loaded, or distributed on a bell curve. This subtle distinction can be significant as the activity data is compiled for the first report of the resource-loading process, the resource histogram.

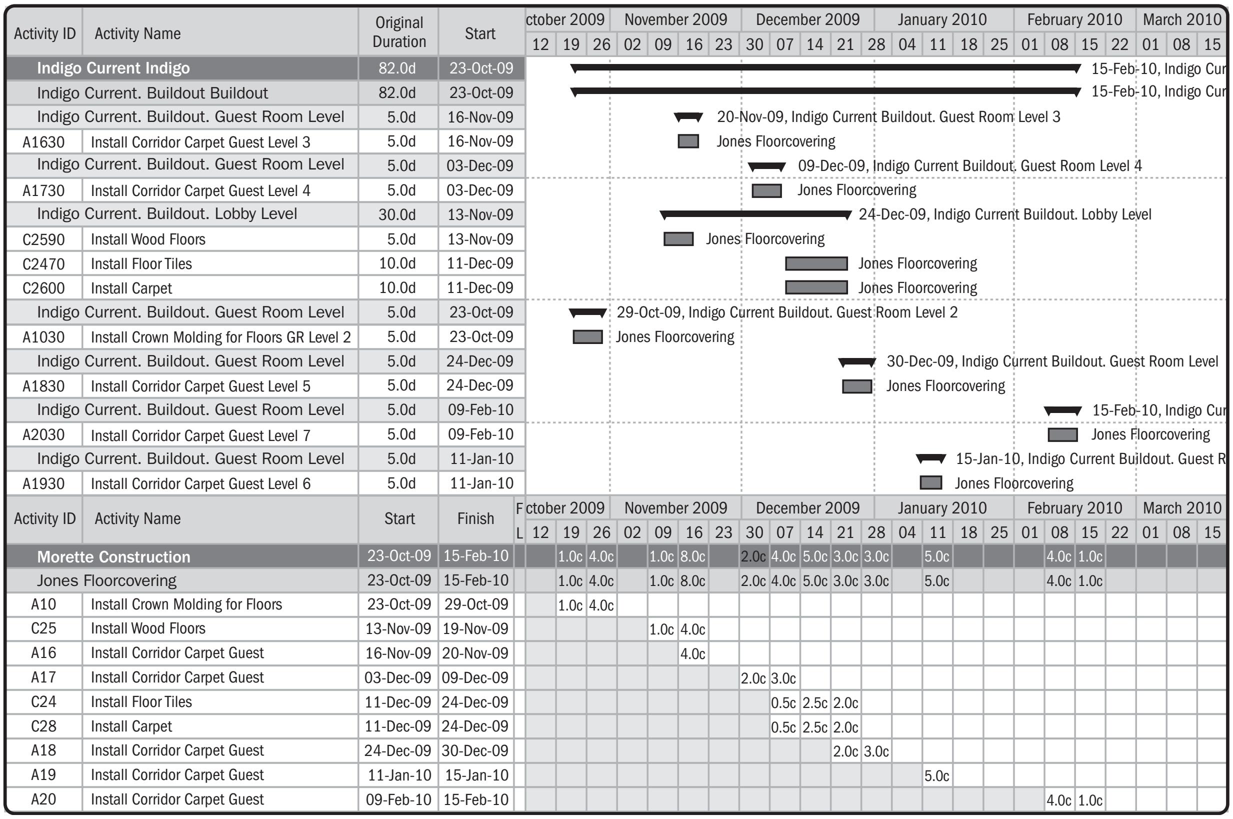


Figure 3-10: Resource usage spreadsheet

Figure 3-10 is a resource usage spreadsheet displayed below the corresponding Gantt chart and activity table, an intermediate report used in the creation of the resource histogram. In the resource usage spreadsheet, the application allocates the budgeted units from the start of the activity to the end of the activity, horizontally. Vertically, the values for each activity summed by week form a manpower estimate for the project for that week. In this particular example the unit was a crew. This makes the unit of labor a crew-day. A single crew assigned for a week will yield five crew-days of available effort per week.

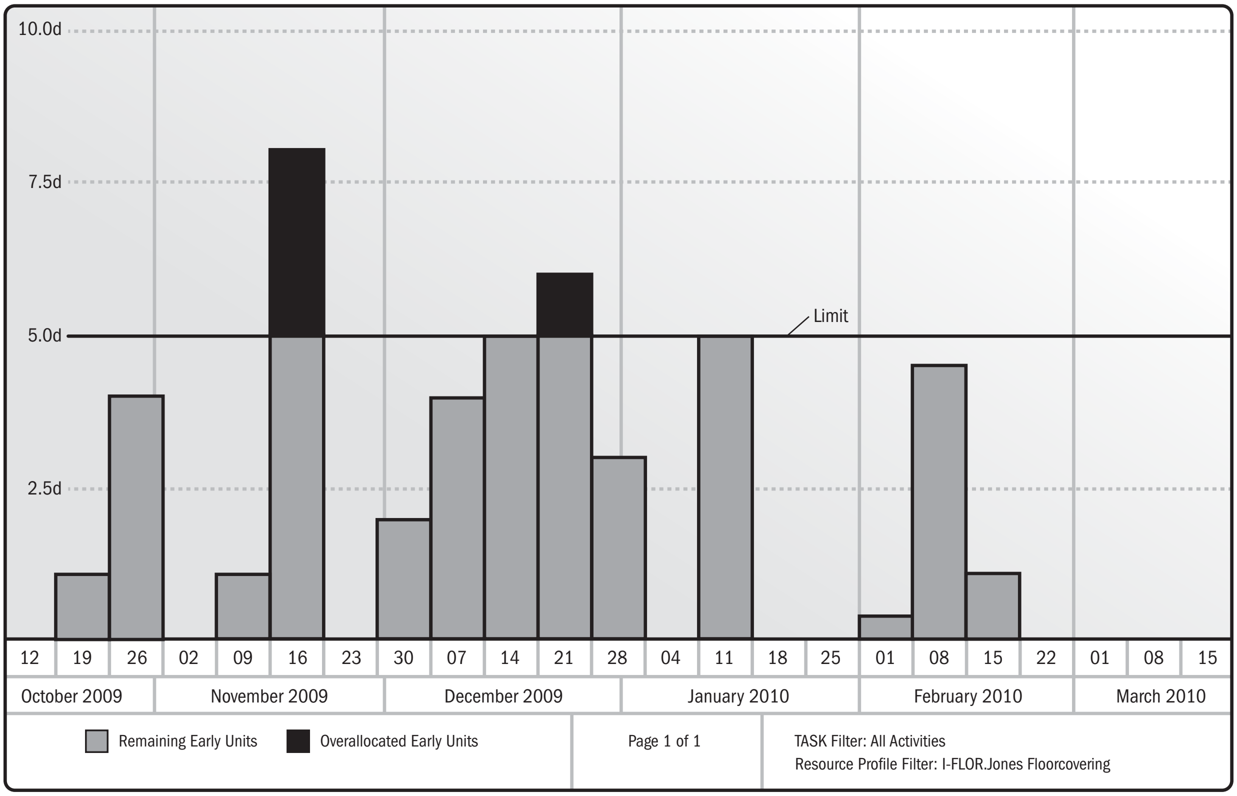


Figure 3-11: Resource histogram

Many project team members do not relate well to a large table of disparate numbers. The same data can be more compactly and efficiently displayed in a resource histogram. Figure 3-11 is the resource histogram that corresponds to the raw data contained in the usage spreadsheet in Figure 3-10. By displaying the data in this manner a number of features of the subcontractor's scope become apparent. The heavy black horizontal line at the five crew-day level represents the maximum available resources per week. From this histogram, the projected effort required, based on the early dates, will exceed the available effort of the subcontractor during the weeks of November 16 and December 21. Further, as the schedule is presently structured, the effort required of the subcontractor varies greatly from week to week and is discontinuous at some points. This is an undesirable condition for the subcontractor. The project manager can expect the subcontractor to take action to smooth out, or level, the workload to avoid repeated mobilizations. The project manager would request the revised schedule from that subcontractor with new accurate resource-loading.

3.11.1 Resource Leveling

Projects that are to any degree resource-driven will have the schedules leveled in some fashion, either manually by the project management team in case-by-case actions, or automatically using the built-in process in the scheduling software, or possibly by the field management outside of any project schedule interaction. The physical realities of putting too many people in the same space at the same time (space stacking), or too many people for the available resources (trade stacking), can easily cause delays and disruptions in the work. If the resources required by the project are in excess of the available resources, there will likely be problems in general, with the activity durations prolonged due to less total production, unless the project is monitored and controlled by adjustments in sequencing or resource consumption.

If not resolved during the planning phase of the project, the leveling may occur at the lowest management levels on an ad hoc basis in a random manner, by the field superintendent or foreman. Resource conflicts may be managed on a case-by-case basis by taking steps in the field at the time of the conflict, which often includes increased costs to perform the work.

One of the problems in most construction projects is that the project management team, specifically the general contractor or construction manager at risk, rarely has a good understanding of the resources available and the needs of the full project management team, so it is very difficult for a project manager or scheduler to make decisions about how to staff the job to limit risks of location or trade stacking. A typical construction project might have dozens of subcontractors, each of whom will supply some number of trade workers. This problem is amplified when the project management team is a broker, self-performing little work. It is very difficult to get detailed information related to available crew sizes and composition, as well as the productivity needs to meet project durations, from the subcontractors.

Another industry problem related to individual resource-loading is the risk of overlapping when work is performed out-of-sequence during periodic updates. A schedule cannot accommodate every project management decision about which specific activity to start and when to move partial resources to another activity. If this is not planned very carefully in the resource-loading, the project resource predicted requirements will quickly increase out of proportion to the needs.

An example of this is a "frame metal studs" activity requiring 10 workers per day, with a duration of 10 days, followed by a 15-day "hang drywall" activity, requiring 10 workers per day as well. On the seventh day of framing, the subcontractor might take three of the metal stud workers off the metal stud activity, since the remaining workers can finish the task in the original duration, and start hanging the first side of the drywall. The subcontractor who provided the resource-loading would have supplied estimates of 10 workers per day throughout the metal stud and drywall installation. However, by the schedule's predictions of resources, when the drywall activity started out-of-sequence (because the framing activity was not complete), the program would show a need for 10 workers per day for drywall and the original 10 workers per day for the metal stud work, even though the total counts were different and the activities now are operating concurrently. So the schedule would show a need for 20 workers per day, when the original plan and the contemporaneous need was still 10 workers per day. This risk has made contractors suspicious of the benefits of good resource loading.

Automatic Leveling

It is recognized that work can be completed more efficiently when it is performed continuously. It is also more cost effective to avoid working overtime. Referring to Figure 3-10, when the start date of the activity is changed, the estimated effort is adjusted in the spreadsheet, and correspondingly in the resource histogram (Figure 3-11). There are a number of tools within the software applications, compiled into the series of schedule-leveling algorithms that enable the schedule to move activities or resources to achieve the best solution. This is automatic leveling of resources, and great care should be taken in any automatic leveling efforts.

Automatic leveling of resources involves a number of subjective and general decisions that will need to be programmed into the software to allow the algorithms to operate effectively. These decisions, once made, will be used by the software to make the adjustments to the schedule, based on factors such as float, production rates, and durations.

Set limits for all resources—Limits must be established for each resource of concern, such as the number of units available and the time periods associated with the specified level of availability. Other characterizations such as the degree to which overtime can be employed may also be specified.

Select resources to level—In many instances a single resource will pace many, or a sequence of trades. All the resources may appear to be over-allocated. But once the driving resource is leveled the conflicts for multiple resources are also resolved. In other instances, level of effort resources may be assigned over a wide range of activities alongside driving resources. These will sometimes stack and appear over-allocated. The scheduler will likely choose not to level the level of effort or hammocked resource. At the other extreme, the project management applications often provide the option to "level all." This can result in relatively short-term projects exploding into multiyear behemoths. Suffice it to say, use this option with caution.

Define the limits/approaches to leveling—Resolving resource conflicts by leveling will not always extend the length of the project, but the expectation is that it will. Project management applications provide options to limit the extent to which the algorithm is allowed to reschedule activities. One popular option is to "level within available float." This limitation will allow the algorithm to reschedule activities and spread out the effort, but not extend the overall duration of the project. In the end, you may still have some resources over-allocated, but overall the resource allocations will be more tolerable. The option to globally level all resources is available in all the software applications cited above. This frequently results in unrealistically long schedules due to limited availability of an obscure resource that could be closely managed and its impact mitigated in a manual leveling scenario.

Manual Leveling

For schedulers who do not have experience with the leveling algorithms available in the various project management applications, the results they obtain may appear and actually be unpredictable or inappropriate. In the effort to produce a realistic schedule in a resource-constrained environment, many schedulers will choose manual schedule techniques.

Manual leveling of resources involves loading the resources in each appropriate activity and using the resource profiles during schedule development and during the quality control check to limit the resources to those available for the relevant trades, locations, and market conditions.

Adjusting resource dependencies is the primary approach to manual leveling of resources. This approach is intended to mimic the path of a single resource, or crew, with trace through the network. This approach will succeed in de-conflicting the resource, but with some drawbacks. As priorities change the crew may need to perform its assigned tasks in a different sequence, or another crew may become available and perform an activity out of sequence. This could cause some of the out-of-sequence issues noted earlier. At the very least this approach requires constant attention to prevent erroneous results by reviewing and adjusting resource logic with each schedule update.

Use of lags to push the work out of the resource can also be an approach, although best practices should be followed for use of lags (see Section 3.7.3). The drawback is that pushing the effort out into the future tends to bump the over-allocation from one time period to the next, until most of the activities are moved out into the future. As with resource dependencies, this approach will require constant effort to ensure the resulting schedule is realistic.

Sometimes schedulers use constraints to limit or adjust resource consumption, but this is not recommended. This approach is fairly straightforward, but requires adding numerous constraints that may not be permitted under the scheduling specification. Again, this approach will require constant effort to ensure the resulting schedule is realistic, and analysis of the schedule will be more difficult, as noted in Section 3.9.

The applications cited above also enable the scheduler to select which resources to level. This is significant because, over the course of a long project, different resources will pace the project. Through manual inspection of the resource histograms, it is possible to select candidates for leveling. Running multiple trials, it is possible to estimate which resources are critical. Leveling these resources resolves the over-allocation of the paced resources and yields reliable results without incurring the burden of frequent maintenance.

Best Practices

In most construction projects, the best practices primarily include the use of manual resource leveling, performed during scheduling development, and verified and adjusted during the quality control check of the baseline schedule.

In construction projects—outside of process plant-type and maintenance and shutdown-type work, where the bulk of the resources are typically controlled by one contractor—automatic leveling of labor resources is not commonly performed. Outside of those industries, the subcontractors often cannot determine how many workers will be used for a particular activity scope of work, and as a result cannot come to terms with their own concurrent work risks that quickly drive up the number of workers needed.

One good solution for the complexities of individual resources is the use of crew resources. This is accomplished by defining crews for each of the trade contractors to include the number and types of worker planned for each crew. An asphalt paving crew, for example, might include a paving machine, a number of dump trucks to supply asphalt, a foreman, 10 laborers, as well as a roller and operator, and several flagmen. But the realities are that each paving subcontractor will operate their work using a different number of these resources, and attempting to acquire the details for each activity related to paving can be time-consuming and difficult. With crew resources, the project management team recognizes that it takes one crew for each paving activity, so when multiple paving activities overlap the number of crews required concurrently goes up.

This is a reasonable and appropriate method to plan for manual leveling of resources, allowing quick loading, accurate and simple totals, practical reviews, and reasonable discussions of the number of crews available to work the tasks.

Recommended Practice

Advisories

Schedulers who venture into this style of scheduling will be confronted with a wide range of features that will affect how the resource is allocated and how the scheduling algorithm for a given application acts on the schedule overall. If it is to be implemented, automatic leveling of resources must be undertaken very carefully. It is not uncommon for the automatic leveling process to completely change the intended logic of the schedule, affecting the means and methods. Manual leveling is much less likely to create a problem with the schedule model.

3.12 Risk Management Implementation

Risk management planning is the process of deciding how risk management is going to be accomplished on the project. This section covers the various acceptable schedules a project can possess. There is a three-level approach to risk management, which has its benefits and implications.

Level 1: Risk identification is the formal act of identifying risks and opportunities for projects. Typically, this includes the use of a risk checklist, and/or the start of a risk register.

Level 2: Deterministic risk analysis is the act of analyzing risks through a single-point estimate of potential impacts. Typically, this involves a probability x impact matrix, prioritized list of risks, and/or expected value for contingency allocation of schedule or cost.

Level 3: Probabilistic risk analysis is the act of analyzing risk through probability distributions estimates of potential impact, known as Monte Carlo simulations. Typically, this involves cumulative distributions of potential outcomes for identification of the probability of achieving project targets, and is the most sophisticated of the three levels.

In the following sections, we will describe the use of risk management as it relates to project schedules:

3.12.1 Risk Management Planning Introduction
3.12.2 Identification of Risks
3.12.3 Qualitative Assessment
3.12.4 Risk Event Drivers

PMI's Project Risk Management Community of Practice is a good source for more in-depth information about risk management and analysis information.

3.12.1 Risk Management Planning—Introduction to the Schedule

Guidelines

Risk management planning is the process of deciding how project risk management will be accomplished. This section will discuss the various acceptable schedules a project can include.

Definitions

Risk management planning involves deciding how to execute the risk management activities for a project. It should be conducted in the early stages of project planning.

Purpose

Risk management planning is conducted to establish risk management as an integral part of project execution and as a contributor to its success. We make risk management a part of the team's job, rather than an unwanted extra that has to compete with other project work. We do this early in the project so team members can get started identifying, analyzing, and responding to risks and become comfortable with the process. Risk management planning is usually done once, at the beginning of the project planning phase, although mid-course corrections may be made (for instance, to add personnel if more risks arise than originally anticipated). A risk management plan is developed to indicate how risk management will be conducted, and that plan is made a component of the project management plan. Risk standards are developed and made public. Risk activities are added to the schedule at appropriate places, and risk management resources are added to the budget.

The purpose of risk management planning is to ensure that risk will be examined and handled from the beginning of and throughout the project life cycle. Usually, a project will contain risks that can affect the ability to finish according to schedule. The sooner these risks are identified, prioritized, and addressed through mitigation or other measures, the more likely the project can adhere to the schedule. Hence, risk management activities should be planned to commence as soon as risks are identified. Through the risk management plan, management should demonstrate a commitment to addressing risk proactively and consistently throughout the project.

The term risk management planning is one of the six risk management processes identified in the *PMBOK® Guide* – Fifth Edition (PMI, 2013), but does not encompass identification, analysis (prioritization of individual risks or calculation of overall project risk), or risk response. Those important functions are addressed by other risk management processes.

Default Condition

Every project should have a risk management plan that is incorporated into the project management plan. This plan should drive the risk management activities from beginning to end of the project life cycle.

Best Practices

The risk management plan, the output of risk management planning:

- Identifies the type of risk management activities that will be performed. (Risk management should be included in the WBS.)
- Specifies when these activities will be performed. (Risk management activities should be included in the schedule.) Typically, major risk management activities such as quantitative risk analysis of the schedule and cost should be performed before major project decisions such as authorization for design, authorization for expenditure, and the like, to be part of those decisions and help determine the need for new activities to mitigate the high-priority risks. Risk analysis should also be performed during the execution where, even if mitigation cannot be performed, a measure or reality in our expectations of completion dates can still be achieved. These decisions as to when to perform various risk management activities will be included in the risk management plan.
- Determines who will own those activities (included in the task assignment matrix), and to whom the risks, their responses, and monitoring their status should be reported.
- Identifies which resources will be used and how much budget will be assigned (included in the project budget), such as including the entire project team and some participants outside the project team, and perhaps including contractors or subcontractors.
- Specifies what techniques, methods, and definitions will be used. For instance, for some projects full-on integrated quantitative cost and schedule risk analysis will need to be performed, but for others qualitative risk analysis will suffice.
- Indicates what risk mitigation methods are permitted and which are not. For instance, as the cost estimate is expected to include a contingency reserve below the line, is the schedule permitted to include a contingency reserve of time?
- Indicates who is responsible for the compiling and disseminating of lessons learned.

Recommended Practice

It is recommended that the best practices outlined above should be followed, suitably tailored to the specific project. For instance, a multi-billion dollar refinery might require a risk management structure and support committee of people to determine how to handle risk management, whereas risk management planning for a smaller project might be done by the project manager and deputy project manager. For a large project, the risk mitigation actions may be serious and expensive, sometimes requiring policy decisions (e.g., direct negotiation with suppliers versus competitive bidding), so the reporting would need to be at a high level in the organization. Tailoring the risk management plan to the specific project, consistent with the practices of the organization, is also recommended.

Advisories

A frequent problem with risk management planning is that it is not done during planning of the rest of the project execution. There was no thought about it at the beginning of the project, therefore the first time we have to address risk management there is no provision for scheduled activities or resources. Everyone who is dragged into the risk identification or risk prioritization exercise feels that this is work outside of their already too-full plate. They do not have charge numbers for risk management activities, so they have to do their already-assigned work late into the evening. They do not have a well-thought-out plan of conducting risk analysis, so there may be some startup issues and false starts, further wasting time and turning risk into a four-letter word. To avoid this scenario, project risk management needs to be planned the same way we plan for all aspects of the project execution.

3.12.2 Identification of Risks

Guidelines

Risk identification involves identifying risks that may occur on a particular project, and, if they do occur, affect our ability to achieve project objectives such as time, cost, scope, or quality. Determining which risks might actually affect the project schedule and documenting their characteristics is part of qualitative risk analysis. Risk identification is an iterative process because new risks may arise, and existing risks may be retired.

Definitions

Risk identification develops a list of risks that may affect the project. It starts with a clear understanding of the project purpose, objectives, benefits to be delivered, success criteria, constraints, and assumptions, among others. Broad views of appropriate risks should be encouraged. Hence, a tool such as the risk breakdown structure is useful to encourage participants in this process to look beyond their discipline to other sources of risks.

Purpose

Risk identification defines all possible risks that are knowable at the time of the exercise. The risks need to be identified for us to have confidence that, when we prioritize them for further analysis, we have identified all risks that could be important in particular to schedule risk during qualitative risk analysis, quantitative risk analysis, or to risk planning.

Risk identification results in an unordered list of possible risks, although the risks may be grouped by sources such as technical, external, organizational, or deficiency in project management.

Default Condition

Every project should include risk identification as defined in the *PMBOK® Guide*. Risk identification is practiced continuously, or at least periodically, during the project, since more risk is revealed as the project progresses through its life cycle. Project risk should be discussed in all staff meetings, and project managers at each level of management should be able to discuss their top five risks to the schedule at any time.

Best Practices

The risk identification process determines the risks to the project and specifies their characteristics. Sources of risk may be in the assumptions (explicit or implicit) that are made. Schedule risk may arise because the project schedule is planned to an unrealistic set of time-cost-scope-quality objectives. External risks may arise from markets for equipment, materials, labor or even subcontractors, regulatory, or myriad other sources.

The requirements of the project may be unclear, incomplete, or changing, so the sponsoring or performing organizations may not be able to make timely decisions, and technical advances required may not be assured. Even poor project management may be the source of project risk—for instance, if planning is done without a work breakdown structure, scheduling discipline is not adequately applied, the schedule is built on optimistic assumptions, or the project management team does not sufficiently or effectively lead the team.

Risk identification takes many possible sources of risk into account. Often engineers like to talk about their technical issues, completely missing other risks that are external to the project or come from the organization itself. One of the difficulties of risk identification is that it relies on information from people using their expert judgment, and expert judgment is not always unbiased. Lessons learned from prior relevant projects can also be sources of possible risks, as can checklists compiled from earlier projects. The risk breakdown structure is a method for encouraging people to think outside of their own discipline to other risk sources. Another tool is the strength-weakness-opportunity-threat (SWOT) analysis that points people toward opportunities as well as threats, and also focuses on organizational weaknesses as well as strengths. (See the *PMBOK® Guide* – Fifth Edition [PMI, 2013], Section 11, "Project Risk Management," which mentions some of these techniques.)

The result of risk identification is a list of risks that are clearly stated. Risks need to be distinguished from their causes and the effects that may result if they occur. This sentence structure can be used to describe the risk: because (the cause) exists, (the risk) may occur, and if it does (the effect) will happen. For instance, we do not say "we have a schedule risk." That is calling the risk by its impacted objective. A better approach would be to say: "Because the technology is challenging, the engineering design team may not be up to the task, leading to a delay in creating the final design." In this sense, a technical cause interacting with an engineering team risk, if it occurs, has a schedule risk impact.

Recommended Practice

It is recommended that risk identification be conducted as early as possible in the conceptual stage of the project and continuously throughout the project life cycle. Project team members are clearly important sources of project risk identification knowledge. Others such as management and discipline leads who have experience can also be useful sources. People who have done similar projects but are not assigned to this project should be consulted, since their perspective may lead to new and unbiased information. Contractors may be helpful in the risk identification process, but they have some contractual biases that should be recognized by the owners.

Often risk identification workshops are conducted with large groups of people, but interviews of individuals and small groups can also be effective in gathering risks. It is useful to have a facilitator with knowledge of the project and the industry, as well as the risk management discipline, to conduct these sessions.

Risk identification should be conducted frequently, since new information can lead to a better appreciation of the risks, or recognition of risks that had not been imagined before.

In practice, risk identification and qualitative risk analysis are conducted together, although they are separate actions with distinct deliverables. Risk identification delivers a list of possible risks stated in the structure of *cause, risk, effect*, whereas qualitative risk analysis results in prioritized risks that can lead to further quantitative risk analysis or risk response planning.

Advisories

Risk identification needs to be done without bias in favor of, or jeopardizing, the project objectives. In some organizations the corporate culture is such that risks are not often discussed, and some risks are not permissible topics. Unfortunately, the organization is often biased in favor of the project, so some risks are just not allowed into the conversation. We cannot have a good project risk management culture if it is not possible to talk openly and without fear of retribution about real project risks.

3.12.3 Qualitative Assessment

Qualitative assessment of the schedule risk is usually viewed as a quick and inexpensive approach to identifying the risks that are important to mitigate in order to achieve schedule success. The qualitative approach does not provide the discipline and does not actually use the project schedule in coming to its conclusions. However, for many projects this analysis can highlight the important risks to a project's schedule.

Guidelines

Definitions

Qualitative risk analysis of the schedule is part of qualitative risk analysis. It takes the undifferentiated list of potential risks to the project from the risk identification process and characterizes their probability of occurring and impact on the project schedule if they do occur using ranges of probability (e.g., 40% to 60%) and impact (e.g., from 10 to 20 days' delay). Typically the interviewees' qualitative judgment is used for these calibrations, rather than reference to the structure of the schedule or where the risk may impact the activities' durations. (Parallel analyses are conducted simultaneously with respect to other project objectives such as cost, scope, and quality.) Then, based on the project manager's or other stakeholders' (e.g., customer, owner) view of those combinations of probability and impact that make a risk to schedule "high" (as opposed to "moderate" or "low"), the risks can be prioritized as "red," "yellow," and "green" risks to the schedule.

Purpose

The purpose of a qualitative schedule risk analysis is to compile a list of those risks that are thought to be important to jeopardizing the success of the schedule, and to distinguish those from other risks that may be more important to other project objectives but not to the schedule. This distinction allows the risk analyst to answer the question: "Which risks are most important to watch or mitigate to protect our completion date?" This list of important risks to the schedule can be used in a quantitative schedule risk analysis or directly in a risk response exercise. The qualitative risk analysis deals with individual risks one at a time and cannot provide an estimate of the likelihood of overrunning the total schedule, nor of how much overrun there might be. Answers to those questions are found in quantitative risk analysis.

Default Condition

Qualitative risk analysis is practiced when the project does not yet have a detailed schedule but participants have a subjective "feel" for the risks' importance to the schedule. Also, it is practiced even if the program team proposes to progress to quantitative schedule risk analysis so that the results of qualitative schedule risk analysis can be used as inputs to the quantification of schedule risks.

Best Practices

Qualitative risk analysis does not use sophisticated computer analysis software (e.g., Monte Carlo simulation) and it is not precise (e.g., it lumps probabilities and impacts into ranges as described above). This does not mean that qualitative risk analysis is not disciplined. In fact, a disciplined qualitative risk analysis of the schedule will use interview or group data-gathering techniques, being alert to and diffusing the presence of bias in the assembled group for the highest-quality data. Each risk identified will be assessed applying the same ranges, and those ranges will be set in advance by the project manager, perhaps in consultation with other stakeholders. In this way the project schedule risks will at least be ranked in an ordinal sense (as in, this risk is more important than that risk), although it is debatable whether the difference between risks can be calibrated in a cardinal sense (as in, this risk is twice as important as that risk). So for qualitative risk analysis the risks can be compared because the analyst has used good data collection methods and definitions consistently applied to each risk.

Qualitative schedule risk analysis can be applied well before the project schedule has been developed if the participants are knowledgeable about the project and the environment within which it is being conducted. It is usually faster to conduct than quantitative risk analysis. For small or repetitive projects the exercise of talking about risks improves the project management team's possibility of effective risk mitigation.

All successful application options consider the two major dimensions of project risk: the risk's probability of occurring, and its impact (here, on schedule) if it does occur. They also rely on the constancy of the definitions used in data collection. Collecting qualitative risk data requires sophisticated data collection techniques in some respects, such as identifying individual or group biases.

Qualitative schedule risk analysis requires that the impacts of each risk be recorded for each objective of time, cost, scope, and quality. This provides for definitions of impact ranges that apply to the objectives specifically, defining the meaning of "very low," "low," "moderate," high," and "very high" impact. Different probability and impact matrices (sometimes known as "red-yellow-green" charts or "5X5 charts") for each objective may also be used. The project stakeholders, often represented by the project manager, decide all of this with the overall perspective of the project, where the project fits with other organizational objectives, and other strategic considerations.

Qualitative risk analysis does not require specialized software, although software exists that will permit effective displays for presentations, assessment of risks over time as risk mitigations are planned, and recordkeeping to easily identify the risk owners, risk action owners, and time frame for risk mitigation. These packages are generally marketed as risk register software.

Recommended Practice

The preferred application method is described above. It deals with the project manager making definitions that are applied across each risk during risk interviews or workshops that are as free of bias as possible.

Advisories

Avoid trying to conclude anything about total schedule risk exposure; this is provided by quantitative schedule risk analysis.

- Do not conduct a qualitative risk analysis where the risks' impacts to specific objectives are not sorted out, or are combined in the definitions of impact ranges.
- Realize that risk to the project may not be risk to the schedule, and vice versa, so that a risk may be green for scope, red for time, and yellow for cost (or other combinations). Identify the risks to each objective separately, using the same probability, but in each case also using the definitions of impact on specific objectives.
- Avoid trying to do qualitative schedule risk analysis without definitions. Some have said: "I think the impact is low (or moderate or high)," but when asked about the definitions of those terms they have admitted that definitions do not exist. The "I know it when I see it" approach is completely subjective, not disciplined, and cannot provide useful answers to any questions.

3.12.4 Risk Event Drivers

The focus on risk event drivers represents our getting "back to basics" by using the identified risks to drive the analysis of schedule or cost risk. Using risk drivers means that the *risks are used directly to drive the uncertainty in activity durations*. This allows us to describe risks by both their probability and impact, which is the most logical way to describe risks. It also allows us to directly use the risk register that contains the list of prioritized risks, so that qualitative and quantitative risk analyses are clear and related.

Contrast the risk driver's method with the most common approach that uses three-point estimates applied directly on activity durations. A lot of risk analysis starts with the *effect of risks on the activity durations* (or estimates of costs) by specifying a three-point estimate range of optimistic (or low), most likely, and pessimistic (or high) values. This has been a serious criticism of the traditional way that quantitative risk analysis is practiced, pointing out that it focuses on the effect of risks rather than on the risks themselves.

The problem with the traditional three-point estimate approach is that it represents the effect of all of the risks on the activity's duration, but does not distinguish the various causes of that uncertainty separately.

- Since the combination of the risks' effects on activity durations is potentially a complex interaction of perhaps several different risks, each with their own values of probability and impact, the calculation of the duration's three-point estimate must be done using mental arithmetic rather than modeling how those risks interact. This proves to be difficult in practice.
- Since the result of the mental calculation combines impacts of various risks, there is no way to untangle those individual risk influences when we want to estimate the influence on the schedule of an individual risk. Their impacts are combined in ways that are probably not understandable, repeatable, and useable in the three-point estimate.

- Since a risk may affect several different activities' durations, there is no way to capture the whole impact of a risk across activities by specifying three-point estimates one activity at a time.
- Experience shows that the three-point estimates that are entered into the risk analysis are not actually carefully computed from the basic information about risks. Rather, the respondents (interviewees, risk workshop participants) will "eyeball" the numbers and compare later three-points with earlier ones and adjust, but without reference to the underlying risks. In fact, the risk register, where the risks are listed, described, and prioritized is frequently not used during these data collecting interviews.

Guidelines

Definitions

Risk drivers are the fundamental risk factors that cause project objectives to be uncertain and project plans to be difficult to maintain. Risk drivers are those risks that arise from technical, external, organizational, or other factors,[1] causing activity durations to be uncertain or causing the project to have activities not included in the baseline project schedule. Risk drivers are often identified by risk identification, prioritized by qualitative risk analysis, and included in a well-formed risk register.

Risk drivers are the root causes of project uncertainty. Unless we can identify, quantify, and prioritize the risk drivers, we will be inefficient in determining risk responses. The risk drivers need to be identified in order to develop effective strategies to handle them. We need to maintain the distinction between risk drivers, their causes, and their impacts.

- The causes can be specific, such as "the ore deposit is found in the Amazon in Brazil." This is not disputable, nor is it uncertain or changeable, since we cannot move the ore deposit just because there is no transportation in or out of the deposit area. Offshore oil deposits can also be "causes" because of the depth of drilling necessary to produce the oil.
- The risk driver is a factor that has some degree of uncertainty, either less than certain likelihood of occurring or uncertainty of severity of impact on activity durations if it were to occur, or both. For instance, the risk driver could be: "Logistics getting to the jungle ore deposit may be more difficult than we planned for," or "The technology for deep-water drilling is not yet mature, so there may be starts and stops in implementing a drilling program."
- The effect of a risk's occurrence is the impact of that risk on the schedule or cost of the project. Thinking in terms of the traditional specification, the three-point estimate is an effect, not a risk. It is an intermediate effect from which the total schedule risk can be derived. Traditionally, we have derived the total effect on project schedule from the intermediate effect of risks on activity durations (the three-point estimate) *but not from the risks that cause that intermediate effect.*

Purpose

The purpose of using risk drivers rather than traditional three-point estimates is to derive the overall total schedule risk directly and clearly from the risks themselves. This is what is meant by "back to basics." The basic relationship is from the individual risks through the schedule to total risk of overrunning the scheduled delivery dates. Any device that is inserted between the basic risk and the total schedule risk confuses the method. The model needed is the project schedule, with its activities and logical relationships. When risks drive activity durations through the model, with its logic, float values, parallel paths, and merge points, their individual impact on the overall total schedule risk can be documented. Since individual risks' influence on the total schedule risk, say at the 80th percentile, can be estimated, prioritizing risks can lead to efficient risk responses, making the risk model with risk drivers into a tool for improving the possibility of achieving project schedule success.

[1]The risks can arise from many different root causes. See the definition of the risk breakdown structure in the *PMBOK® Guide* – Fifth Edition (PMI, 2013), Section 11, "Project Risk Management."

Default Condition

Any time the project schedule is uncertain because of individual risks we need to know how the individual risks lead to overall project uncertainty. The best way to find that out is to specify the risks as drivers of total schedule risk and to let the simulation of the schedule determine which risks are most important to the possibility of overrunning schedule.

Best Practices

Some of the most important requirements for the risk driver's method include:

- One of the important requirements was the ability to characterize risks by their probability as well as their impact, since a project risk is "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives" (*PMBOK® Guide* – Fifth Edition, PMI, 2013, p. 310). Risks are important both because of their probability and their impact. The older approach, putting three-point estimates on activity durations, does not provide for the risks' probability of occurring, just their impacts. If the probability of occurring is less than 100%, say 40%, then the risk occurs on 40% of the iterations chosen by the computer at random. In the other 60% of the iterations, the risk does not occur and the activity durations to which it is assigned are unaffected.
- Another important requirement was that risks should be assignable, potentially, to many activities, and those assignments should be made obvious to the client. If the condition that causes the risk, say construction productivity, may differ from that assumed in the baseline, several schedule activities will be affected. This means that any risk can be assigned to more than one activity, and any activity may have more than one risk assigned, but these assignments are clear and transparent to the user of the method.
- Of course activities' durations can be affected by several risks. During the simulation a probability distribution of each activity's duration is generated from the impacts of all assigned risks with their probabilities of occurring, and risk range factors if they do occur. Instead of using mental arithmetic, resulting in three-point estimates to determine these probability distributions, the distributions are generated as it occurs in real projects from the interactions of all assigned risks.
- A third requirement was that the impact should be to reduce or to increase the durations on the activities to which it was assigned. Hence, the risk factor could be, for instance, .90, 1.00, and 1.15 for low, most likely, and high impact.

These points become important because in sensitivity analysis we must capture the full extent of the risk's impact which may extend to its impact on many activities. With the traditional three-point estimate, the risk on one activity is not linked in the software to the same risk's impact on any other activity. (This has to be done in three-point estimating by using correlations between activities' durations, which is notoriously-difficult to calibrate.) In our approach, correlation between activity durations arises automatically during the Monte Carlo simulation. Since some risks affect two (or more) activities, those activities become correlated. The strength of correlation between two activity durations depends on the presence of risks common to the two activities, and the presence and strength of risks that are not common to the two activities. Essentially, correlation is modeled so there is no fear of inconsistent correlation matrices.

When the risks are all calibrated and assigned, they allow us to generate by computer the ranges of the durations of activities that are in the schedule. But, what about activities such as unavailability of the fabrication yard or failing a qualifying test that causes new activities to be required? A risk may cause recovery activities to take place, activities that are not usually included in a baseline schedule. These can be handled by standard probabilistic branches or existence activities. Also, duration estimating uncertainty due to a lack of mature data can be handled using standard three-point estimates, since its probability is 100%. We can combine all the methods with the risk drivers method as appropriate in our analysis.

A key strength of the risk drivers method is that when we derive the risk results, we can also run sensitivity analyses to determine which individual risks are most important in generating the schedule risk. The way we do this is by reducing the probability of a risk to zero and rerun the simulation. When the probability is set to zero that risk has no impact on any of the activities to which it was assigned.

Recommended Practice

There are not many simulation software packages that can be programmed to use the risks to drive the uncertainty in the durations of activities that exist in the schedule. At present, Primavera schedule risk (previously Pertmaster) has implemented the risk factors module to do this. Some other software packages can also be configured to do this using macros.

The recommended practice is to start with the project risks, usually found in the risk register, then specify their probability and impact range (in multiplicative terms so they can be assigned to long and short activities appropriately), and assign them to the activities they will affect if they occur. Then, if a risk occurs on an iteration, the durations of all activities to which it is assigned will be affected. An activity may be affected by multiple risks, although it is important to determine whether the risks will occur in series (tip-to-toe) or in parallel.

The risk drivers method shows exactly which risks are important, how those risks are calibrated with probability and impact, and which activities they impact. Because the risks occur within the structure of the CPM schedule, the importance of each risk depends on where the assigned activities occur, whether on the risk critical paths or on risk-slack paths.

Because the risks are driving, we can neutralize the impact of a risk by setting its probability to zero. Rerunning the simulation, we can calculate in days saved the impact of specific risks. This approach allows us to prioritize the risks, providing management with a list of the most important for risk mitigation exercises.

Advisories

Driving the duration of schedule activities with risks is not the same thing as using the growing number of risk register capabilities in schedule risk analysis. These risk register capabilities generally introduce new activities into the schedule with their probability and duration range. These are existence or probabilistic branch-type risks, not risks that drive the duration of existing activities. There is a place for the risk register or existence risks as well, since most schedules are success-oriented, and the conditions under which the risks exist often cause recovery-type activities to be added.

3.13 Schedule Finalization and Buy-In

Guidelines

Definitions

Schedule finalization and buy-in refers to the culmination in the development of a project schedule and occurs prior to establishing a project baseline schedule. The process should involve all of the project stakeholders, including the project manager, key project management staff members, and the owner of the project, as well as designers, subcontractors, and suppliers. The buy-in becomes a milestone for the project where all of the project stakeholders accept and agree to the project schedule.

Purpose

The purpose of getting final schedule buy-in is so that all stakeholders on the project can agree on the timeline for the project based on a specific scope, prior to its start. This will lead to the establishment of the baseline schedule and provide the basis for measuring project performance. It also identifies the project scope and becomes another tool to track change control.

Default Condition

Every project, regardless of size, should seek out and obtain final schedule approval and buy-in prior to starting work. This will ensure that all project parties are working from the same plan to accomplish the project within the agreed time frame. The buy-in bonds the project team with a common objective and the method to achieve it.

Best Practices

Once the project is approved, or bid, the effort of developing a project plan and schedule begins. During this development stage every effort should be employed to seek out and engage all of the significant contributors to the project, the entities responsible for actually performing the project evolutions. This will ensure that the team considers all aspects of the project and the interdependencies of each phase. Once a rough draft is developed a joint review meeting should be conducted with as many of the stakeholders as possible. The objective of this meeting will be to explain and visualize all of the interface roles and dependencies, review the durations of the activities, and the resource requirements for the resulting schedule, and determine if any aspects are missing or understated. The owner or major stakeholder should also be present in this meeting, if possible, so that they will begin to understand the interdependencies and relationships being developed.

The outcome of this meeting will be a set of revisions that, once incorporated into the schedule, will result in a draft ready for completion of the schedule development, recognizing that the schedule has tentative final approval and buy-in. During this final buy-in process it is often good to have all of the stakeholders sign a summary-type report of the final schedule, to publically display their commitments and buy-in. This also has the added benefit of galvanizing the project group to a single objective as the project moves into its next stage—implementation.

Once schedule development is complete, with all quality control implemented, the final schedule should be compared to the draft schedule with tentative approval, and alignment assured with that draft. If the completed schedule was developed in compliance with the draft schedule, the approval is still secure. If there were changes made during the quality control process in completing the schedule, another submission for approval should be made, with all revisions identified and explained.

Recommended Practice

When developing the project schedule, ensure that all of the various organizations responsible for implementing portions of the project are involved.

Ensure that each stakeholder has input to the schedule, adequately defining their role in the project within the schedule.

Extra attention needs to be devoted during planning for interface or handoff points from one group to another. In a similar manner, convergence areas where multiple paths or sequences of events come together are also in need of extra scrutiny. These areas are extremely important to the ultimate effectiveness of the schedule.

Conduct review meetings with the project management team during the schedule development phase to ensure compliance with the team's identified needs. Experience has shown that when groups review the schedule together additional interface points are discovered, and studies show that this improves the quality of the schedule, raising the rate of success. This should make the final approval meeting easier and shorter.

For the final approval meeting, submit the completed developed schedule as noted above. It is important to have the stakeholders and implementers approve this schedule, and many projects have the team members physically sign the final schedule to represent their buy-in. This serves two purposes: first, people generally do not sign something they do not think they can do; second, it shows the other project members that they have committed to the project objectives.

Display the signed document for the team to see as a re-enforcement of the team's commitment to the project.

Advisories

Ensure that all parties responsible for project efforts are involved. Do not develop the schedule in a vacuum back at the office. Seek out and engage the parties who will be doing the work.

Ensure that the stakeholders sign and agree to the project schedule. Often, when asked to sign a document, additional issues will be discovered. These could change the schedule or define assumptions that alter scope.

If the interfaces between groups, the hand-off points, are not understood and adequately planned, the project schedule will most likely fail.

In a similar manner, if project areas of convergence are not adequately covered and understood, project problems will arise.

It is recommended that project work not start until the schedule is finalized and buy-in achieved.

3.13.1 Schedule Philosophy and Theory

Whether or not the schedules are approved, as long as they are used for management and implementation on the project, those schedules will need to be addressed in any conflict or dispute analysis. The use of a formal schedule approval process allows the owner to provide input to the contractor, and generally helps achieve a better and more reasonable schedule for the project. The owner's review also exposes risks to the project from the schedule, so it's an important effort.

Merely accepting the baseline schedule does not suffice to reduce the owner's risk of accepting responsibility for means and methods. Rather, it increases the risk that the project will not achieve success. Studies show that owner involvement in schedule review is a factor for success.

If the owner reviews the schedule from a technical perspective, supported by good scheduling specifications, and provides feedback in the form of comments and suggestions for improvements, and the contractor implements the good recommendations, the schedule will have a higher quality and be more useful and "accurate" as the benchmark for progress monitoring and analysis of any changes or delays.

3.13.2 Organizational Schedule Philosophy and Theory

The organizational schedule philosophy and theory becomes a critical element in how schedule management will be implemented and infused within the organization.

Guidelines

Definitions

The schedule philosophy and theory are the guidelines and infrastructure that are used to employ schedule management.

Purpose

The purpose of espousing and following a schedule theory or practice is to formulate the ground rules that can be followed to implement a successful schedule management plan (SMP). A successful SMP will help ensure a plan that is viable, includes the scope to be achieved, and is executable.

Default Condition

This schedule philosophy would be used by any organization that is committed to ensuring the success of their projects or programs. The schedule, in addition to a vital planning tool, is the primary communication tool on the project and supports project controls to minimize cost and time overruns, while achieving project goals.

Best Practices

The topic of scheduling is an overall philosophy that takes on a life of its own based on how an organization will embrace the concept and prioritize its use throughout its membership. Scheduling in general can mean many different things to different groups and individuals based on their previous experiences and uses. A schedule best practice is the full use of a comprehensive schedule management plan. This would encompass the full use of schedule development and advanced schedule analysis, with the culmination of schedule risk assessments to determine the probability of meeting critical delivery dates.

Organizations that can embrace the topic of scheduling and its use in their respective organizations can reap the benefits and return on their investment. In many instances, the practice of schedule management becomes a core value that is embraced on fulfilling the organizational need for successful projects.

Recommended Practice

The preferred application method is for a formal implementation of a schedule management infrastructure. The SMP provides direction and helps ensure that good scheduling, including the range of phases, schedule design, schedule development, schedule maintenance, and schedule usage, supports the project goals throughout the project life cycle.

Once an organization understands the value and benefits of having a fully operational schedule management infrastructure, they can then move to the next maturity level in schedule management. The schedule management system example provides a glimpse of identifying a core schedule infrastructure. This allows for an understanding of how it can foster the development of customized software solutions, new tools, and approaches within the schedule community. These approaches provide a channel for lessons learned and can be infused into solutions for customers and internal teams**.**

Advisories

A shallow effort to provide scheduling simply to meet a project requirement will not achieve the robust and useful schedule philosophy that improves performance. A schedule management system and infrastructure should be implemented based on full support from senior leadership of the organizations.

In addition, a grassroots effort to implement and infuse the importance and benefits of schedule management can also be implemented successfully, if the project management team is fully bought in to the benefits of the SMP and supports implementation of a good scheduling operation based on the schedule philosophy.

3.14 Reporting Level of Detail

Guidelines

Definition

The level of detail describes the amount and depth of information that should be included in the reports issued to different stakeholders. As explained earlier, different stakeholders have different needs and the different schedule reports should be tailored according to those needs. Reporting to senior management is usually different than reporting to the customer and/or reporting to the on-site project team executing the work. Senior management reports should be brief but formal while reports to the on-site project team will necessitate much more details, explanations, and an in depth-analysis.

Purpose

Defining the proper level of detail falls within the context of implementing the correct communication strategy. A message heard is a message well communicated. While most issues found in the schedule are worth reporting, it might be deemed necessary at times to report these same issues at different level of detail in accordance with the report's intended audience.

Default Condition

The choice of reporting detail is mainly dependent on the type and intended purpose of the message and, most importantly, the type of stakeholders that will receive it. At any time when message type, message purpose, and stakeholder audience varies, the reporting level of detail should be redefined and/or rechecked for accuracy.

Best Practices

Keep information to the required level of detail. Don't give out too much or too little information. The key is to provide enough information. Constantly watch for cues and feedback to your issued reports. Most of the time a comment, remark, or question asked in a specific manner will clearly indicate ambiguity in the information presented, missing information that might be of interest to the recipient, and/or a more elaborate level of detail is needed by a certain stakeholder. As an example, senior management personnel may ask for more details on the schedule recovery efforts during a period of time when the project is suffering from chronic underachievement while these same personnel might not be interested in hearing about the same topic in detail when all is proceeding according to plan.

Recommended Practice

A general rule of thumb is to report according to WBS levels. For executives and upper management, reporting on WBS levels 1 or 2 is most adequate, while reporting to on-site team might be more adequate at levels 2 or 3 of the WBS.

Advisories

Unsuitable detail level in reporting leads to misunderstandings, misinterpretations, and false impressions. In turn, this might lead to uninformed decision making and could have adverse effects on project outcome.

Section 4

Schedule Maintenance

Maintaining the project schedule requires continuous effort to ensure the current schedule closely resembles the project's current scope, activity sequences, activity durations, as well as other parameters such as resources and costs. The periodic review of the project schedule and input of activity progress is termed updating and/or statusing. The schedule update is a record of past performance and relates the impact (positive or negative) of past performance upon anticipated performance. An important aspect of the update is to gauge whether progress on the project is meeting expectations, exceeds expectations, or is slipping and, given the status, determine actions, if necessary, by one or more of the project stakeholders to meet the overall project objective. The schedule update benefits the entire project team and stakeholders.

4.1 Schedule Maintenance Process Overview

The object of updating the schedule is to capture physical progress, current sequences and logic, duration changes, and scope changes to provide a snapshot of the project at a particular point in time so that contemporaneous schedule information can be used by the project's stakeholders in managing all aspects of the project at the time of the snapshot.

The Status Update Process

The update process requires several steps involving data acquisition, reviewing results, and finalization. It should be prepared utilizing information from the project personnel who are most knowledgeable about the project (preferably on-site field supervisors and/or managers), but organized and managed by a qualified scheduler. Specifications for Critical Path Methodology (CPM) scheduling are usually developed by the owner or design team consultant, dictate the scheduling requirements for the baseline schedule and periodic schedule update submittals, and may include specifications for acceptable practices, reporting requirements, time extension request methodology, and anticipated weather days. If CPM is not a contract requirement, but a contractor elects to use it, selection and specification of the CPM approach is the contractor's option. Contractors, in this case, may decide to hire a third-party consultant.

4.1.1 Data Acquisition

Typically, in a traditional delivery system, the general contractor (or the construction manager) has the responsibility of updating the schedule. Capturing schedule update information is usually accomplished by a representative of the contractor who physically walks the job and validates the work in progress. In addition, to further support the updating process, schedule information such as remaining duration of an activity may be obtained from interviewing the individual with the most intimate knowledge and who is closest to the day-to-day events occurring in the field, usually the project supervisors. Discussions with superintendents have the advantage of bringing any schedule concerns to the attention of the scheduler and the project manager. Schedule data obtained from walk-throughs and discussions with supervisors and other appropriate field personnel may be most useful if performed on a frequent, periodic basis in order to capture the changing nature of the critical path and the contemporaneous plan. On a typical construction project, this might be weekly, even if formal schedule updates are performed monthly.

Current software is capable of recording and capturing activity data using a variety of formats and attributes to describe it. Sources for preparing the schedule update need to be consistent with the entire project record. Aside from walking the project, other commonly found sources are available on a typical project:

- Procurement records
- Daily reports and job diaries
- Meeting minutes
- Tracking of contract milestones
- Progress charts, schedules, and reports
- Correspondence and memoranda
- Inspection reports
- Change order files
- Requests for information
- Photographs
- Weather reports
- Shop drawing logs
- Submittal logs
- Cost and budget records
- Non-compliance logs

Parallel with updating the installation and physical progress is the procurement process, which includes the preparation of submittals, architect/engineer approvals, fabrication, and delivery of materials or equipment. Procurement is usually the responsibility of a project team's contracts manager. Often scheduling specifications require the procurement activities to be included in the schedule, and this is important since procurement often causes delays to the project. The number and types of procurement activities included in the schedule should be discussed with the schedule reviewer and agreed on within the first few weeks of the schedule development effort. Certain types of projects, especially industrial projects with large equipment needs, may require additional software to support the schedule. To update procurement activities in each update, phone calls to the vendors confirming actual progress and/or anticipated delivery dates should be made to support the activities representing the start of installation. Special attention should be made to material/equipment deliveries of activities that are critical or near-critical, or those that have long lead times.

4.1.2 Review of Durations and Sequences

Activity durations are initially established by considering the combination of quantities and the contractor's resources used to determine productivity (crew size, equipment, formwork, material, and so forth) that are available to perform the activity, tempered by the project team's experience. Activities that are in-progress should be updated by estimating the remaining duration of an activity for monitoring of time, not by estimating a percent complete, which is used to monitor costs of performance. A superintendent can easily determine how much time is remaining to complete a scope of work versus taking a guess at the percentage of the work that is complete or remaining. In-progress activities may need to be adjusted based on the amount of resources committed to the activity, or based on the current productivity of the resources. Remaining duration should be based upon the time necessary to complete the work logically holding up the substantial start of the successor activity and allowing that activity to continue without interruption. Therefore, it is important that activity durations are regularly reviewed and validated to ensure they are in line with current and forecasted resources.

In reviewing a schedule's sequencing, activities should be sequenced to reflect resource apportionment and crew flow from one area to the next. For instance, when one crew (resource) is being utilized to perform many similar activities, these activities should be linked in an organized sequence to reflect that one crew—or multiple crews, if necessary—is performing the work. Additionally, when several crews are performing similar activities, these activities should have separate linked sequences equal to the number of crews performing the work. Activities should be logically connected and coded to reflect the crew (resource) performing the operation.

4.1.3 Logic Changes

Logic and sequence changes are typically addressed after incorporating actual progress achieved since the last update. Consequently, it often addresses out-of-sequence activities where activities have been started and/or completed before their predecessors have been completed. Out-of-sequence work that impacts the critical or near-critical path should be reviewed carefully and corrected to allow appropriate network calculations.

In this manner, the contractor's progress can be accurately measured against its prior approved forward-looking plan for construction, which is generally the previous update if it matches contractual requirements or the formal baseline schedule. Revisions or changes in logic should be made if the contractor chooses to perform the work in a modified approach as compared to the one originally envisioned. Changes in sequence are inevitable due to a variety of reasons such as differing site conditions, inaccurate drawings, response to owner-directed changes, labor issues, or changes in means and methods.

The schedule should reflect real-time conditions of the project. Changes in sequencing, resulting from modified work scope and/or contractor means and methods, delays, and disruptions always need to be reflected so that the schedule can be used as a management tool to guide the work toward a timely completion. One way to accomplish this is with an as-built schedule as the work progresses by recording the actual sequence and resultant logic changes if different from the planned logic as the work progresses.

4.1.4 Revisions versus Routine Maintenance

It is important to differentiate between a revision to the schedule and maintenance to the schedule. Maintenance to the schedule includes the minor changes necessary to keep the schedule as a good model of the contemporaneous means and methods, and generally does not require a resubmission to the owner for approval. Maintenance is important to keep the contemporaneous schedule as a good benchmark for analysis of delays, trending, and completion predictions.

A revision includes changes to the schedule to reflect changes in the project plan, and is much more extensive than maintenance. A revision alters the contemporaneous schedule, often changing the predictions of critical path and near-critical path work, which significantly alters analysis of the schedule. Revisions generally need to be resubmitted to the owner for approval because they may change planning and dates relied upon by the owner after baseline schedule approval.

The purpose of a revision to the schedule is to insert intentional changes to the existing plan, either to account for changes to the project or improve upon the previously chosen means and methods. Typically a revision to the logic is not required for a simple deviation from the plan, as long as the contractor's overall objectives are to continue with that plan.

Consider the example of a contractor installing a glass curtain wall system on a high-rise office building, where the original baseline schedule reflects installation beginning along the north elevation and progressing in a clockwise manner. The contractor begins work and progresses as planned, when suddenly design changes are required along the east elevation, where the contractor is next scheduled to mobilize. The design change will prevent work from starting at the east elevation for two weeks. Due to this impact, the contractor now has to work counterclockwise and remobilize crews into the west elevation. Moreover, to offset this two-week impact, the contractor also has to deploy additional resources, with a second crew starting at the south elevation and working toward the east.

To address these changes in sequencing and their resulting overall impact to the project's critical path, the schedule's sequencing should be revised. In addition, the original resource and cost loading conditions for the affected activities have to be revised as well.

Obviously, this example is one of a major change in sequencing that may not only impact the contractor's means and methods, but also the resource allocation. Revisions to the schedule to accommodate changes in sequence should be inserted after the schedule has been statused for the progress achieved since the last update. A separate forensic schedule analysis allows a scheduler to distinguish the cause of impact that may have delayed the project's completion date, if any. (See Section 5.2, Routine Schedule Analysis.)

Another type of sequence change involves crew movement. In the typical linear schedule approach, it is assumed that each activity has one or two allocated crews, and those crews will simply move on to the next scheduled task in series upon completion of the previous task. However, when more work needs to be accomplished in a shorter time span, the contractor may employ additional crews working in multiple areas simultaneously and in sequence. Similar to the previous example, the schedule is modified accordingly to reflect these changes in sequencing, all the while mindful of resulting impact to the schedule's critical path and forecasted completion date.

A third type of sequencing that does not receive much attention, but is important, pertains to constructability restrictions. During the development of a project's baseline schedule plan, consideration should be made not only in terms of the contractor's intended means and methods approach, but also to the constructability of the project.

Many types of constructability restrictions are inherent within the overall project that require consideration while preparing the schedule update: hot/cold weather, design-related work area access, utility restrictions, local agency and environmental issues, traffic control, and physical constraints. The schedule's sequencing should account for these types of restrictions to reflect planned and expected area crew/equipment movements in producing accurate and reliable forecasted schedule dates for all follow-on work.

4.1.5 Change Orders

In the typical construction contract, the owner reserves the right to make changes in the work, and, in addition, contractors face differing field conditions that necessitate a change in activity scope, duration, or sequence. The change order clause in the contract may require the contractor to have a fully executed change order before starting the change order work; however, in some contracts the contractor may be allowed to start work before the change order is executed.

Also, it may be necessary to maintain the schedule in two versions (i.e., the contract schedule and the time impact analysis and a projected schedule with the change order work activities included) at the same time to address the impact a change order may have on the current schedule. A copy of the current schedule update should be created that reflects the status of the project at the time the change order was first identified. Change order activities would then be added to the current updated schedule in the form of a time impact analysis (TIA) to assess the impact on milestone completion dates from the change order. (See Section 5.7, Change Management.)

The next step addresses maintenance or revisions to the contractor's plan, which may include logic revisions and/or duration changes that may be necessary due to field conditions, changed conditions, or utilizing a different approach to perform the work. This is an important step in the update process, as it provides the rationale for shifts in the contractor's intended plan of work. However, the contractor must not confuse the revised sequences of future work to act as a TIA, which should be performed carefully in accordance with change management requirements and requires submission and approval of the analysis.

4.1.6 Updating Resources in a Resource-Loaded Schedule

In updating a resource-loaded schedule it is important, just as it is in the development of the baseline plan, to check and confirm the resource parameters and options available within the schedule software. Statusing a project with resources employs a number of preferences and options that may require more than one iteration before finalizing the results.

After the progress data has been incorporated into the schedule and any necessary logic changes have been made, the resource, expense units (hours and quantities), and cost—both the actual to date and to complete—are then updated. To facilitate the process, templates may be created for each of the update categories. Resource values may be automatically updated by the scheduling software from the percent complete, or imported directly from accounting records.

The Resource Leveling Aspect

A project requires resources to execute the scheduled activities. Resources include labor, material, and equipment to execute the work. In the ideal world, resources would be unlimited and always readily available for use. However, resources are not unlimited and the project team should consider available resources. They may also need to adjust activity durations by leveling resource usage and consumption. (See Section 3.11.1, Resource Leveling.)

In a resource-loaded schedule, resource overloads and inefficiencies may exist and should be identified so the peaks in resource demands can be properly managed. Leveling is defined as performing activities at the time resources are available. Resource leveling can be done using a variety of methods through sequence logic changes, constraining activities, or the software's resource leveling function—all of which are viable approaches to forecasting the scheduled start of an activity and, therefore, its completion based on the availability of resources. In the context of using the software's resource leveling function, the process is simple, but should be monitored closely to verify the results and may require several iterations to confirm that the forecasted leveled dates comply with the contract milestones. Note that resource considerations should be similar to those assumed in the baseline schedule development, or explanations for changes should be carefully made.

Normal and maximum levels of resources are typically set at the time of the baseline schedule, where normal reflects current minimum resources needed for the project and maximum reflects additional resources that could be deployed on an emergency basis. Resource leveling may result in a schedule with resource leveled dates after resource leveling techniques are applied. The newly forecasted dates may or may not be later than the late start and finish dates. The resource leveling effort may identify a time period when resource limits are exceeded, and either additional resources should be identified or a revision to the current sequence may be necessary.

4.1.7 Updating Cost in a Cost-Loaded Schedule

De-Link Percent Complete From Remaining Duration

Schedule software typically allows for the option to link or de-link percent complete with remaining duration. The option of de-linking the percent complete with remaining duration allows time (i.e., work-in-place progress) and cost to be updated separately. In some industries, there is a significant advantage when the costs entered can be based on actual costing records (i.e., invoices, job cost reports, accounts payable) and not on construction progress, as the metrics calculated from the schedule costs will allow the actual costs to show a loss, as is not uncommon in a construction project. These actual costing records obtained from the accounting department are a lagging input, not usually available until the month after the incurring of the costs.

However, in many and probably most of the construction sectors, actual costs are not kept and entered into the schedule, but rather the actual costs that are updated are merely the percent complete of activities, providing the comparison of where the schedule costs should be with respect to the planned budget. In this case, the costs have no relationship to the actual project costing records from the accounting department.

Earned Value Management

Earned value management (EVM) is a technique used to monitor the mass volume work in a project in general. While it can be used to analyze subsets of the schedule data, such as critical or near-critical path work, location work, or trade work, it is more commonly run simply on the project data as a whole. It is very important to monitor the critical path, near-critical path, and mass volume work (also called non-critical path work, although it generally includes both the critical and near-critical path work). The critical path work will immediately delay the project. The near-critical path work because will cause a mid-period critical path delay and go unidentified because of the team focus on the critical path work. The mass volume work is the work that will slip and cause severe trade and location stacking at the end of the project. In addition, if the CPM network is not of high quality, it is likely that the float values will be unreliable to force work from non-critical path to near-critical path to critical path such that the updates will be able to identify delays early enough to mitigate. (See Section 5.5, Float Management.)

When used properly, EVM provides the ability to track the progress and status of a project and forecast the likely future performance of the project. EVM technique integrates scope, schedule, and cost and tracks the physical accomplishment of work. It is used to show past and current performances of the project in predicting future performance through use of statistical techniques.

EVM is a science within itself that provides valuable insight into both the cost and schedule performance of a project. See the *Practice Standard for Earned Value Management* – Second Edition (PMI, 2011a) for more information about earned value management systems.

In general, time and cost dimensions can be combined to forecast the rate of spending on a project. If the project is on schedule, the contractor will earn the cost of an activity somewhere between the early finish and the late finish dates.

Earned Schedule

As noted above, when the actual costs are not the real job costs supplied by the accounting department and based on field labor, materials, and equipment records, they are used within the EVM system as simply the percentage of the original budget, modified by changes, that is complete at the time of the update. In that case, which is the more prevalent situation in construction projects, the EVM system metrics related to earned value (schedule variance and schedule performance index) will continue to improve simply because the project is installing costs and the total installed costs are getting closer to the original budget, or the budget at completion as modified by changes.

With this situation, no matter the progress record of the project, at some point in the project life, the metrics start to improve just because more work is put in place, no matter how late it is. When the project is falling behind, the EVM system will provide unreliable earned value (EV) metrics. Walter Lipke invented a process similar to the EVM system that he called earned schedule (ES), which uses the remaining duration records along with the as-built data to determine where the project is compared to where it should be at the time of the update, based on the original schedule. The schedule metrics used by ES are no longer calculated in terms of costs, but rather in terms of the time that the project is late based on the current status.

This makes ES more reliable than EV for projects that are behind schedule, and it is recommended that ES management is included with any EVMS process as another way to provide accurate metrics, especially during periods of schedule slip and time delays, and to ensure on-time completion.

4.1.8 Finalize the Update Status

Once the activity progress data is collected and uploaded into the schedule, the schedule calculates the project status as of the date of the update, referred to as the data date. The newly forecasted completion date is then reviewed to determine the appropriateness of the resultant critical/near critical paths and whether the status of the project is predicting ahead of schedule, on schedule, or behind the contract completion date. The results gauge the contractor's progress achieved to date based on the forecasted activities from the prior update.

Once the update is finalized progress reports are produced that enable project stakeholders to analyze trends and make decisions that best serve organizational and project needs.

4.2 Significance Of The Schedule Update

The schedule update process plays a significant role in understanding the ebb and flow of a project. The schedule, when properly prepared and updated, serves as a valuable tool to:

- Identify the project's critical path or paths;
- Monitor the forecasted completion date during construction;
- Manage resources: labor, equipment, and material;
- Provide "what if" scenarios and a platform to investigate alternative approaches to construction means and methods;
- Forecast the dates of future activities, sequences, and significant project milestones; and
- Measure the impact or potential impact (favorable or adverse) of an event that occurs during construction.
- Assessment of the update's accuracy is significant for project stakeholders.

Recommended Practice

Assessment of the Update

As part of the update process, it is necessary to establish the status of the project at a point in time. Additionally, it may become necessary to determine the amount of time actually lost because of various types of delays encountered during the life of the project, or the amount of time recovered to overcome delays encountered.

With review of the as-built status of the project as part of the first phase of the update (the statusing), the foundation for analysis of the as-planned portion of the schedule is laid. It is important to separate the as-built condition from the as-planned condition of the schedule, since the as-built condition shows any delays that have already been absorbed into the schedule. Analysis of these delays must be done with a forensic analysis methodology. (See the AACE International *Recommended Practice No. 29R-03*, "Forensic Schedule Analysis", for information about methodologies.)

While the documentation and analysis of the as-built condition of the schedule is very important, this is the start of the analysis of the as-planned condition of the schedule. (See Section 5.2, Routine Schedule Analysis.)

Therefore, careful assessment of a CPM schedule update is required and typically includes an evaluation of:

- The forecasted completion date against the contract completion date or the previous schedule update (gain time or lose time);
- The critical/near-critical path (Did activities consume float during the previous update period?);
- Thoroughness and timeliness of added scope resulting from changes incurred through the course of the project's design and/or construction activities; and
- Future sequences of the work (Did the method/sequences change to accomplish the work and were the changes necessary to overcome unforeseen conditions or project changes?);
- Increase/decrease in the amount of work anticipated versus the amount of work actually performed as compared to the previous schedules and (Did the work impact the forecasted completion date?); and
- Compliance with the contract specifications (Did the update follow the specifications outlined in the contract and all required [as agreed] information submitted as part of the update package?).

The measure of progress accomplished for the project and, therefore, measured by the schedule update, occurs during the time period between the previous update and the current update, especially for critical and near-critical activities. Often, changes are made to activity durations of future activities (those activities in advance of the data date), causing them to become critical path activities and potentially skewing the actual progress accomplished as measured in the time period prior to the data date. In these examples, the reviewer should divide the assessment into separate analyses to account for actual progress before the data date, and for modifications to future activities, in order to resolve potential delay issues. Changes made to future activities that revise the critical path introduces elements of a time impact analysis into the update process and may distort the true progress (or lack of progress) accomplished during the update period.

Often, a contract specification may require a measure of delay to be performed contemporaneously and performed through a process called time impact analysis. Its objective is to pinpoint, isolate, and quantify any time impact associated with specific and discreet issues and determine its time relationship to past or current delays. One of the significant aspects of maintaining an accurate schedule update is that a schedule update may be used as the basis to measure project delays. Preparation of time impact analysis is discussed in Section 5.7.2.1, Prospective Time Impact Analysis.

The schedule reviewer should invest in a schedule comparison program if the changes made to the schedule update are not provided as part of the schedule update submittal. Certain contract specifications prevent the contractor from making major changes to the schedule without the owner's consent and/or formal approval. In these examples it may be necessary for a contractor to submit more than one schedule update and would require the reviewer to examine the project status of the unmodified version against the version with the major changes applied. Specific reasons for making major changes should be included in the update submittal package.

Aside from an evaluation of the critical/near-critical activities, an assessment should also include changes made to the schedules, such as:

- Added/deleted relationships, activities, constraints, calendars;
- Increased remaining durations;
- Construction accomplished, as reflected in activity progress;
- Accuracy of actual dates and/or forecasted dates; and
- Resources levels and/or requirements.

4.3 Approval/Acceptance Of The Update/Schedule Meetings

Under certain contract specifications, the owner must approve/disapprove the contractor's schedule update submittal, and often the owner's action may be tied to payment of the requisition. Typical reasons for an owner's disapproval of a contractor's schedule update include, but are not limited to:

- Non-compliance with the schedule specifications;
- Inaccurate data, i.e., actual dates or forecasted dates; and
- The contractor's use of the update as a time impact analysis, as opposed to a progress report.

Some owners will never approve the update because they don't want to, on the supposition that approval means acceptance and the sharing of risk associated with the project—especially if the project is behind schedule and the owner is potentially at fault for the delay. Means and methods of construction are usually determined by the contractor, so by approving or accepting the schedule update the owner does not relieve the contractor from their responsibility to apply means and methods according to the contract requirements.

To reach a consensus regarding the project's status, meetings are typically conducted between the owner and the contractor on a periodic basis to discuss the contractor's schedule update submittal. During these meetings, the contractor may present all aspects of the schedule update submittal and the owner may provide their review of the schedule update and a critique of the contractor's schedule related to contract conformance, status, and/or sequencing of activities.

The best use of the joint meeting is to timely resolve significant issues that may at some point adversely impact the project's forecasted completion date, and perhaps agree on the current status of the project.

Comparison to the Previous Update or Baseline

One of the most significant aspects in reviewing the schedule update is to view the schedule in comparison with previous updates, or even the original baseline schedule. These comparisons are useful in understanding how the project may have changed since its initial schedule. Rarely does a schedule remain static through the entire project's duration, given the dynamic nature of the construction process, especially for fast-track projects.

If the forecasted completion date contains negative float, then the project is late or behind schedule. Remedies for negative float may be included in the contract specifications and may require the contractor to prepare a recovery schedule, acceleration plan, or time extension request, depending on the circumstances and accuracy of the forecasted completion date. Specific activity comparisons between previous updates and the baseline may provide guidance in interpreting the causes of the schedule differences in terms of recovery or delay.

If a project encounters numerous unforeseen conditions or numerous changes, it may be necessary to prepare a revised schedule to indicate a modified sequence to complete the project, since the original plan may no longer effectively model the current project conditions. A revised schedule may contain new crew flow sequences (change from north/south to south/north). The measure of progress accomplished for the project and, therefore, measured by the schedule update, occurs during the time period between the previous update and the current update, especially for critical and near-critical activities. Often, changes are made to activity durations of future activities (those activities in advance of the data date), causing them to become critical path activities and potentially skewing the actual progress accomplished as measured in the time period prior to the data date. In these examples, the reviewer should divide the assessment into separate analyses to account for actual progress before the data date, and for modifications to future activities, in order to resolve potential delay issues. Changes made to future activities that revise the critical path introduces elements of a time impact analysis into the update process and may distort the true progress (or lack of progress) accomplished during the update period.

Often, a contract specification may require a measure of delay to be performed contemporaneously and performed through a process called time impact analysis. Its objective is to pinpoint, isolate, and quantify any time impact associated with specific and discreet issues and determine its time relationship to past or current delays. One of the significant aspects of maintaining an accurate schedule update is that a schedule update may be used as the basis to measure project delays. Preparation of time impact analysis is discussed in Section 5.7.2.1, Prospective Time Impact Analysis.

The schedule reviewer should invest in a schedule comparison program if the changes made to the schedule update are not provided as part of the schedule update submittal. Certain contract specifications prevent the contractor from making major changes to the schedule without the owner's consent and/or formal approval. In these examples it may be necessary for a contractor to submit more than one schedule update and would require the reviewer to examine the project status of the unmodified version against the version with the major changes applied. Specific reasons for making major changes should be included in the update submittal package.

Aside from an evaluation of the critical/near-critical activities, an assessment should also include changes made to the schedules, such as:

- Added/deleted relationships, activities, constraints, calendars;
- Increased remaining durations;
- Construction accomplished, as reflected in activity progress;
- Accuracy of actual dates and/or forecasted dates; and
- Resources levels and/or requirements.

4.4 Progress Measurement And Recording

Guidelines

Progress measurement and recording is the backbone to analysis which we carry out during the life of a project to assess its health and consequently take necessary actions.

Definitions

Measuring the progress during a project's lifespan is equally significant to execution of the work. It means having a basis to gauge the level of completion of work at any given time during the project. As mentioned in Section 2.1 of PMI's *Practice Standard for Earned Value Management* – Second Edition, "Feedback is critical to the success of any project. Timely and targeted feedback can enable project managers to identify problems early and make adjustments that can keep a project on time and on budget" (PMI, 2011a, p. 5).

The word feedback in the above definition refers to the health of a project, which can further assist the evaluation of how good or bad the progress is.

Recording is validating and storing the as-built data, which becomes the baseline for any future trend analysis and evaluation. Keeping a record of actual data also contributes to final documentation of project controls, which in the end can be handed over to the client as part of project documentation. Recording is also important because, if the general contractor and the client end up in some dispute (usually over extension of time, disruption of the work due to the client, etc.), this as-built data can then be referred to as a base document to support the discussion.

Purpose

The purpose of progress measurement and recording in any project is to measure and report the physical work, and thereby provide a basis for checking and analyzing progress and performance, and for forecasting the remaining work.

Default Condition

As work commences after project award, progress measurement and recording becomes mandatory for both the project manager and the client, to keep track of the project from the beginning and to see the performance. Whether the first activity is start of work on an engineering document, floating an inquiry for procurement services, or geo-technical investigation (construction), measuring progress becomes necessary for evaluation or making any decisions.

Hence, very early in the project, the procedure for measuring and recording progress should be defined, prepared, and shared with all stakeholders, allowing them to understand how performance measurement will take place on the project.

Best Practices

As mentioned in Section 5.6.2.1 of the *PMBOK® Guide* – Fifth Edition, "Project performance measurements are used to assess the magnitude of variation from the original scope baseline" (PMI, 2013, p. 139). So as soon as we have started performing work in a project, the need to monitor that work on some basis exists simultaneously. Just as it was recommended that the process of progress measurement and recording should be defined very early in the project, based on that procedure, so should the project controls team implement the processes with the start of work. *TCM Framework* (AACE International, 2012, p. 201) describes a process map in Section 9.2.2, Progress and Performance Measurement, as including the following steps:

- Plan for progress and performance measurement
- Measure physical progress
- Track resources
- Status the schedule
- Measure work process performance
- Review progress and performance measures
- Report progress and performance measures

Hence, planning for the measurements is the first step, followed by measuring the physical progress. As this topic is primarily focusing on measuring and recording, we will review the methods typically used by projects around the world.

PMI's *Practice Standard for Earned Value Management* – Second Edition (2011a) explains in Section 2.2 under "Earned Value Measurement Techniques" that

> Earned value is the measure of work performed, expressed in terms of the budget authorized for that work. (p. 8)

Techniques for measuring work performed are selected during project planning and are the basis for performance measurement during project execution and control. Earned value (EV) techniques should be selected based on key attributes of the work, primarily 1) the duration of the effort, and 2) the tangibility of its product.

Product of Work	Duration of Work Effort	
	1-2 Measurement Periods	>2 Measurement Periods
Tangible	Fixed formula	Weighted milestone Percent complete
Intangible	Apportioned effort Level of effort	

Table 4-1: Earned value techniques

TCM Framework (AACE International, 2012) also acknowledges in Section 9.2.2.2 these methods for monitoring progress.

Various methods for Earned Value Management (EVM) include:

- **Fixed Formula**
  A typical example of fixed formula is 50/50 technique. With this method 50% of work is considered completed when the work has started, regardless of how much work is finished. The remaining 50% is achieved at completion of work.
- **Weighted Milestone**
  The weighted milestone technique divides the work to be completed into segments, each ending with an observable milestone; it then assigns a value to the achievement of each milestone. The weighted milestone technique is more suitable for longer duration tasks having intermediate, tangible outcomes.
- **Percent Complete**
  The percent complete technique is among the simplest and easiest, but can be the most subjective of the earned value measurement techniques if there are no objective indicators to back it up. This is the case when, at each measurement period, the responsible worker or manager makes an estimate of the percentage of work complete.

- **Apportioned Effort**
  If a task has direct, supportive relationship to another task that has its own earned value, the value of the support task may be determined based on (or apportioned to) the earned value of the reference base activity. Examples of proportional tasks include quality assurance and inspection activities.
- **Level of Effort**
  Some project activities do not produce tangible outcomes that can be measured objectively. Examples include project management and operating a project technical library. These activities consume project resources and should be included in earned value management planning and measurement. In these cases, the level of effort (LoE) technique is used for determining earned value. A planned value is assigned to each LoE task for each measurement period. This planned value is automatically credited as the earned value at the end of the measurement period.
- **Remaining Duration**
  One of the most reliable ways to determine the status and progress of a scope of work is to determine the remaining amount of time that is needed to complete the scope of work represented by the activity once that work has started. Most construction superintendents have a very clear idea how much longer an activity is going to take to complete it versus determining percent complete or some other method described above.

Once process measurement processes are in place, the next step is to analyze the progress by performing variance analysis, updating the status of the schedule, checking performance indices (e.g., SPI, CPI), etc., which consequently assists in making decisions (change management) for corrective or preventive actions. While recording all the as-built status of the project helps in various analyses, it will also contribute to organizational process assets. As mentioned earlier in definition, and to reiterate it here, this as-built data can be used later in the project as a basis for many discussions (contractual, dispute, clarification, variation, etc.) with the client, the engineer, and within the project team. Hence, appropriate effort should be made to record the data in the most effective way.

Recommended Practice

PMI's *Standard for Earned Value Management* – Second Edition (PMI, 2011a) states that:

> Earned Value Management (EVM) has proven itself to be one of the most effective performance measurement and feedback tools for managing projects, and it enables the project team members to compare performance against budget plan and forecasts. EVM can help to clearly and objectively illuminate where a project is and where it is going—as compared to where it was supposed to be and where it was supposed to be going. EVM uses the fundamental principle that patterns and trends in the past can be good predictors of future.

Having these key data points, and budget at completion (BAC), enables us to examine variances (schedule variance [SV], cost variance [CV], variance at completion [VAC]), indices (schedule performance index [SPI], cost performance index [CPI], to complete performance index [TCPI]), and forecasts (time estimate at completion [EAC], estimate at completion [EAC], estimate to complete [ETC]). These variances, indices, and forecasts can be used to answer all the key project management questions. For further details and definitions of processes, PMI's *Practice Standard for Earned Value Management* – Second Edition (2011a) should be consulted.

Advisories

Do not forget to plan and document progress measurement and recording procedures much earlier in the project life cycle. Even if the company is completing part of the project, e.g., engineering and procurement, whereas construction is being undertaken by a consortium, joint venture, or subcontractor, etc., make sure systems are in place for all partners. Getting data correct and on time is the first step for accurate and timely analysis, which can avoid the shock factor for stakeholders. Similarly, record the actual data as and when it happens. This will assist stakeholders and different departments (e.g., contracts, legal, and procurement), including project controls, to attain data whenever they need for different analyses and validation.

4.4.1 Extent of Scheduling Involvement

Guidelines

The extent of schedule involvement evaluates the level of acceptance, responsibility, and ownership of schedule management within the organization—the stakeholders.

Definitions

Schedule Sponsorship (SS): The extent of senior leadership in the sponsorship of schedule management practices within the organization.

Purpose

The extent of schedule involvement takes place through various parties and at different levels of maturity across the organization. This is important because each group that is involved in schedule management has a role in ensuring that the schedule management processes are applied appropriately.

Default Condition

The extent that members are involved in scheduling is based on their goal of ensuring the success of their projects or programs.

Best Practices

The extent of schedule involvement will in many cases be contingent on the needs and level of schedule maturity of the organization. A schedule best practice is for the following roles to be played out by each respective group. RACI (responsible, accountable, consult, and inform) methods should be developed during the schedule design phase of the project to ensure the team members understand their role in the development and ongoing maintenance and analysis of the project schedule.

Each group of schedule stakeholders is responsible for ensuring the success of the project.

Recommended Practice

The preferred application method is for formal implementation of a schedule management infrastructure. This allows each of the roles and groups to work in a unified manner to integrate the elements of schedule management.

Advisories

The positive extent of the support and guidance from the various schedule management stakeholders will be critical for a project's success. Less than the full participation of the project manager and their respective project team should be avoided at all costs.

4.4.2 Timing of Updates

Guidelines

Definitions

One of the issues that must be considered during the project schedule model development phase is the update cycle, which encompasses the timing of updates. The *Practice Standard for Scheduling* – Second Edition, Section 3.3 (PMI, 2011b, p. 33) states that schedule progress is reported as of a specific data date, known as the status date, current date, time now date, or as-of date.

Purpose

The update cycle is a critical component in the development phase of a schedule model for a variety of reasons.

The timing of updates will affect a number of things, such as when project performance review meetings will occur, when project performance payments will be made, or when project reports will be issued. The update day, also known as the data date or status date, is the point in time that the activities contained within the schedule model are properly updated or statused. Typically, the update focuses on recording starts, finishes, percent completes, remaining durations, etc., for the project activities. This status is then utilized in providing performance data for the project and to forecast future events. The project management team utilizes this data in managing the project. In order to do this effectively the reported data has to be current and timely so that it is relevant. The cycle time must also be sufficient to allow actions that were taken as a result of the previous performance data to work prior to the occurrence of that next update. This allows the project team to see if the actions they took are having a positive effect, or if additional actions are required.

Large projects are often comprised of multiple organizations responsible for specific portions of the project. These organizations are required to maintain a portion of the project schedule model in an integrated fashion where portions are linked together. This maintenance requirement also requires the entity to report status on their portions of the schedule model. Therefore, the update point also serves to establish a specific point in time when all organizations must look at their performance to date so that the project gets a good assessment of where it is and where it is going.

Default Condition

When developing the schedule model, the project team must consider two issues.

First, which day of the week does the update occur? The update will include reporting progress and other information to that date. Consideration must also be given to the time necessary to generate the project reports and analyze the project data. Sundays tend to be a good day for updates, since it is at the end of a weekend and could be utilized for recovery time, if needed. In addition, Monday starts a new week. We can then perform an analysis and generate reports on Monday, for review early in the workweek. We always strive to get data and reports out and into the user's hands as quickly as possible.

The second consideration is the length of the cycle itself. Once again, this varies from project to project, and also with discipline. If performing construction efforts, weekly updates are most appropriate, since many things can happen in a week's time in this environment. Conversely, if engineering is being performed, monthly cycles may be more appropriate. A facility outage (when every day that the facility is down is critical to the operation cycle and company profits), may require that a good cycle period be daily, or even performed each shift. Each project team should consider the issues and determine what cycle is most appropriate for the project.

Usually the update cycle is determined by the contract and the scheduling specifications prior to anyone doing anything with the schedule in terms of development.

Best Practices

One of the essential elements that will need to be considered when developing a good schedule model is to establish the optimum update cycle for the project. The timing of this update has a bearing on other aspects of the project, such as activity durations, project review meetings, and payment cycles.

Therefore, the project team will determine two things, the actual day of the week that the update will occur through, and the period of time between updates (daily, weekly, biweekly, monthly, etc.).

Recommended Practice

When developing the project schedule model, it is important to ensure that all the various organizations responsible for implementing portions of the project are involved and participate in determining the update cycle.

Be sure that the update cycle includes not only the duration between updates, but also the specific day of the week or time if done daily.

In conjunction with the update cycle, determine the timing of meetings and other actions that must occur following the update.

Ensure that any project processes or procedures clearly define the update cycle period and cutoff points. This will ensure all parties responsible for reporting progress will be ready by a specific time and not cause an impact to the project update timing.

Advisories

Ensure that all parties responsible for project updates are involved. Do not establish the cycle period in a vacuum back at the office. Seek out and engage the parties who will be doing the work and reporting the progress.

Ensure adequate time exists between update cycles to effectively use the data produced.

Ensure all organizations adhere to the cutoff times, so that project information will be timely.

Do not allow organizations to hold the process hostage by waiting for their input. Strictly enforce the cutoffs and move forward without input from offending organizations if necessary. They will then have to explain their lack of performance and inability to meet requirements to the larger project team. Experience has indicated that this generally happens only one time, and then the offending parties adjust their performance.

4.4.3 Data Capture and Verification

An accurate model of a project at a particular moment in time can only be constructed by using accurate, timely status information. The information used in a schedule update needs to be gathered from the correct sources and verified against the observed status of the installed work. The data collected is the as-built data, which will be used during the update to provide the basis for analysis.

Guidelines

Definitions

Data capture is simply the process of obtaining accurate schedule update information for each update period. The data obtained depends on the level of schedule performed, but generally should include at least the remaining duration, actual start, and actual finish information for each activity performed during the update period. Verification is the process of ensuring that the data obtained is accurate.

Purpose

The quality and usefulness of a schedule update depends on obtaining and recording the proper data. Inaccurate remaining durations on critical path activities will likely have a day-for-day impact on the completion date. Inaccurate actual start or actual finish dates can likewise have a day-for-day impact on the project completion. Even the makeup of the critical path and near-critical path can change based on inaccurate information.

Default Condition

This section applies only to the collection and verification of data for use in schedule updates. Typically, the baseline schedule has been reviewed and approved (although approval is not a condition of use of this section).

Best Practices

Determine how the topic should be handled, when it should be used, what the application options are, and the best ways to handle the topic.

1. Define the update information needed and the method of collection early in the project; perform any necessary training during the initial update.
2. Collect remaining duration (RD) for schedule progress and percent complete for cost completion. Select the option for breaking the tie between percent complete and RD. Collect actual start and actual finish data consistently. Collection options are:
   a. Update forms filled out by contractor personnel at the site (perform either full verification or sample the data).
   b. The scheduler or discipline superintendent walks the site to determine progress.
3. Discussion of substantial completion of activities: Actual start of an activity is the date when significant and continuous work starts on the activity. Completion is different for schedule progress than for payment purposes. An activity that is 95% complete for purposes of payment may very well be substantially complete for schedule purposes. For data collection purposes, an activity should be considered an actual finish when the last workday is complete on the activity; where minor work needs to

be completed, consider calling the activity complete and adding a "come-back" activity or include the final work to complete an activity in the punch list process.

4. Process:
   a. Scheduler should print out update form using the reporting function from the software, organized in a format that will aid the data collector. Information should include fully defined activity description and ID, Original duration (OD), Early Start (ES), Late Start (LS), Previous Remaining Duration (RD); fill-in data columns RD, AS, AF. For schedule purposes, RD should be used, and for cost purposes, percent complete (PC) should be used.
   b. Field personnel fill out an update form, and transmit it to the scheduler.
   c. Scheduler inputs RD, AS, AF, PC.
   d. Run schedule (create record copy before any logic adjustments); closely review critical and near critical activities; review ongoing work for out-of-sequence progress due to retained logic; make necessary schedule changes; incorporate fragnets that record new issues; verify any suspect data; and issue preliminary schedule update before progress meeting (create record copy).
   e. Schedule progress meeting at site.
   f. Scheduler samples progress through direct observation, or collects additional project status on day of progress meeting.
   g. Progress meeting: obtain agreement on RD, AS, AF, and percent complete with key subcontractors and the general contractor. Discussions of out-of-sequence work and rescheduling.
   h. Data input/change
   i. Analysis of critical and near-critical paths
   j. Narrative
   l. Issue schedule update.
5. Requiring daily reports to reference schedule activity ID's for each daily work activity helps superintendents and field personnel to follow and accurately report schedule activity. This information is then readily available for the schedule to be used as needed.

Recommended Practice

Data Capture

- Project information gathered for a schedule update should be based on a particular status date.
  - Hard copies of the anticipated schedule update worksheets should be provided to project personnel for verification. All project shareholders including but not limited to:
    - Project management team
    - Subcontractors
  - Scheduler or contractor personnel should obtain update information from other stakeholders, including:
    - Designers
    - Government agencies
    - Material suppliers
  - Information requested in schedule update worksheets includes but not limited to:
    - Current RD
    - Actual start
    - Actual finish
    - Suspension of work
    - New activities
    - Revised schedule logic calendar changes
  - Activities should be updated using remaining duration, not percent complete.
  - All records pertaining to the schedule update date should be retained.

Data Verification

- Field verification by an independent, knowledgeable scheduler of at least a sampling of activities, including photo documentation where possible
- Comparison with project records

- Field inspections
- Daily field reports
- Progress reported in pay applications
- Progress report in schedule/progress meetings
- Progress photos
- Site progress meeting to get concurrence with other schedule stakeholders

Advisories

A project schedule is a tool for report out of project progress and if erroneous information and data is used to status the schedule then the resulting output of the update is only as good as the data that was used to status it in the first place and will cause improper allocation of project resources to meet project goals.

Avoid use of progress data for tactical advantage. There is some gray area in the collection of progress data—Is the activity 95% complete, or only 90%? Will we really get that activity done in two workdays, or should we allow for three? However, the systematic manipulation of data by any party is improper, and could lead to charges of false claim or fraud.

Schedulers should strive to support their clients by being independent and understanding that the client's best interests are served by reporting the facts with respect to update data. A schedule is a report out of project status. If the project is on schedule then the report will not alarm the team members. However, should the schedule reflect the project is behind schedule, then as the scheduler, you are the bearer of information no one wants to hear, and you may be criticized for issuing the report. Remember you are only the messenger and as such you owe the project team the truth whether or not the project team wants to hear negative information.

4.5 Adjusting And Revising Schedules

This section is focused on adjustments or revisions made to the project schedule during the updating process.

Guidelines

Definitions

Adjusting and revising the project schedule is part of the updating process. The development of project schedule updates consists of a two-step process: (1) progress-related changes and (2) changes to the schedule. The first step (progress-related changes) consists of inserting the new update with the progress achieved on the project between the data date of the previous update and the new update. The second step (changes to the schedule) consists of adjustments or revisions to the project schedule. (See Section 4.4.3, Data Capture and Verification.)

Purpose

The purpose for making the adjustments and revisions to the project schedule mentioned above in a timely manner is to ensure that the project schedule includes the entire scope of work in the contract when work is added and deleted, and that the sequence, means, and methods of work match the current plan to complete the project as accurately as possible, such that the project schedule can be used by the participants to manage the project and the risks as they arise.

Default Condition

Adjustments or revisions to the project schedule can and should be made to ensure that it depicts the most current plan for completing the project. The reasons for adjusting or revising the project schedule are: (1) the insertion of activities into the project schedule that represent new work added through a properly executed modification to the contract, (2) to delete activities from the project schedule that represent work that was removed from the contract by a properly executed modification to the contract, and (3) to change the schedule activities' durations and schedule's network logic to represent changes in the sequencing or means and methods of the work to match the current plan for completing the project.

Best Practices

When adjustments or revisions need to be made to the project schedule, the party making the adjustments or revisions should clearly describe both the changes being made and the basis or reason(s) for them. This transparency enables all parties to understand and agree upon the changes that are made to the project schedule.

Recommended Practice

The preferred application of making adjustments or revisions to the project schedule is a contract stipulation that requires the contractor, who is typically the party responsible for development and maintenance of the project schedule, to identify and explain the basis for every change made to the project schedule whenever a change is made, and to certify that the update of the project schedule that is submitted represents the contractor's current plan to complete the project.

There are two schools of thought on this topic. The first is that once the schedule is updated, an evaluation and analysis is made on how that update affected the critical path and all downstream activities and scopes of work that have not started in the schedule. The first school of thought says that those activities cannot be changed or altered by either adjusting logic or durations to change the critical path. The second school of thought says you can adjust logic and durations, mainly due to the fact that the general contractor owns means and methods. Also, any contractor who does not build some risk management, float, or time into the schedule as a way to cover unforeseen conditions or delays which are due to the contractor, or any other party for that matter, is doing himself or herself a disservice and taking on unnecessary risk. Building a "just in time" schedule is not a best practice on the contractor's part. Granted, an owner would love it, as long as he or she was never found at fault for a delay to the schedule.

Advisories

Owners should not allow contractors to constantly make changes to the project schedule without providing an explanation for the change. Constant changes undermine the reliability of the project schedule to accurately depict the sequencing of work and forecast the completion dates of the project. However, the owner must also recognize that the project schedule, in most cases, represents the contractor's plan to complete the project, and so should be weary of directing or mandating whether the contractor can change it. The owner, though, should not hesitate to scrutinize or question whether changes should or should not be made to the project schedule, to ensure that it is not being used as a project management tool that only protects the contractor's risk and interest.

4.5.1 Review of Durations and Sequence

This topic discusses the importance and key considerations when reviewing durations and sequencing during schedule maintenance.

Guidelines

Definitions

The review of durations and sequence during schedule maintenance phase is the re-evaluation of activity durations and the sequence of the work.

Purpose

The purpose of reviewing the durations and sequence during the schedule maintenance phase is to verify the remaining activities durations are accurately forecasted and likelihood of successful completion with the current sequencing shown.

Default Condition

Even without a major change or re-sequence, a project's schedule should be critically challenged at every update interval, which includes a review of the remaining durations and sequence of activities. Remember, the project schedule is dynamic, not static, thus the schedule must be evaluated continually due to its constant state of change.

Best Practices

Once you are ready to review the activities' durations and sequences left to complete the project, it is important to evaluate where you are and how you got there. How are you doing on the original durations and sequence in the schedule? Were the projected durations and sequencing right on, fairly similar, or way off? What caused the delta(s)? Review the historical production rates for the project to date and compare. Do you see any trends you can identify? If so, look to apply those trends for the remaining activities and sequences in the schedule. Don't forget to document the as-built rates of production for critical work cycles to apply to your next schedule, creating a "rules of thumb" database for time frames.

Next, you will need to consider items in your review by looking forward. It is important to consider possible variables that may have changed since the last review of the durations and sequence and evaluate the affect they may or may not have on the current plan. Some items to consider include, but are not limited to, changes regarding:

- Project scope (additive or deductive)
- Project delivery timing (acceleration or extension)
- Site conditions/constraints
- Manpower
- Equipment
- Material/ resources
- Means and methods
- Unseasonable weather conditions
- Stakeholders, management, vendors, or trade partners
- Work restrictions
- Concurrent work/trade stacking, affecting productivity

Recommended Practice

After acknowledging past productivity results (looking backwards) and realizing future constraints (looking forwards), one can start systematically analyzing the remaining durations and sequence left to complete the project.

Formulate your own opinions as to the likelihood that the durations and sequencing is realistic based on your experience and information.

Constructively challenge the stakeholders, management, vendors, and trade partners as to the durations and sequence. Can it be done faster? Is it too aggressive? It is important to continually question and challenge, challenge and question. Ensure that you have their buy-in and agreement that the current schedule makes sense and represents a realistic plan to complete the project. Remember, the more eyes that look at the schedule, the better the final product.

Evaluate the critical and near critical paths—do they make sense? Is the trade stagger/stacking shown too aggressive—have they agreed to this plan? Is the work now repetitive enough (learning curve) to decrease some of the crews durations?

From the implementation of these types of questions/exercises, your schedule will remain current. Remember, the schedule is dynamic and needs to be reviewed and tested continually in order to stay current.

Advisories

Avoid making revisions to the durations and sequencing just to make it fit within the contractual time constraints. It is your responsibility to ensure the schedule is a realistic, useable plan which contains viable durations and sequencing and that all pertinent team members have contributed to its development and maintenance.

4.5.2 Keeping the Schedule Model Current

Guidelines

Definitions

Keeping the schedule model (project schedule) current means that, as the plan for completion changes or evolves over the course of the project, the project schedule, which represents that plan, should also change to include the entire scope of work, added or deleted work, and changes to the construction requirements and project conditions.

Purpose

The purpose for keeping the schedule model (project schedule) current is to ensure that it can be used as an effective project management tool. A project schedule that is properly updated and also represents the current plan for completion will enable the project participants to make informed decisions that include, but are limited to, mitigating potential delay, changing means and methods, etc.

Default Condition

The contractor, who is typically responsible for developing and maintaining the project schedule, should adjust and revise the project schedule to ensure that it represents the current plan for completion whenever it is submitted to the owner.

Best Practices

As the plan for completion changes over the course of the project, the project schedule should represent that changing plan to ensure that it depicts the current plan for completion. The changes may include adding or deleting activities, changes in relationship logic, and modification of activity durations to represent changes in means and methods.

Recommended Practice

The preferred application is to change the project schedule such that it always mirrors the current plan for completion.

Advisories

Although it is recommended that the project schedule always mirror the current plan for completion, it should also be recognized that the project schedule is a model of the plan for completion and the goal is not perfection. The project schedule should not be continuously changed to include every minor alteration to the plan for completion; rather, the changes made to the project schedule should be based on reasonability and good judgment.

Adjustment of durations and logic while updating the schedule are necessary to reflect what is going on in the activities that have started but not completed, and in the activities that started and completed in the update cycle. Adjustments to activity durations and logic on all downstream activities outside of the update cycle, however, need to be thought out very carefully. It is a practice, usually by general contractors (GCs), to want to adjust those durations and logic when the project completion date goes negative during the update process. An astute GC will build time and logic into the schedule to allow for some manipulation of logic and duration, and to control the end date, in order to recover lost time when the responsibility for the lost time is theirs. They can only do that for so long, though, if the project is going to be very late in completion. Eventually, they will have to insert a delay fragnet into the schedule to declare and identify the cause and remedy, especially if the delay is not their responsibility.

4.6 Baseline Management

Guidelines

Definitions

A baseline is a copy of the project schedule model as it exists when the schedule model is approved by the project team. It is generally created before project work begins, but after buy-in from the project stakeholders. The baseline schedule provides a common point from which the project moves forward, documents the project timeline before work begins, and provides a reference for measuring project performance.

We know that all projects are dynamic, and schedule models need to reflect this evolution by depicting the latest project plans. The current schedule model accomplishes this by accurately reflecting reported progress and changes within it. The baseline schedule model, however, is a copy of the approved schedule model at a specific instant in time, and as such it is static in nature. This allows us to compare the current schedule model against this static baseline schedule. However, as the project proceeds, the project will need to incorporate approved changes and progress, both good and bad. This progress and the changes are reflected into the current schedule model, which tends to drive the baseline and the current schedule model apart. Much of this variation can be explained when changes are considered, but not all of it. Some is attributed to lack of performance. To help differentiate these differences, it is common to incorporate approved changes into the baseline. This is accomplished by actually incorporating the logic associated with the change into the baseline schedule model as if it existed at the time the baseline was created. This is called baseline management.

Purpose

Baseline management is performed so that project performance values can be as accurate and relevant as possible. The current schedule model for any project is a dynamic and living thing. It is always changing based on the latest project scope (approved changes) and progress to date on the project. The approved changes are valid changes to the project plan that need to be accounted for in the baseline in order to remove those variances that are legitimate and can be easily explained. Variances from other causes are the ones that need to be addressed and resolved if the project is to be completed on time and within budget.

Therefore, the project should have a process or procedure in place to deal with incorporating approved changes into the approved baseline. This will allow the current schedule model and the baseline to be on the same level when performance issues are addressed.

Default Condition

Every project, regardless of size, should capture a baseline. This baseline will be created (copied) from the approved schedule model prior to the project work starting. Once created, the baseline schedule model will be maintained by incorporating approved changes into it.

Best Practices

Once a project is approved, the effort of developing a project plan and schedule begins. The culmination of this effort is the approved project schedule model—one that all the key stakeholders can agree on. A copy of this schedule model is made and called the project baseline.

As the project changes are approved they are added to the current schedule model, but in some cases may also be added to the baseline. In this case, the logic added to the current schedule model is added to the baseline and the reasons for the change documented. This is sometimes done with cost-loaded schedules in order to create a "re-baseline" which will reflect the appropriate contract value.

Recommended Practice

Ensure that a copy of the initial project schedule model that is approved is captured as a baseline.

Ensure that the project has an approved process for dealing with change. (See Section 5.7, Change Management.)

If a re-baseline is required, ensure that the approval process is followed and a copy with documented changes is saved upon approval.

Advisories

Ensure that all key stakeholders on the project are involved.

Ensure that all documentation concerning changes is retained in project files.

Do not re-baseline unless necessary. Each re-baseline effort resets the project's performance values, in essence starting over at the point of approval.

4.6.1 Baseline Management—Recording and Documentation

Guidelines

Purpose

The basis of schedule provides a complementary text to the baseline schedule to substantiate activity durations and work sequence representations. It can be an invaluable tool for understanding project deviations from the plan later, and as documentation for schedule claims.

Recommended Practice

At a minimum, a listing of core assumptions as described in the paragraph above should be prepared and placed in the project files for future reference. A copy of the basis should be issued to the project manager, primary project execution team members, and to the client, as complementary information to the baseline schedule.

It is further recommended that an appropriate basis of schedule be prepared for any subsequent revised (re-baselined) schedule or for an extension of time request submitted as a change notice.

Advisories

Precaution should be taken to prepare the basis of schedule or keep notes at the same time as the baseline schedule is being developed.

Often the scheduler may be under time constraints for administrative pressures to issue the baseline schedule and may find it difficult to also work on the basis of schedule at the same time. This, however, leads to the risk of forgetting some of the details or finer points which are important assumptions in the schedule. Therefore, an informal set of notes should be kept for later formal incorporation into the basis of schedule, in order to avoid serious omissions.

4.6.2 Preservation

Guidelines

Definition

Preservation is all about maintaining the historical record of the baseline schedule as it is updated and statused on whatever reporting cycle is dictated by the scheduling specifications in the project contract. This also includes preserving the iterations of the schedule that were used to ultimately create the baseline schedule. Once the baseline schedule is created—whether approved or not by the owner—and the project has actually started, and the schedule begins its update process, each iteration of the schedule needs to be frozen and stored to preserve the historical record.

Purpose

If there is no preservation or historical record—based on the update cycle as dictated by the contract—then there is no way to understand how the project came together by looking at the project schedule at any given point in time during the project life cycle. This is critical to understanding what went well and what went wrong if the project ends up in litigation, arbitration, or court. Without it, the project has nothing. Maintaining a library of the schedule updates allows the stakeholders to compare progress from one reporting cycle to another, or to the baseline.

Default Condition

There is absolutely no condition or instance when this practice cannot or should not be used. No matter the length of a project—one month or two years—the maintenance and preservation of the historical record is paramount to scheduling best practices and guidelines, period! Outside of the creation of a schedule using best practices and guidelines to build the project in the first place, this is the core of what scheduling is all about and one of its main reasons for being.

Recommended Practice

There are several ways to accomplish the preservation of the historical record. The main gist of the practice is the creation of a numbering system that will work for the life of the project. The only reason this becomes important is because it is the scheduling software used that dictates in a lot of instances just how many characters can be used in the title of a schedule. Ideally, the use of a date, such as the data date, that the schedule was updated to is the best and clearest. Remember that the schedule is a graphical representation of the project, and schedulers look at schedules and their screens all day. However, that is not true with many of the rest of the stakeholders, who are more than likely upper management types and not familiar with what they are looking at. So it is important to keep the numbering system simple.

1. The process starts with the baseline schedule. If the contract says that the schedule needs to be updated on a monthly basis for report out to all stakeholders, that is the starting point. For example, if the project starts on Day 1 of any given month, then it is the baseline schedule itself that is updated. The scheduler's first task is to make a copy of the baseline schedule and name it DD/MM/YY. This should be done because the baseline schedule itself is part of the historical record and it is forever frozen in time and cannot ever be altered or manipulated once it is approved and becomes the official schedule for the project.
2. The scheduler goes into the copied baseline and performs the update for month one. He or she updates the activities on or near the data date by adjusting the actual start, actual finish, or remaining durations of the activities. He or she then does an analysis of the effect the update had on the schedule. Did the update push the project completion out past the contract date, causing the schedule to go negative, etc.? Once that is reported and absorbed, and hopefully approved by the stakeholders, the update of that schedule is complete. To preserve the historical record, that schedule is then copied to create the next month's update. The schedule just updated, and the source for next month's update, is now forever frozen in time and preserved in a secure database. It is suggested that it be preserved in more than one database in case of a computer or server failure.
3. This process is repeated every month until the project is complete. So for a two-year (24-month) project there would be 25 different schedules in the historical record. Of course, that could change depending on the addition or subtraction of change orders or delays to the project, but in a successful project that is the number of schedules the historical record should contain, at a minimum.
4. Having a library of monthly updates allows the stakeholders to target the latest schedule against all others, including the baseline and targeting any one schedule against another. This is one of the main tools used in schedule forensic analysis and is a required practice.
5. As a standard practice, it is also a good idea to create a hard copy of the schedule just in case all else fails.

Advisories

Avoid at all costs NOT preserving the historical record of a project. To do so is inviting big trouble and definitely not a scheduling best practice and guideline.

Avoid doing a continuous update on the baseline schedule. This means there is only one schedule for the project—the current one. When all is said and done, there will be a nice as-built schedule of the project, but a useless tool for forensic scheduling analysis and no way of knowing how to assess progress during the life cycle of the project. Continuous updating only allows you to know where the project is right now, at the data date, which is okay for that point in time, but useless otherwise.

4.7 Documentation Purposes/Requirements

As with any endeavor, or in this case project, there is a huge amount of data created during a project life cycle. All this data needs to be captured, recorded, and stored in a secure environment for use during the project, and for future use after the project is complete.

Guidelines

Definitions

Documentation refers to any hard copy or electronic retrievable information that is specific to the project schedule. This will include but is not limited to:

- Scope of work;
- Correspondence (memos, letters, emails, etc.);
- Drawings—original contract drawings and any attachments that may accompany correspondence;
- Calculations as they may pertain to production rates and durations;
- Meeting minutes;
- Action item lists;

- Contract specifications;
- Change orders;
- Requests for information (RFIs);
- Procurement ledgers;
- Bid packages; and
- Schedules
  - Baseline
  - Updates
  - Look-aheads
  - What-if narratives
  - Targets
  - Forensic analysis
  - Reports
    - Critical path/paths
    - Digger-type analysis
    - Float
    - Filtered

Purpose

To define what documentation is, provide a clear understanding of the purpose for documenting the schedule and the scheduling process, and identify documentation requirements.

4.7.1 Documentation Purposes

Guidelines

Definitions

Documentation is the act or instance of supplying documents or supporting references or records, or the documents or references so supplied. It also means the collation, synopsizing, and coding of printed material for future reference and ease of accessibility.

Purpose

The purpose of schedule documentation lies in the ability to:

- Establish the work required as defined in a project's scope of work;
- Establish when deliverables will be available;
- Establish how the project schedule was created;
- Establish or re-create why and how the schedule changed during the project life;
- Establish and re-create a record of progress; and
- Provide a means for evaluating performance.

Best Practices

Maintain a concise history of the schedule during the project life.

A written procedure should be developed outlining what and how information is to be kept, organized, and made available for retrieval. Stakeholder needs should be included in the procedure. Cross-referencing information should be investigated to minimize storage, avoid conflicting data, and reduce work requirements.

Security measures should be evaluated and enforced, to maintain documentation integrity. This may include the creation of a backup of documentation at a set increment of time, maintaining live storage at a remote location, running redundant live storage media, or a combination of these.

Recommended Practice

Any established best practices need to be used as a base for documentation requirements and procedures. Upon this, specific requirements of the project and stakeholder needs should be incorporated into a procedure document and distributed to those parties associated with the schedule development, maintenance, and review.

This document should include:

- What documentation will be retained;
- Where documentation will be stored;
- How the documentation will be stored;
- How the documentation will be organized; and
- Who will have access to the documentation.

Incorporating the project work breakdown structure as a framework for document filing will facilitate referencing documents to the schedule. Also, the coding structure used in the project schedule should be incorporated in tags that may be added to documents.

Any client documentation retention policy should be reviewed and incorporated when preparing a documentation policy.

Advisories

Extraneous notes from meetings or telephone conversations should not be discarded, but rather recorded. Memory fades, and written notes often refresh information that may be pertinent at a later date.

4.7.2 Documentation Requirements

Regular reports and documentation allow the project team to evaluate, track, and plan. Being consistent and flexible with reporting facilitates the dissemination of information and improves the project schedule.

Guidelines

Definitions

Documentation requirements are the policies and procedures for records that are used throughout the course of the project.

Purpose

Consistent creation and distribution of the schedule brings consistency and flow to the project.

Default Condition

Documentation policies and procedures should be created and maintained for every project. This is even more important when a scheduler is working on multiple projects with specific reporting needs on each.

Best Practices

The project contract should address what documentation is officially required and the specifications will identify the type, number, and frequency of reports. A thorough review of these documents will enable the scheduler to create a project-specific process for project documentation.

Recommended Practice

Review the contract documents to be sure all contractual requirements are being met. Meet with the owner/CM/contractor to review contract requirements to be sure they are consistent with project management needs. Additional reports may be required, and if some contractually required documents will not be used be sure to collect the appropriate documentation that the requirement is being waived. Create a process document (see Figure 4-1) that illustrates the policies and the process and distribute the document to all parties. Be aware that the project needs may evolve, and the process will need to be updated to reflect the changes.

Advisories

The main purpose of the schedule is to communicate the plan to the rest of the team. If reports need to be added/changed to facilitate communication it is a good idea to do so. Find out if any additional/changed reports are one-time needs or will be required regularly. Open communication can help all parties find the balance between consistency and flexibility.

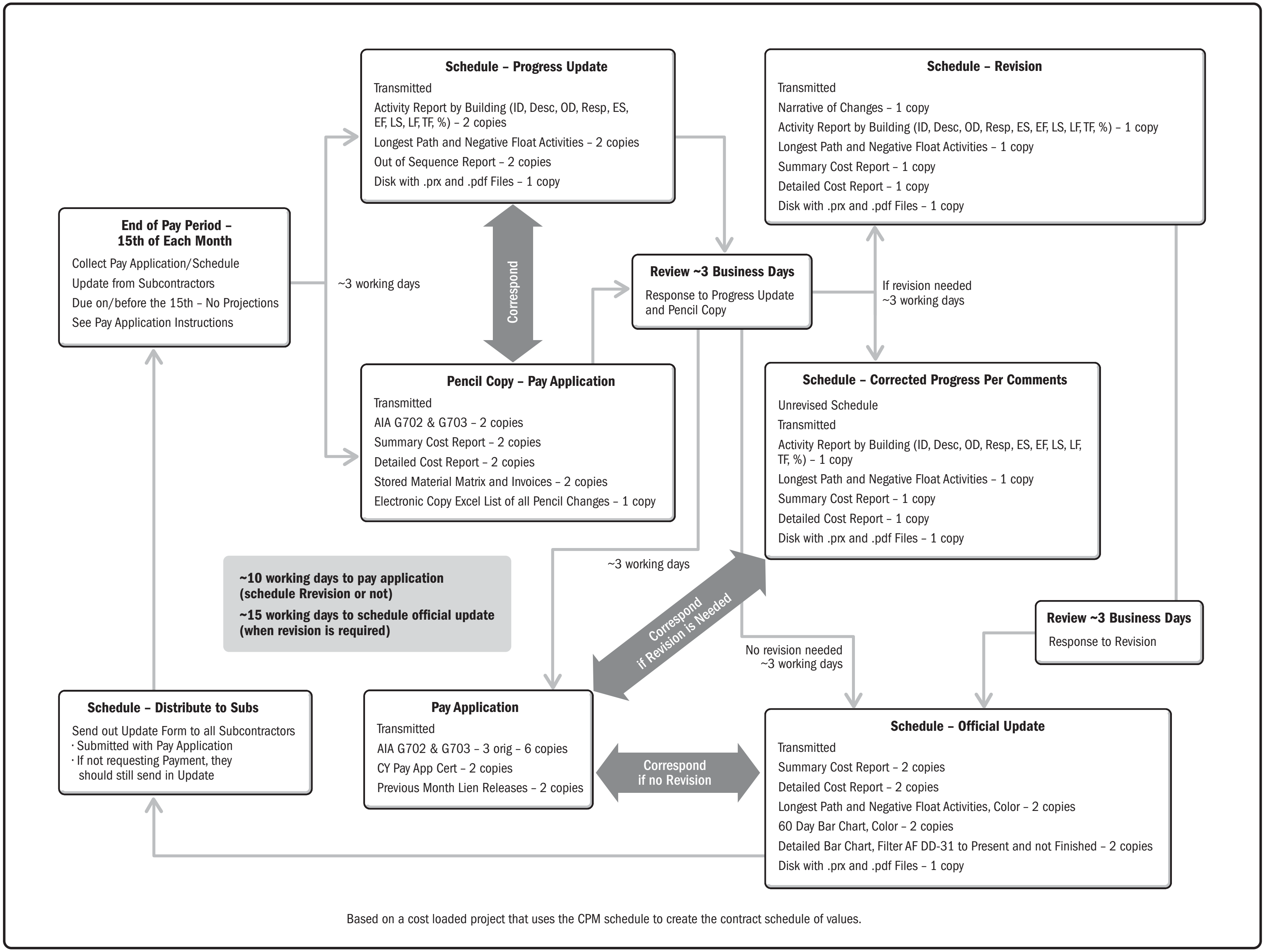


Figure 4-1: Sample schedule process document

4.7.3 Documentation Distribution

Distribution of reports and documentation allows the project team to evaluate, track, and plan. Being consistent and flexible with documentation facilitates the dissemination of information and improves the project schedule.

Guidelines

Definitions

The policies and procedures for records describes where and to whom they were sent.

Purpose

Consistent creation and distribution of the schedule brings consistency and flow to the project.

Default Condition

Documentation policies and procedures should be created and maintained for every project. This is even more important when a scheduler is working on multiple projects with varying distribution needs for each.

Best Practices

The schedule should be regularly distributed to every company that needs to know the plan for completing the project.

Recommended Practice

The schedule should be regularly distributed to the owner, architect, contractors, and any other parties that need to be kept informed of the project's progress. When distributing the schedule to each group, it should be sent to the person responsible for coordinating the day-to-day activities on the site (superintendent) and the person responsible for contract administration (project manager). Because the different contributors to the project have varying needs, the schedule distribution will often have various layouts and filters so that it will effectively communicate the plan. On smaller projects one or two reports might suffice, and on a larger project each of the following reports might be required (with frequency of distribution in parenthesis):

- Two to three week look ahead (weekly);
- Two to three month look ahead (monthly);
- Milestone schedule (quarterly);
- Entire schedule grouped by BLDG/AREA (monthly-quarterly);
- Entire schedule grouped by RESP/TRADE (monthly-quarterly);
- Longest path (monthly-quarterly);
- Negative float (monthly-quarterly); and
- Update form (weekly-monthly).

Advisories

Schedulers are often told that a contractor or supplier has a small part and does not need to get the schedule. Do not fall for that misconception. Any party that is contracted to complete a portion of the work is entitled to and should receive the schedule updates.

4.7.4 Historical Data

The availability of past project schedule and execution data can be highly valuable intellectual property for organizations. This information is useful for reference in preparing schedules for new proposals, as well as assessing ongoing projects.

Guidelines

Definitions

Historical Data—Collection of information recorded upon project completion to document how the execution actually took place.

As-Built Schedule—The final update to the schedule, with a record of dates for each activity's actual start and actual finish.

Baseline Schedule—The original schedule developed and implemented on the project for the purpose monitoring schedule progress of activities and forecasting completion of the project. Serves as a basis of comparison to future updates to identify variances in start and finish dates. Also known as target schedule, plan schedule, master plan, or other names, depending on the terminology used for a given contract or a company organization.

Updated Schedules—Once the baseline schedule has been built and adopted and the project has started, all updates to the baseline schedule become part of the historical record and data.

Basis of Schedule—Document issued to record the assumptions and other considerations made which provide the basis for the schedule.

Purpose

Having a collection or archive of past completed project historical data serves as a good reference for future projects of similar nature. This information can be very useful during the proposal stage to support the development of proposal schedules which reflect the reality of past experience. The historical data can also support the estimating efforts for time-related cost on new proposals.

Another area of application is for benchmarking purposes. By creating an extensive archive of past projects, statistical analysis can be applied and various project execution metrics derived for comparison purposes or assessment of ongoing projects. Some of the example relationships which can be useful on projects are:

- Construction duration to estimated labor hours;
- Construction duration per equipment count and\or plant capacity;
- Construction duration per level or floor;
- Construction duration per a set amount of square footage;
- Typical time span overlap of design to engineering and engineering to construction, whether fast-track or normal pace execution;
- Typical completion times, to name a few, for:
  - Mechanical installations
  - Electrical installations
  - Instrumentation installation
  - Site preparation
  - Foundation installation
  - Structural erection
  - Interior finishes
  - Punch list
  - Commissioning
  - Landscaping/hardscaping
- Typical proportion of various craft labor for a given type of construction; and
- Other possible use of specific historical data for any particular project would be for use in preparation of documentation in the event of a dispute, claim, or litigation between owner and contractor after the project completion.

Default Condition

At a minimum, all project progress reporting and issued schedule updates should be properly archived and kept on file in a central location (company file storage or schedule department archives).

A copy may also be retained by the scheduler assigned to the project. This person is likely to also have some additional personal information and insights on the history of the project. However, this may be an unreliable procedure to depend on for historical data collection, given the mobility of such personnel to different assignment locations and companies.

Best Practices

A final project close out/completion report should be prepared to contain the following information:

- A copy of the final as-built schedule update should be retained. Preferably one hard copy printout showing all activities' actual dates versus baseline target dates, and one backup electronic file copy of each of these schedules.
- A copy of the original baseline schedule as agreed with the client or issued by/to the project team at the start of the project.

- A final version of the basis of schedule document, to record the project execution decisions which are reflective of the project schedule outcome.
- A narrative history of the project, which highlights:
  - Analysis of the major causes of and reasons for project performance problems and implemented recovery actions;
  - Major decisions or change order notices which affected the outcome of events;
  - Identification of lessons learned from both a project execution and project controls methods improvement point of view;
  - Copies of the last update for earned value management progress curves;
  - Copy of actual staffing histograms or monthly head count; and
  - Compilation of the essential project statistics, such as construction labor work hours, engineering design hours, key installation quantities, key milestone completion dates, location of facilities, plant capacity, type of contract, etc.

Recommended Practice

At a minimum, a record copy of the final as-built schedule update should be retained. Preferably both a hard-copy printout showing all activities' actual dates versus baseline target dates and a backup electronic file copy in native format. A brief history narrative should also be prepared to give future users an understanding of the events which resulted in the as-built schedule.

See Topic 4.5.2, Preservation, for information on how to capture the historical record of project schedules that lead up to the final as-built schedule.

Advisories

Upon project completion, allowances should always be made for time and effort to carry out closeout reporting. The availability of past project experiences always proves to be highly valuable intellectual property for the organization. Loss of this information should be prevented by making assurances that project personnel will create the historical records. This should be considered as part of their professional requirements and completed before destaffing and moving on to their next project assignment.

4.7.5 Project Contract Documentation

Good project contract documentation strengthens the schedule and helps avoid misunderstandings, disputes, and claims.

Guidelines

Definition

Project contract documentation comprises records that are kept throughout the course of the project and the items that will be saved for years after project completion.

Purpose

Proper project contract documentation improves project scheduling and helps avoid disputes and claims.

Default Condition

Documentation should be kept for every project.

Best Practices

Thorough documentation helps to avoid conflicts during and after the project. Keeping records of communication both in and out can be used to resolve misunderstandings later. When other people know that the scheduler is collecting, using, and retaining thorough documentation it instills confidence in the schedule and improves the quality of information received.

Recommended Practice

Project contract documentation should include the following documents:
- Project contract;
- Project change orders;

- Specifications and drawings;
- Baseline schedule, as officially approved by the owner/CM/contractor/scheduler;
- Progress updates as accepted;
- Schedule revisions as accepted;
- Any specific coordination documents that were distributed (fragnets, breakdowns, details, contingencies, what-ifs, etc.); and
- Input from the owner/contractors/other that was used to create the baseline, revisions, and updates (dates, durations, sequencing, costs, resources, etc.).

Advisories

Always plan and record the documentation procedure prior to starting. This will help keep the documentation process consistent throughout the project. Record any changes in the documentation process and be aware that each time the process changes the risk of not being able to find a needed document increases.

Section 5

Schedule Maintenance

A schedule is a tool that can provide valuable information during the life of a project. The effectiveness of this tool is no better than the information assembled and used to create and maintain it during the life of the project.

A schedule has many uses during the life of a project, including and not limited to, the following. It provides a:

- List of work and deliverables defined by a project;
- Timeline of when work will be performed and when deliverables will be available;
- Visual representation of the sequence of work;
- Visual representation of the time required to perform work;
- Means for adjusting the project for the unexpected;
- Means for forecasting the possible outcome of events; and
- Means for measuring progress.

5.1 Schedule Usage

Guidelines

Definitions

A schedule usage process is a document that describes how the schedule is to be used. Usage here means how the project manager will apply the schedule as well as how other users of the schedule will derive benefits from its use (e.g., information might be extracted from it to give to finance, PMO, contracts, executive management, marketing and communications, and external contractors). In essence, the document describes how schedule management is to be done.

Purpose

The purpose of developing a schedule usage process is to clearly outline management expectations of how the schedule is to be used, including guidance and tips in the way the process and the toolset can be easily applied. From an overall project/program perspective, the objective is to raise maturity of schedule management by providing a consistent set of processes and guidance in the application of same.

Default Condition

Consider writing a schedule usage process when a consistent approach is needed for schedule usage across projects and programs. Consider also the level of project/program management maturity within the organization before embarking on writing one. Write something that fits purpose and maturity of the target audience.

Best Practices

In more mature organizations, a schedule usage/management document is made available for all new start up projects/programs and is a referenced document for conducting project/program audits or health checks.

The development of a schedule usage process normally falls under the responsibility of the scheduler, schedule manager, PMO manager, or project director ideally at the beginning of the project/program and is continually updated as new requirements for use come in throughout the duration of the project/program. It may also be developed as part of a strategic management area or center of excellence area within the organization. It may be part of a suite of general governance guidelines to cover all the project management areas as issues, risks, change, scope, and vendor management.

This document can take the form of a scheduling guidelines document or a schedule management document for the program, business unit, or division. In smaller projects, this can be a subset of a broader governance document such as a project management plan.

Some of the topics it may contain will be:

- WBS structure
- Project management or development methodology/lifecycle (if any schedule templates are to be applied);
- Schedule storage (if any EPM tool is to be used, file naming and storage);
- General toolset standards (e.g., views, calendars, tables, user defined fields, etc.);
- Dependency and resource utilization/management;
- Baseline management and the calculation and application of contingency and buffers;
- Calculating critical path or critical chain;
- Schedule control, statusing and/or updating (including regular updating cycle and roles responsibilities);
- Schedule reporting.

Recommended Practice

Consider first if there is value in having a schedule usage process. If so, check to determine if a process already exists within the organization (from the PMO area or a similar project). Consider also the intended audience (and most specially their project management maturity) and tailor the scope and level of detail of the document accordingly.

Choose the applicable topics from the above list. Write the document with the minimum set of topics and expand later. Publish with sponsorship of the program director or the highest governance authority to champion it.

Advisories

Tie it to any health check or audit process that will give you an indication of the level of compliance and its usefulness. Prepare a draft highlighting an existing sample project to use for mockups and screen shots. Trial the usage process before rolling it out and keep it simple and brief. Make sure to keep updating it as the project/program goes along to keep it current, fine-tuned, and applicable. Clearly articulate your assumption of maturity of the intended audience to avoid insulting anyone's intelligence and experience.

5.1.2 Developing a Schedule Usage Process

Guidelines

Definitions

A schedule usage process is a document that describes how the schedule is to be used. Usage here means how the project manager will apply the schedule, as well as how other users of the schedule will derive benefits from its use, such as information that might be extracted from it to give to finance, project management organization, contracts, executive management, marketing, change and communications, and external contractors. In essence, the document describes how schedule management is to be done.

Purpose

The purpose of developing a schedule usage process is to clearly state management's expectations of how the schedule is to be used, including guidance and tips on how the process and toolset can be easily applied. From an overall project/program perspective, the objective is to raise the maturity of schedule management by providing a consistent set of processes and guidance in the application of the same.

Default Condition

Consider writing a schedule usage process when it is beneficial that a consistent approach needs to be adopted across projects and programs. Consider also the level of project/program management maturity within the organization before embarking on writing one. Write something fit for the purpose and to the maturity of the target audience.

Best Practices

In more mature organizations, a schedule usage/management document is made available for all new startup projects/programs and is a reference document for conducting project/program audits or health checks.

The development of a schedule usage process normally falls under the responsibility of the scheduler, schedule manager, project manager, or project director, ideally at the beginning of the project/program, and it is continually updated as new requirements for use come in throughout the duration of the project/program. It may also be developed as part of a strategic management area or center of excellence area within the organization. It may be part of a suite of general governance guidelines that cover all the project management areas such as issues, risks, change, scope, and vendor management.

This document can take the form of a scheduling guidelines document or a schedule management document for the program, business unit, or division. In smaller projects, this can be a subset of a broader governance document such as a project management plan.

Some of the topics a schedule usage may contain are:

- WBS structure;
- Project management or development methodology/life cycle (if any schedule templates are to be applied);
- Schedule storage (if any Electronic Project Management [EPM] tool is to be used, file naming, and storage);
- General toolset standards (e.g., views, calendars, tables, user defined fields, etc.);
- Dependency and resource utilization/management;
- Baseline management and the calculation and application of contingency and buffers;
- Calculating critical path or critical chain;
- Schedule control, statusing, and/or updating (including regular updating cycle and roles responsibilities); and
- Schedule reporting.

Recommended Practice

Consider first if there is value in having a schedule usage process. If so, check if one already exists within the organization (from the PMO area or a similar project). Consider also the intended audience (especially their project management maturity) and tailor the scope and level of detail of the document accordingly.

Choose the applicable topics from the above list and write the document with the minimum set of topics and expand later. Publish with the sponsorship of the program director or the highest governance authority to champion it.

Advisories

Tie the schedule usage document to any health check or audit process that will give you an indication of how well it is being complied with and its usefulness. Prepare a draft, using an existing sample project for mockups and screen shots. Trial the usage process before rolling it out and keep it simple and brief. Make sure to continue updating it as the project/program goes along to keep it current, fine-tuned and applicable. Clearly articulate the assumption of the maturity of the intended audience to avoid insulting anyone's intelligence and experience.

5.2 Routine Schedule Analysis

Routine schedule analysis refers to the periodic analysis of a schedule, to include:

- An evaluation of the critical path/paths;
- The need for re-baselining the schedule, if necessary, due to significant changes to the schedule by change order or a delay;

- The use of comparative targets, schedule variance analysis, and documentation of logic changes; and
- The use of statistics.

The word "routine" refers to how often this analysis needs to occur. That time frame is dictated (or should be dictated) by the schedule specifications in the contract (see Section 5.3, Schedule Compliance Analysis). No matter what the schedule specifications say, the schedule should be updated at least once a month and analyzed accordingly to ensure that all stakeholders are aware of what is going on with a particular project.

5.2.1 Evaluation of Critical Paths

Guidelines

Definitions

To have a critical path in a schedule, the schedule must be built in accordance with CPM standards. The critical path is the longest path through the schedule. A project schedule will always have one, at minimum, and often it will have many. The number of critical paths is usually determined by several factors, including:

- **The complexity of the project.** For example the schedule for a high rise condominium tower will in most cases have only one critical path extending from foundations, structure, exterior finishes, interior finishes, punch list, to final commissioning and approval. Whereas the schedule for a microprocessor chip plant will have many critical paths because there are many buildings and systems that have to be in place before the project is complete and the first chip can be produced.
- **The number, description, and type of milestones dictated by the contract specifications.** Some owners are only concerned about the milestone "substantial completion" because they know that is when they will receive their building. Others may want to track the interim milestones and steps in the construction of the project that get them to substantial completion. Those other milestones may be on the critical path to substantial completion, or they may be on their own.

The evaluation and analysis of a critical path is the process of determining what project activities and scope of work are critical to its completion. "Critical," meaning that the durations and logic of those activities on a critical path must be adhered to per the baseline schedule, or the project could suffer a delay which would push the contractual end day out and cause all kinds of problems and concerns. Knowing the critical path at the beginning of a project allows the stakeholders to recognize and prepare for those activities and the scope of work that is on it. Knowing the critical path during the life cycle of the project as it progresses allows the stakeholder to know if there are any changes to the original critical path, what those changes are, and the new critical path if it has in fact changed. It also provides a heads up as to how to deal with it. Evaluating the critical path after the project is complete is usually of no concern to anyone if the project was successful. If it wasn't a successful project, that means there was usually a delay claim involved and then the analysis and evaluation of the critical path is very important and has many ramifications—some good and some bad.

Purpose

The main purpose of evaluating the critical path is to understand the state of the project, after performing an update to the schedule. Is the project on track, meaning the total float of the critical path is positive or zero? Or is the project losing time and being delayed for whatever reason, and the total float of the critical path is negative? A quick evaluation, and use of a critical filter, will answer these questions right away. If the project is on track then all is well, but if the critical path is negative, the analysis will tell you right away which activities led to the criticality and provide direction as to what to do to correct the problem.

Default Condition

An evaluation of the critical path should be performed each time the schedule is updated, once the baseline of the schedule is created. During schedule development and creation prior to the baseline schedule, knowing which activities and scope of work are really on the critical path is difficult until the schedule is fully developed and detailed.

Best Practices

The easiest way to evaluate a critical path is to create a filter so all that is visible on the computer screen is the critical path. The filter should show all activities that have started but not finished, and all activities that have yet to start and complete. If the project schedule is in progress, those activities that were on the critical path at some earlier date in the project cycle will not show up once they are completed activities and the start and finish dates are actualized. A project schedule that was built to proper CPM standards and is a complete as-built schedule will show no critical path. Once a project schedule is complete, the critical path or paths that led to final completion will be unknown if all one is looking at is the final project schedule database. In analyzing the critical path of a completed project, one would need all of the updated schedules to determine what the critical path or paths of the project were.

It needs to be pointed out that, if a project schedule really goes south and encounters a major delay that shoves the end date way out past its contracted time, the negativity on total float may be so great that almost the whole schedule can go critical because the large negative float works its way backwards and can affect all activities. When this happens, a filter needs to be created on the most negative total float to determine the real most critical path.

Recommended Practice

Once the baseline schedule is in place, construction has begun, and the schedule is being updated on at minimum a monthly basis, an evaluation of the critical path should be one of the first things performed at the completion of each update.

Advisories

Avoid at all costs failure to perform an analysis of the schedule. Why create and update a schedule if it is not being analyzed accordingly on a regular basis?

5.2.2 Re-Baselining

Guidelines

Definitions

Re-baselining is the process of adjusting the schedule to reflect a major change to the original plan of execution of a project schedule. The original baseline and plan of execution is no longer valid due to the change, so the schedule is completely redone in terms of reworking the activities that have started but not completed and all of the successors to those activities. Activities and work completed are just that—complete and out of the picture. It is all subsequent work that needs to be looked at to reflect whatever occurred on the project to force the change. Activities and scope of work will have to be added or deleted to reflect changes.

Purpose

The purpose of a schedule is to create a plan of execution for the construction of a project, and once the project is underway the schedule provides a way to track the progress of that work through the update process. It is a tool for managing the project. The completed and fully detailed schedule to all stakeholder satisfaction then becomes the baseline schedule for the project. It is the as-planned schedule. If, however, the project encounters a delay or a major change of scope (change order) the original as-planned schedule is no longer a good tool to track progress. The schedule needs to be reworked to reflect that added or deleted scope of work or to account for the delay. Once all the information is known the schedule can be adjusted and the process of doing so is called re-baselining. It is essentially a rebuild of the schedule to reflect a change that has a major impact on project execution, which means the original plan is no longer valid.

Default Condition

The only time re-baselining is needed is when there is a major change to the scope of work of a project or a delay which requires that the schedule be reworked to reflect that change or delay. Otherwise, the schedule can be left alone if all is going as planned.

Best Practices

The project stakeholders will in most cases know in advance that a change is coming and that a re-baselining will need to be done. There is always some advanced warning that a change order or a possible delay is going to occur. As events unfold, the schedule can be adjusted to reflect those changes as they become evident. A what-if schedule is usually built that reflects what those changes are going to do to the project so that some degree of advance planning and accounting for the changes and the impact to the schedule can be determined. So once a major change to project execution, and thus to the project schedule, is learned or known, the impacts of that change can be added to the schedule, even if at first it is only a guesstimate of the total impact and what exactly is going to occur. The act of adding the changes early to the schedule informs the stakeholders as soon as possible about the consequences and gives them more time to react.

Take note (and this cannot be emphasized enough): Do not wait until you have all the information concerning the change before you add it to the schedule and then present the change to the stakeholders. Remember the schedule should "tell the truth," so add new information into the schedule as soon as you become aware of it. The project team may not like being told the truth but you did your job in relating it too them soonest. It is up to the stakeholders now to deal with it. The process is to add activities to the schedule that reflect a change as you become aware that there is a change. As time goes on, the activities that are preliminary, vague, and summary in nature can be further detailed as more is known and information becomes available to the team, so that by the time all is known about the impact the schedule will in most cases be ready to be called the new baseline.

Sometimes re-baselining not only means the addition or subtraction of scope of work, but can also mean a total re-sequencing of the work once the change is accounted for in the schedule. The change could be significant enough to warrant a whole new approach to completing the project. When a significant change occurs the team will know early on what the team will have to do to mitigate it if it pushes the critical path, and thus the end date. Now there are company cultures that will not want to mitigate a change, especially if the change or delay is not their fault. They will want to blame the owner if he or she in particular is at fault. A due diligent contractor will help the owner recover some time by looking at re-sequencing if that will gain some time and mitigate the delay.

Recommended Practice

Once the project stakeholders realize that a change is coming which will impact the project and the schedule, begin the process of adding activities to the schedule to reflect and account for the change. Those activities and scope of work may not be fully known in the beginning, but as time goes on the details will become evident and summary guesstimate activities can be detailed to more accurately reflect the time impact and what needs to be changed. A copy of the master schedule could be created first, and an analysis (what-if) performed in that schedule to reflect the impact of the change (sooner rather than later), though the change needs to be incorporated into the master schedule. Remember, there can only be one project schedule.

Advisories

Doing nothing about any major change in scope or reaction to a delay or whatever it was that caused the change should be avoided. To do nothing is irresponsible, not doing due diligence, and more than likely a breach of contract.

5.2.3 Use of Comparative Targets

Guidelines

Definitions

A target schedule is any schedule that is used to compare the progress of one schedule against another. For example, once the baseline schedule is complete and approved for the project, the use of comparative targets is the process of comparing updates of the schedule to the baseline schedule in order to understand if the project progress is maintaining and tracking to what was planned originally. It also refers to the comparison of one month's schedule update to last month's or whatever month or schedule one would want to use for comparative analysis.

Note: The ability to do this is a function of the software, and not all scheduling software offers the ability to compare/target one schedule against another.

Purpose

The purpose of using comparative targets is for the project team to understand the relationship of how a project is coming together (the as-built condition) as opposed to the as-planned or baseline condition. It is a very useful tool to determine if the project is tracking to what was originally planned.

Default Condition

Comparative targets should be used after each update of the schedule in order to track progress and to ensure that the original plan is being adhered to.

Best Practices

In order to use comparative targets, it is necessary to have a historical record of the project. Besides the baseline schedule, each update schedule needs to be saved as its own database. As time moves forward and, depending on the update cycle (biweekly, monthly, or whatever it is per the contract), the list of schedules in the historical record will grow accordingly. If the software being used has the functionality to use comparative targets after each update, it is a good idea and a useful tool to compare that update to the baseline to see how progress is tracking against the original plan.

If the target bars and the progress bars of the schedule line up exactly (their start and finish dates are the same), then the schedule and the target are progressing as planned. If the target bars are to the right of the progress bars (target early start and finish occur later than progress early start and finish), the schedule and the project are progressing faster than planned. Both of these scenarios and outcomes are good, and the team deserves a pat on the back. If, however, the progress bars are to the right of the target bars (progress early start and finish occur later than target early start and finish), then things aren't coming together as planned, and it should raise a red flag to the team to figure out why and make corrections, if possible, especially for activities on the critical path.

A comparative target is also a useful tool for schedule analysis schedule if the project and the schedule are involved in a delay claim. Comparing what happened from one month to another is useful in determining what happened and when.

Recommended Practice

Again, if the scheduling software allows the use of comparative targets, then the analysis should be performed after each update to determine if the project schedule is tracking to what was originally planned. If the project is veering from the original plan, the use of target schedules allows the team to see where it went off track and what steps, if necessary, need to be taken to get it back on track.

Advisories

There is really nothing to avoid in the use of comparative targets. If the scheduling software allows the use of target schedules (comparing one database against another), it is a useful tool. If the software doesn't allow this use, a visual comparison of one schedule against another can be done, or one could simply look at the critical path and total float of each schedule and compare them. If total float is negative it is a pretty good assumption that the original plan is in jeopardy and the project wandered off of it somewhere along the line.

5.2.4 Schedule Variance Analysis

Guidelines

Definitions

Schedule variance analysis is the process of comparing one schedule to another and noting the changes between the two. An example would be the analysis of comparing the latest recent schedule update to the previous one, to note the changes. The changes one would look for, but are not limited to:

- Any addition of activities
- Any deletion of activities

- Changes in duration
- Changes in logic
- Changes in lags
- Changes in total float
- Changes in the critical path
- Changes in the code structure
- Change of calendars
- Change in dates—ES, EF, LS, and LF
- Change of activity type
- Changes in resources

Purpose

The purpose of analyzing schedule variance is to reach an understanding of changes made between schedules. This tool is actually used more by owners and their construction managers, to help them better understand what their general contractor (GC) is doing with the schedule. Unfortunately, there are those GCs who manipulate the schedule by adjusting lags or logic to bury float or cover a delay caused by them, rather than just telling the truth. An analysis of schedule variance will flush out any unscrupulous changes. That is not to say that all changes to a schedule have negative intentions. A major change to a schedule because of a change of scope or delay (see Section 5.2.2, Re-Baselining) will also result in a lot of schedule variance, which is understandable and without negative intentions.

Default Condition

An analysis of schedule variance would be conducted after each update of the schedule to mark any changes between the updated schedule and its predecessor.

Best Practices

Variance analysis after each update of the schedule should be done to mark any changes to the schedule. It is a good tool and practice understanding what was done to the schedule. In many cases it is a required report out that is dictated by the specifications in the contract. The best and easiest way to perform the analysis is to use a software product such as Digger. There is also other software out there that performs a similar function. To perform the analysis by hand would require a lot of time and frustration, unless the person doing the analysis was also the one who performed the update. If one were to create a log of all changes made to a schedule during the update process, a good start would be to look at changes made to the process.

What would be really time-consuming is to have to track and compare the changes in dates for all the activities in two different schedules other than the end dates for each schedule.

Recommended Practice

If the scheduling program works with other analysis software such as Digger, the analysis is easy. If not, it will be a long process. In either case, the analysis should be performed after each update.

Advisories

Again, doing nothing should be avoided. Schedule variance is a useful tool that should be incorporated after each schedule update in order to better understand what is going on with the schedule and the project.

5.2.5 Documentation of Logic Changes

Guidelines

Definitions

Similar to variance analysis, the documentation of logic changes is the tracking and recording of any logic change made during the update of a schedule. Unlike variance analysis, though, changes in logic can have implications other than the fact that logic has changed.

Purpose

The purpose of first analyzing logic changes and then documenting them is to have a full and complete understanding of what changes were made to the logic during an update of the schedule. Some scheduling specifications in the contract are very specific and strict about this, and others are not. In any case, it is a good idea to understand what is going on with a schedule during its updating process.

Default Condition

An analysis of logic changes and the documentation thereof should be done at each update.

Best Practices

There are some things that need to be remembered here that pertain to logic changes. During the process of building a schedule—prior to the baseline schedule—logic changes are going to occur all the time until the schedule is finalized and the baseline schedule is complete. There is no need to track any of those changes to logic.

Once you have a baseline schedule, the activities and their durations and relationships to other activities are called the as-planned condition. This is the plan for building the project. Once the project starts and the tracking of progress begins then it is necessary to track any changes of logic.

It must also be noted that the calculation method, if available in the software, must be "retained logic," even if you are given a choice between it and "progress override." Some scheduling software doesn't give you that option. Even if the option is not available, it is still good practice to note logic changes. The only time logic changes can be made is during the update process, and only on those activities that are being updated. The use of retained logic means that you have to change the as-planned logic to as-built as you progress the schedule.

The official wisdom in the scheduling world is that one should never change downstream logic on any activity that hasn't started and is outside of the updating period, or to the right of the data date. Having said that, though, as all general contractors (GCs) know, contingency/buffer/padded time is usually added to the back end of the schedule somewhere to give the GC a place to recover time if needed. It is either covered by the use of lags, or buried in activity durations (dummy activities). This practice is considered wrong by the scheduling purists, but absolutely necessary by the GC realists. You have to have some time buried somewhere as part of the risk management plan, and yet not be too obvious about it.

So after an update the end date of the project goes negative and the reason for it is the GC's problem. He will change the logic on one or several of these contingency activities to adjust and account for the negativity. Of course the opposite is true if the cause for delay is not his responsibility. He will let it ride and hope for a claim. This is where the documentation of logic changes comes into play. It is not a tool used by the GC, but rather by the owner or his representative (CM) to understand what is going on with the schedule. They pay particular attention to logic changes made to the right of the data date, to look for any sequestering or manipulation of float.

If there is a major change to a schedule because of a change order or delay that drastically alters the original plan, the documentation of logic changes should be clearly apparent. It should be obvious that any and all changes of logic need to be documented so that all the stakeholders understand what was done to the schedule because of the change.

Recommended Practice

There are two ways to document logic changes. The first is to just write them down as they are adjusted in the form of a list. The second is to use software such as Digger that notes all changes made to a schedule by comparing the latest update to its predecessor, the baseline, or whatever schedule one wishes to make the comparison against.

Advisories

Understand what took place during an update of a schedule, and keep a record of changes to it.

5.3 Schedule Compliance Analysis

Guidelines

Definitions

Schedule compliance analysis is the process of determining whether a project schedule generated by a general contractor follows the owner-generated project schedule specifications as outlined in the project contract at a minimum, and the construction industry scheduling best practices and guidelines at a maximum.

Purpose

The construction of a project schedule isn't much different than the construction of the project itself. There are certain and specific steps, stages, and logic to building the project, just as there are in building the schedule that is the plan for building that particular project. The purpose of schedule compliance is to ensure—to the satisfaction of all parties concerned—uniformity, accuracy, proper accounting for progress, sufficient detailing of the scope of work, and the ability to account for change and impacts to the project.

Default Condition

Schedule compliance with the specifications in the project contract and scheduling best practices and guidelines from a multitude of sources must be adhered to in any and all schedules.

Best Practices

The aim here is not to provide an example of a schedule specification, but rather to give you an idea of what a schedule specification should include. It is necessary to follow both the contract specs and industry standards to build a project schedule because in many cases the degree of detail in specifications can vary greatly. In all cases, the industry standards should be followed, as adherence to them will create a properly built project schedule, no matter what the owner specifies. Owner-generated contract specifications can include the same standards as the industry standards, but in some cases they won't or can't, depending on what the owner's demands are for schedule development and report out, or his or her knowledge of what a proper scheduling specification should be in the first place. It can generally be said that construction industry standards are detailed and cover all the bases. Owner specifications can be very simple and straightforward; they can mirror or mimic industry standards, or they can go way overboard and be very detailed and controlling.

Recommended Schedule Specification Content

- Purpose of the schedule
  - Planning and coordination of the work—Plan the work/work the plan
  - Monitor progress
  - Impact and change analysis
- Related specification
  - Notes other spec sections that contain information pertinent to schedule requirements.
  - Need to read/review all noted spec sections.
  - Related Division 1 sections include the following—taken from the master format:
    - Summary of Multiple Contract, for preparing a combined contractor's construction schedule
    - Payment Procedures, for submitting the schedule of values
    - Project Management and Coordination, for submitting and distributing meeting and conference minutes
    - Submittal Procedures, for submitting schedules and reports
    - Photographic Documentation, for submitting construction photographs
    - Testing and Inspection Documentation, for submitting a schedule of tests and inspections
- Software requirements
  - Notes what scheduling software must be used for schedule submissions
  - May only state what the owner is using, but data must be compatible
  - Sometimes called a relational database

- Data exchange requirements
  - Standard data exchange format
  - Allows database exchange between Primavera and other systems
- Master dictionaries and reports
  - Dictionaries for activity codes, activity IDs, work breakdown structures, resources and cost accounts, and report formats
  - The schedule will and should be rejected if these dictionaries are not utilized in the submittal schedule
- Preconstruction meeting
  - Preparation for the meeting
    - Need for a sequencing plan
    - Need an understanding of contractor resources
      - What work is done in-house/self-performed
      - Crew availability
      - Trade issues—buyout and availability
    - Contractor needs for mobilization
    - Understand completion time and all milestones
- Qualifications of the scheduler
  - Software certifications
  - Years of experience
  - Specific project experience
  - Industry certification
  - Scheduler resume submitted needs to show compliance with specs
- Required submittal contents
  - Electronic
  - Paper
    - Report sizes
    - Report formats
    - Required information
    - Copies
    - Distribution
- Owner-mandated milestone treatment
  - Need clear definition
  - Identify all predecessor activities
  - Identify all successor activities
  - Identify any outside influences on completion
  - Decide how to incorporate the milestones in the schedule
  - Use of constraints and the type of constraint
- Float ownership
  - Float is not for the exclusive use or benefit of either party but is an expiring resource available to both parties on a nondiscriminatory basis.
- How is weather contingency being handled?
  - Normal weather
  - Abnormal weather
- Prohibitions on manipulation of a schedule
  - Use of float suppression techniques such as preferential sequencing or logic, special lead/lag logic restraints, and extended activity times or durations are prohibited and use of float time disclosed or implied by use of alternate float suppression techniques shall be shared to proportionate benefit of the authority and contractor.
  - Use of any network technique solely for purpose of suppressing float will be cause for rejection of schedule submittal.
  - Need to have a rationale for any time contingencies incorporated in the schedule.
  - Eliminate or define all lags, to eliminate concern about float sequestering. Remember, a lag is essentially an undefined activity.

- Negative lags are counterintuitive to most schedule users, and should not be used in any circumstances.
  - Check all SS and FF relationships with lags for possible sequestering.
- Planning units and calendar requirements
  - May specify smallest planning unit
  - May also specify other total project shutdowns—for example, a Department of Transportation winter paving halt
- Coding of activities
  - Allows for the filtering out of specific information from the schedule
- CPM network requirements
  - Ensure the spec calls for CPM
  - Precedence scheduling normally required
- Duration definitions and restrictions (level of detail)
  - Limitations on size of duration
    - Tied to update period size
    - Tied to project length
    - Tied to project complexity
    - Could be just a limitation, such as maximum 20 workday duration
    - A good rule of thumb is: no duration longer than the reporting period, except for long-lead procurement activities.
- Scope definitions
  - Level of detail sufficient to track progress
    - This also ties in with duration.
  - As a general rule, try to eliminate in any activity description the scope of work to be performed by multiple subcontractors. For example, in the activity "Form/Rebar/Pour Spread Footings in Zone 1" there are at minimum three different subcontractors involved in performing that activity—the formwork sub, the rebar sub, and the concrete placement and finish sub. There could also be at least three more if electrical, mechanical, or plumbing trades are needed to perform their scope of work in the embedded concrete.
- Initial project schedule (IPS) submission
  - First 90 to 120 days of project
  - Highly detailed for this period
  - Conceptual for balance of work
  - Allows monitoring and management of initial work period
  - Usually details procurement process and permitting
  - Must incorporate all milestones and completion
- Detailed project schedule (DPS/baseline) submission
  - Use IPS so there is only one schedule
  - Fully detailed with all scope of work on project
  - Must incorporate all scope of work
  - Must incorporate correct milestones and completion time
  - The DPS/baseline is also called the ICPM (initial critical path method schedule)
- Schedule updates
  - Usually dictates strict requirements
    - Field verification meeting
    - List of people involved
  - Spec dictates time and process for updates
  - Formal reporting typical
  - Narrative requirement common
  - Checklist of submittal reports required
- Delays and time extensions
  - Details process necessary to prove delay earning time extension
  - Time impact analysis requirement
  - Notification requirement
    - Important process to follow
    - Usually tied to discovery of delay event
    - Can be three-part: notice of delay event, submittal of analysis, and request for time extension

- Recovery schedules
  - If the project encounters the need for a major revision of the schedule due to a change order or a major delay, a rework of the schedule is needed to create a new baseline schedule.
- Early completion schedules
  - Specifications may be silent, i.e., no language about submission of a schedule showing early completion.
  - Early completion schedule contains total float, so planned project completion is earlier than contract requirement.
  - Sometimes there is no benefit to the owner for early completion.
  - Sometimes specifications require change order to advance contract completion to planned completion.
- Final as-built submittal
  - Usually requires one final submittal with all activities progressed to 100%
  - Need verification of accuracy
  - Spec may require additional activities showing change orders or impact events
- Short interim schedules (look-aheads)
  - Sometimes called "rolling wave scheduling"
  - Can be produced from a full baseline schedule, or developed weekly by superintendent
  - Contains more detail allowing day-to-day management of project
  - If created in another database or software package other than the baseline, the detailed activities in the look-ahead MUST match the overall less detailed/summary activities in the baseline in terms of overall duration, especially as pertains to the critical path.
- Cost and resource loading
  - Cost loading
    - Commonly done to produce invoices based on schedule progress
    - If required, should unlink percent complete from remaining duration in software
    - Check to see how general conditions are handled (general conditions are the project's time-based costs: trailer, staff, project utilities, etc.).
      - General conditions may be loaded in hammock or level of effort activities.
  - Resource loading
    - Resources can be manpower, specific equipment, or materials.
    - Units can be hours, days, equipment hours (running hours), crews, cubic yards, linear feet, tons, etc.
    - Used to enable earned value management
    - Good data in the case of a delay, so planned equipment use can be compared to actual
- Narrative requirements
  - Spec may have a specific list; for example:
    - Work performed and/or completed this period
    - Work to be performed in the next period
    - The critical path
    - Areas of concern/impact to project
  - Initial project schedule narrative should identify sequence and workflow.
  - Updated schedule narratives should identify ALL changes to the planned workflow.
  - The narrative must "Tell the truth, the whole truth, and nothing but the truth."

Recommended Practice

The preferred practice is that there is a schedule specification for all projects. There are many sources available to create your own schedule specification (see list below). The origination of contract schedule specification is dependent on the project delivery system. If the project is design/bid/build, the schedule specifications (and all the other specifications) are usually created by the owner and/or one of his representatives (the architect, CM, etc.). It is rare that a general contractor (GC) will create the specification, because by the time they see the bid documents (drawings and the project documentation, specifications, etc.), they are already created. It doesn't mean that they are etched in stone, however. In most cases, all specifications are negotiable, including the scheduling specs. In a design/build project delivery system the creation of all the specifications could be a joint effort by all parties. Sources for schedule specifications include:

- Association for the Advancement of Cost Engineering (AACE)
- PMI *Practice Standard of Scheduling* – Second Edition
- *CPM in Construction Management* (Sixth Edition), by James J. O'Brien and Fredric L. Plotnick
- *Master Format System* (1995 Edition), Division 1, Sections 01320, 01321, 01326, and 01335
- *Master Format System* (2004 Edition), Section 01.32.16
- U. S. Army Corps of Engineers
- U. S. Department of Energy

Advisories

A project schedule that doesn't adhere to any schedule specifications, or to the schedule specifications dictated by the contract and scheduling best practices and guidelines in general will:

- More than likely not be a project schedule approved by the owner.
- Be a grave error on the general contractors part for non-compliance of the contract.
- Place the general contractor heavily at risk for using a flawed schedule that may or may not work at all in depicting the scope of work of the project, or be able to track and progress that scope of work. Remember, the whole idea behind a project schedule is to tell "the truth" as the project team experiences it throughout the life of the project.

5.4 Schedule Reporting and Response

Default Condition

Schedule reporting is about communicating vital information related to the project schedule and its status. This is usually done within the confinements of a well-established communication strategy that takes into consideration the identity of the different project stakeholders and their specific reporting needs. This strategy materializes itself through a document known as the project communication plan. Project contract specifications also dictate the types of reports and their frequency.

Several attributes control the process of reporting a schedule. The first of these critical attributes is represented by the actual type of reporting. Reporting should not be limited to the standard target comparative reports and/or variance reports, for example. Schedule reporting should be driven both by a scheduler's proactive approach to project reconnaissance, the project's current needs, and more advanced schedule performance analysis, as well as forecasting ability.

Other important attributes include the reporting level of detail, as well as its frequency. Highly important to schedule reporting is the principle of context. This is best communicated through a narrative. Last but not least, there are several tools out there for schedule reporting. Commercial scheduling tools usually offer software specific reports. For more comprehensive reporting, though, customized tools are typically used, such as traditional spreadsheet or word processing applications and executive dashboards.

Response, on the other hand, is about being proactive as a scheduler and providing more input than just sheer reporting of analysis results. Response is based on a sound and proper understanding of the complex dynamics governing a project. Schedule response is about providing recommendations and solutions to specific circumstances that might arise on the project. These could be recovery scheduling, conformance recommendations, change management-related recommendations, as well as risk-related recommendations, for example.

Advisory

The scheduler should be more proactive in his involvement in the project, starting with the way he or she stays informed about the project's status and current issues. This could easily range from frequently attending project-related meetings—whether they are management-level, site, or internal organization meetings—as well as simply relying on his or her judgment.

Checking how long items stay on the minutes of meetings, for example, could provide a good hint of the project participant's reaction times, and also of probable future delays (long-lead future problems).

Observe and watch, among other things, whether the schedule is being used in site meetings to discuss project progress. Are the people responsible for executing the scope of works using the schedule properly? Are problems being communicated to the office in a timely and proper manner? Are those issues being resolved in a timely manner?

The schedule should be viewed as a tool which could ultimately provide answers to problems, but also ultimately guides project participants into either correcting or maintaining their course as well.

Numerous reports are listed and described in Section 5.4 that can be used by the stakeholders and the project team as report out tools. Be advised that not all may be pertinent or even necessary to the project. The project team will know which ones to use for their particular project.

5.4.1 Schedule Communication Strategy

Using the right communication strategy to convey and report necessary information to the different project stakeholders according to their needs and the project needs is highly important. The scheduler/planner should be able to identify the key project stakeholders and their reporting needs, as illustrated by the project communication plan and/or the contract specifications. Nevertheless, the planner should not limit his reporting strategy and methods to what is in the project communication plan because this document tends to be abandoned halfway through the project and left unmaintained. The planner should also tailor his/her reporting method, technique, and delivery mechanism in line with the intended purpose of the message to be conveyed to a specific stakeholder or group of stakeholders.

5.4.1.1 Project Stakeholders

Guidelines

Definitions

The *PMBOK® Guide* – Fifth Edition defines stakeholders as "An individual, group, or organization who may affect, be affected by, or perceive itself to be affected by a decisions, activity, or outcome of a project" (PMI, 2013, p. 563).

The project stakeholders comprise, among others, project sponsors, project managers, end users, contractors, and design consultants.

Purpose

The first step in defining reporting needs is the ability to identify the stakeholders involved in the project and their level of influence and relevance to the project.

Default Condition

There is a minimum number of stakeholders required for a project to exist. Nevertheless, the nature of these stakeholders and the duration of their involvement changes during the project life cycle. New stakeholders could be added/removed temporarily or for good, as required.

Best Practices

Planners need to be constantly aware of stakeholders involved in the project, the extent of their involvement, and their influence on project outcome. The project management plan is one source for this type of information. An organizational breakdown structure (OBS) is usually included in the project management plan. The responsibility matrix is also used as an indicator of who requires what from whom and when. In addition, the best sources for specific stakeholder needs are the contracts among different project participants. It is also a best practice to familiarize oneself with the different stakeholders involved in the project in a more engaging manner by participating, whenever possible, in meetings and continuously interacting in a direct way with those same stakeholders.

Recommended Practice

Once the project management plan has been put in place or updated, rechecking who the current project stakeholders are, those who have been either added or removed from the project, their level of involvement and/or influence, should be performed.

Advisories

Avoid getting behind on being constantly up to date on the status of the project stakeholders and the extent of their involvement. Do not heed calls by other team members as to the unimportance of such information for you as a planner/scheduler.

5.4.1.2 Communication Strategy

Guidelines

Definition

Setting up a communication strategy focused on the needs of the receivers is important for achieving effective communication. In turn, effective communication is crucial to the successful delivery of a project. The *PMBOK® Guide* – Fifth Edition (PMI, 2013) describes a sender/receiver model for data communication between two points. This sender/receiver model accommodates a feedback system, allowing the sender to confirm the proper receipt of the message as intended.

Project communication should be tailored according to the purpose of the message. This purpose could either be a dissemination of information, a call to action, or an attempt to clarify an issue or advance a specific opinion. The definition of the message purpose simplifies the choice of communication technique to be adopted. Techniques could be classified as Interactive, Push, or Pull. The choice of which technique is to be adopted is in itself also vital for the selection process of what is the best type or form of communication: formal structured reports, face-to-face meetings, or phone calls.

Purpose

Determine a unified set of rules and methodologies for project communication that is the most efficient possible.

Default Condition

Communication strategy is not a static process. Constant feedback and corrective actions are normally required. Whenever communication inefficiency or failure is detected, the whole strategy should be revised and readjusted so that it serves its initial intended objectives.

Best Practices

It is preferable that the planner contributes to the drafting and creation of the communication strategy. As a minimum, the planner should share lessons learned on previous projects, take into consideration the project stakeholders defined and identified in the previous section, and make suggestions as to the communications techniques to be adopted. At first, a segregation of messages into message purposes should be initially made. The message purposes identified so far should help assign a proper communication technique to each message, at each stage of the message propagation (initial contact, follow-up, presentation, etc.).

Advisories

Projects with no clear communication strategy in motion will proceed in an efficient manner most of the time. Bad communication can easily mean project failure.

5.4.1.2.1 Communication Plan

Guidelines

Definition

The communication plan documents the approach to communicating most efficiently, in line with what was previously defined in the communication strategy. This communication plan usually describes:

- Information to be communicated, its format, level of detail, content, and frequency of distribution
- The project reporting process, such as status reports and presentations
- The method of distribution of schedules and logs during the project
- Communication flowcharts of the communication process and communication constraints

Purpose

The purpose of the communication plan is to clarify the communication process and its different criteria, variables, and attributes. These will help to streamline this process in a manner that will not cause disruptions to the project.

Best Practices

Proactive involvement in the development of the communication plan is important, especially for those planners whose active involvement starts at project inception. For those planners who enter at a later stage of the project, participation in the update, or at least scrutiny of the project communications plan, is necessary.

Periodically conduct a survey to identify whether stakeholder needs have changed and update the communication plan accordingly. Make sure the communication plan is up to date as to the needs of stakeholders being added to the project.

Make sure that all other team members are aware of the reporting requirements mentioned in the communication plan as well.

Recommended Practice

Whenever any of the stakeholders and/or stakeholder needs change, make sure to update the project communication plan.

Advisories

An incomplete or badly managed communication plan will certainly lead to problems such as delays in conveying messages, conveying sensitive information to the wrong audience, or not conveying any information to stakeholders who critically need to be informed—especially key stakeholders who are decision makers.

5.4.1.3 Scheduling Reporting

Guidelines

Definition

The type of information to be reported includes, among other things, the project schedule baseline basis, and the project status, or progress reports. It usually includes reports on project performance, performance trends, as well as forecasts of project and/or interim milestones/sectional completion dates.

Purpose

The purpose of choosing the type of reporting to be adopted or mixed is to make sure the intended message is conveyed correctly to the right stakeholder at the right time, without undue delay.

Default Condition

The choice of reporting or reporting mix type should be made at each instance where reporting to a project stakeholder becomes necessary.

Best Practices

Despite the fact that the project communication plan should already have all necessary information to properly guide the planner in choosing the type of reporting to be made, it is rather important that judgment be made on a case-by-case basis. If a different type of reporting is found to be necessary, the planner should convey the situation to other project team members and a decision should be made as to what type of reporting should be used. Schedule reporting for a specific project will probably be a mix of the schedule reports we describe in this section. The needs of the project and different stakeholders involved are the basis of what type of reports are adopted or dropped out. A sample table of contents for a monthly schedule performance report format used by the author in a recent project can be found in Appendix A.

Recommended Practice

Check the communication plan to see what the reporting needs of the different stakeholders are the most efficient or necessary.

Advisories

Be careful while choosing a reporting type; be careful not to choose one that might convey the wrong message to a project stakeholder. Always take into consideration who that stakeholder is and what his or her needs are, as well as the purpose of the message you would like to convey.

5.4.1.3.1 Schedule Basis Document Report

Guidelines

Definition

The schedule basis document is a structured report that details the approach utilized, the scope and format of input data, as well as the assumptions and strategies used to develop the project schedule. For more information, please refer to AACE's *Recommended Practice No. 38R* (2009).

Purpose

The purpose of the schedule basis document is information dissemination in order to:

- Get approval and consent on the project schedule;
- Inform participants on the basis of the schedule and the underlying assumptions;
- Become a reference to be used during the schedule change management process; and
- Keep a record of the schedule basis for future reference. This is very beneficial if and when any ambiguity and/or dispute arises which might require clarification as to the nature of the information/assumptions/processes/strategies initially used at schedule conception.

Default Condition

Whenever a schedule is first created, a schedule basis document should be prepared and issued. This document should be continuously updated when the need arises, or any of the underlying information/assumptions detailed in the report changes.

Best Practices

The schedule basis document should be treated almost the same way as a cost estimate basis. Many projects seem to ignore the fact that the assumptions, risks/issues, and strategies used in planning the project vary as the project goes forward. This in turn requires a revision to the project plan, and subsequently to the project schedule communicating that plan. Therefore, it is quite imperative that the scheduler approaches the schedule basis document in this context. It should be treated and used as an ongoing process. The schedule basis document represents a substantiation of why the end date is what it is. Call a meeting for the schedule basis document to be discussed with other team members. Require the contractor's project team to submit such a schedule basis document. The content should at least cover the topics found in AACE's *Recommended Practice No. 38R* (2009).

A sample table of contents for a schedule basis document report format used by the author in a recent project can be found in Appendix A.

Recommended Practice

When and if any element or variable used in the development of the schedule varies, the schedule basis document should be updated. The document should also be kept up to date in line with the schedule change management process.

Advisories

Ignoring, or simply being unable to understand, the value of a schedule basis document could and will most likely lead to a higher probability that the project will fail. This is due to the fact that the variables, assumptions, and risks/issues which the schedule basis document attempts to document should be used to drive the execution of the corresponding project.

5.4.1.3.2 Schedule Review Report

Guidelines

Definition

Most schedule review tasks require writing a report about the findings. This is most certainly the case whenever:

- A baseline schedule has been submitted by the contractor.
- An update schedule has been submitted by the contractor.
- The present project situation requires a thorough review report anyway.

Purpose

The main purpose behind a schedule review report is to communicate the findings of the review process undertaken, identify the various issues, and provide appropriate recommendations.

Default Condition

Whenever a schedule is first reviewed a schedule review report should be prepared and issued. This process should be repeated whenever a revision or re-baseline is issued by the contractor.

Best Practices

Have a systematic review process in place that covers all facets of the schedule. The report should be divided into five sections:

1. **Executive Summary:** This is a summary of the main items, findings, and recommendations.
2. **Submittal Completeness:** This section reports on whether a copy of the schedule was provided by the contractor in its original native format. Also reports on whether narratives as well as an explanation of calendars, lags, and constraints were included in the submittal.
3. **Schedule Architecture:** This section concerns itself with the schedule rules and settings used by the contractor to run his schedule. Rules include, but are not limited to:
   a. "Retained Logic versus Progress Override" setting
   b. Calendars
   c. Critical path definition and setting
   d. Work breakdown structure (WBS) and WBS dictionary
   e. Activity code dictionary

   Rescheduling is also deemed necessary and any variations in either interim or final completion dates are to be noted and will require asking the contractor to revise his schedule.
4. **Schedule Construction:** This section involves reporting, on one hand, the different activity-related features such as the clarity or lack thereof, activity definitions, the reasonableness of activity durations, the appropriateness of activity logic (including any noted open-ended tasks), any negative lags, and excessive start-to-start (SS) or finish-to-finish (FF) + lag relations. The report should also note whether the level of detail is suitable or not.

   This section also reports on the reasonableness of the critical path, its level of detail, and any manipulations noted, such as float sequestration, improper constraints, or lags through the critical path.

   This section also reports on the reasonableness of high float items, workflow, and any probable trade stacking situations.

   For resource-loaded schedules, check that activity durations are based on resource production rates, that all items are resource-loaded, and that a reasonable use of resource "soft logic" has been used in the schedule.
5. **Issues, Concerns, and Recommendations:** This section should be used to list all previous issues and concerns noted while performing the various schedule checking tasks noted earlier under the previous headings. This section should also provide recommendations, whenever possible, on the best and/or preferred procedure for overcoming the issues and concerns noted.

A sample table of contents for a schedule review report has been included in Appendix A.

Recommended Practice

Make sure to complete the review and issue the report to the contractor as soon as possible, to give them enough time to revise and resubmit their schedule without significantly impacting project control and monitoring.

Conduct live meetings with the contractor, if necessary, to explain any issues or items their scheduler might be having problems understanding.

Advisories

The tendency to solely rely on the narrative submitted by the contractor, however detailed it may be, without performing a proper schedule analysis can be lethal to the project schedule. It could be equally lethal to presume that, since the baseline schedule has been reviewed and revised, any subsequent update or revision release is necessarily appropriate and does not require any review/reporting of review.

5.4.1.4 Schedule Status Reports

This section includes those standard documents mainly used to report progress to a plethora of receivers, including clients, upper management, and on-site project teams. It includes overall progress reports such as those usually sent to management, the progress narrative, and more specific reports such as task management reports and reports related to resource management.

Management Schedule Report

The management schedule report is a text-based summary report presenting high-level project information in a narrative tabular format. It usually targets senior management staff wanting to get a high-level view of the project's present status. The report should mainly include:

- **Project Name:** The name of the project.
- **Project Description:** A short description of the project.
- **Project Health Status:** Project health indicators could be well suited to convey the project health status. Health indicators are usually represented by colored circles. Green means the project is in good shape. Yellow means the project is at risk and might require management attention. Red means the project is currently in trouble and requires management intervention.
- **Milestone Status:** Develop a table showing the present status for each project milestone. The status could be expressed in layman's terms, using statements such as :
  - Ahead of schedule
  - Behind schedule
  - On hold

  The use of variances, for example, could also convey the same information. A milestone could then be said to be behind schedule with 49 days of schedule variance, or ahead of schedule with -20 days of schedule variance. The same could be used to express milestone cost variances (expressed in U.S. dollars).
- **Last Month's Highlights:** Describes any significant highlighted events. The description should be kept at a high level.
- **Major Issues/Risks:** Mentions any concerns or issues that management should be concerned about, or those which might require management intervention. Also included for each item is a brief assessment of the probable impact and what the proposed solution might be.

Schedule Progress Narrative Report

The narrative progress report is mainly a narrative description of the project's plan of construction, the schedule's conformance to specifications and contractual requirements, any deviations from previous progress schedules and/or baseline, and potential schedule problems and current progress. A typical schedule progress narrative report must be created and released each time the schedule is updated, per the contract specifications. A typical schedule progress narrative report can be divided into several sections:

- **Executive Summary Section:**
  - Includes a brief summary of the most important findings detailed later on in the report, including: What happened during the reporting period in terms of scope of work completed, scope of work delayed, and scope of work started earlier than planned.
  - Scope of work planned for the next reporting period

- **Overview Section:** Contains information about the project, the content of the submittal, and a review of the CPM schedule.
- **Progress Section:** Concerns itself with reporting the progress, critical path, milestones, and completion dates. This section also analyzes the current progress and reports any interesting findings.
- **Schedule Changes Section:** Reports any changes made to the schedule since the last release. Such changes, include, but are not limited to:
  - *Activity codes:* Changes made to the activity codes;
  - *Logical changes:* Any changes made to the inter-activity relationships and sequencing;
  - *Constraints:* Any constraints added, removed, or altered;
  - *Calendars:* Changes made to the schedule calendar; and
  - *Resource and cost loading:* Any changes made to the cost and resource loading of the schedule.
- **Summary and Recommendations Section:** This section summarizes any findings resulting from the analysis and observations made by the scheduler as it relates to the topics already described in the earlier section. This section might also provide either an action plan for the contractor to follow, or more detailed recommendations on how to solve some of the issues that were identified.

A schedule progress narrative should also include areas of concern for the future of the project, such as potential delays to drawings, submittals, owner decisions, manpower availability, subcontractor performance, and long-lead procurement delivery and availability.

Comparative Targets Variance

Comparative variance describes deviations from the planned schedule or any other interim schedules by comparing the current update to interim updates, the initial baselines, or any revisions or re-baselines performed. Variance reports can be in both tabular and bar chart formats, S-curves, or a combination of those.

Senior management and customers usually require variance reports to get information on how well the project is performing compared to the initial plan. Most scheduling software allows its users to save multiple targets that can then be used for variance reporting purposes. In addition, EVM-specific variances are also available. EVM offers both cost variance (CV) and schedule variance (SV) indices. The following two types of EVM reports are usually used:

- **CPR Format 5 (also known as the variance analysis report).** CPR stands for cost performance report. The variance analysis report includes both quantified cost and schedule variances. It indicates out of tolerance items based on pre-determined "variance thresholds." Explanation and some kind of problem analysis is also included for variances that exceed the thresholds. The report is usually divided into the following sections:
  - **Header:** Contains quantified cost and schedule variances;
  - **Problem Analysis Section:** Used to explain variances, issues, and problems;
  - **Task/Project Impact Section:** Used to explain the probable time/cost impact on the project; and
  - **Corrective Action Plan Section:** Provides for recovery and risk mitigation.
- **Cost/Schedule Status Report (C/SSR).** This report includes cumulative and at completion summaries for each WBS element, contract information, and range of calculations. It also contains contract price information, and budget and management reserve (MR) related information. This report usually concerns itself with cumulative information.

It is also very common to find cumulative budgeted cost for work scheduled (BCWS), budgeted cost for work performed (BCWP), and actual cost for work performed (ACWP) plotted against time and included in Earned Value Method (EVM)-specific reports. This also involves including a table detailing periodical and cumulative BWCS, BCWP, ACWP, schedule variance (SV), and cost variance(CV) for each reporting period.

Task Management Reports

This report type focuses on the tasks/activities as its reference points. These types of reports are more suitable for on-site staff, project managers, and superintendents, while some also serve as a good tool for frequent monitoring—such as the look-ahead schedules. They include the weekly status report, the critical and near-critical path reports, and look-ahead schedules.

Classic Schedule Report /Weekly Status Report

The classic schedule report is available under either a tabular format or bar-chart based format. The purpose of this report is to inform and guide parties involved in project execution by presenting a general overview for tracking and control under one report.

The information that is usually found in such a report includes, but is not limited to, the following: activity ID, activity description, original duration, remaining duration, total float, early start date, early finish date, start date, finish date, actual start, actual finish, and calendar ID.

The Gantt chart usually indicates the project critical (longest) path in a very clear manner.

The information presented in the report is conventionally sorted by early start date and total float, in increasing order.

The classic schedule report is ordinarily issued on a weekly basis under the heading "weekly status report."

Critical and Near-Critical Path Reports

This report aims to point out to and inform appropriate team members about the planned activities currently on the project's critical and near-critical paths, their progress so far, as well as their variances from the planned schedule. The purpose of the report is to guide the project team in formulating an appropriate response plan. Both text-based tabular formats and graphical bar-chart formats are used to transmit the information. The choice between the two formats should be made based on the stakeholders' need to know and the most efficient method of transmitting the required information. Both critical and near-critical paths should be reported for the project's substantial completion, as well as any other project interim milestones.

Look-Ahead Schedules

Look-ahead schedules are forward-looking schedule snapshots produced to show the planned activities for the next couple of weeks, the next month, etc. The time range is either dictated by the specifications, the contract, or the communication plan, or jointly decided by all team members, depending on the project's current needs. Look-ahead schedules are either formatted as a text-based or bar chart-based report. Conventionally, look-ahead schedules have been extracted from the master schedule by the project planner and sent downstream to the site team for follow-up and action. It is preferable that project managers, superintendents, planners, and others walk into the job with a look-ahead schedule to check the integrity of the planned activities for the short term future. If any defects and/or inconsistencies are found, the appropriate response should be agreed to and implemented. This could include, among others, changes made to the actual sequencing of the works on-site, allocation of more resources, or revisions made to the master schedule itself. The look-ahead schedule is a tool used to monitor and control present status during site meetings at a more frequent rate than that of the required reporting to the client or customer. It is also used to run through the planned activities in the short term and identify any risks or issues that might affect future performance and assign action plans to avoid any negative impact on the schedule.

Resource Management Reports

Initial estimates as to the type and number of resources necessary to execute the project in a timely manner are typically made at project schedule inception and require ongoing monitoring and control to avoid over-allocation of particular resources, trade stacking, and to ensure an overall better coordination between trades. Among the available reports targeting resources are resource assignment reports and resource histograms.

Resource Assignments

Resource assignments, task assignments, or task resource assignments are reports showing:

- The tasks assigned to each project resource, or
- The resources involved in performing each task.

Most scheduling software offers these types of reports in both text-based and bar chart formats. The information provided is commonly used in guiding the flow of resources, their procurement, and any resource leveling activities if deemed necessary.

Resource Histograms

Resource histograms are column chart-based graphical reports used to display the allocation of resources over time. They are useful for:

- Determining overall resource usage, when a resource is first required and how long is it required for;
- Identifying over-allocated resources, meaning resources which have been allocated beyond their availability; and
- Reporting comparative resource usage or actual versus as-planned.

5.4.1.5 Historical Performance/Trend Reports

Trends describe the general direction in which something is moving. For that reason, trend analysis and trend reporting are highly adequate for spotting trouble areas, and they serve as early warning signs of a worsening performance. Trends aid in measuring performance over time, a critical information bit which most standard schedule reports seem to lack. There is a whole range of available trend reports a scheduler can run, such as float dissipation, time performance ratio, EV metrics trend analysis, schedule adherence, and so on.

5.4.1.6 Float Dissipation Reports

Guidelines

Definition

Activities in a schedule mainly possess, among others, two types of float that are normally used: total float and free float. Monitoring near-critical and non-critical mass volume work involves keeping a tap on the usage and waste of float values along different schedule paths. The rate of dissipation or waste is considered a good indicator of a problem requiring immediate attention. Float dissipation reports are either graphical-based charts or text-based reports showing the rate at which float is being consumed during project execution. An alarmingly fast rate of float dissipation during the project's initial stages, for example, could be an indicator of more problems down the road and will require that preemptive and proactive action be taken.

Purpose

To closely monitor mass volume work by tracking float consumption rates through float dissipation charts.

Default

Float dissipation trend analysis should be conducted on a regular basis as part of the standard schedule updating and analysis procedures.

Best Practices

Two separate float dissipation analyses should be conducted for free and total float. Total float dissipation, commonly known as float erosion, is a good indicator of a path rapidly heading toward criticality. Total float dissipation can be most properly reported in any one of the following formats:

- Total float for area versus previous update
- Activities with less than 10d (number is actually project-specific and to be decided upon) versus last update
- Sum of total float versus last update

Free float dissipation reports are also used to indicate disrupted trouble areas. Float dissipation reports sorted by trade can be used in the assessment of efficient usage of resources.

Recommended Practices

Once the schedule has been updated, float dissipation analysis and reporting is one of the next steps to be undertaken. Standard schedule variance alone does not necessarily indicate troubled areas, and float dissipation analysis and reporting should be routinely undertaken after each regular schedule update.

Advisories

Avoid reliance on schedule variance alone as a warning sign of trouble ahead. Failing to perform advanced trending analysis such as float dissipation will most likely result in more reactive and less proactive management of the work, whereas it will be almost impossible to predict and preemptively handle issues and risks.

5.4.1.7 CPI/SPI Metrics Report

Guidelines

Definition

Cost performance index (CPI) and schedule performance index (SPI) are quantitative performance metrics extracted from earned value analysis (EVA) and/or earned schedule analysis (ESA). (Earned schedule concerns itself with providing schedule performance indicators superior to earned value analysis.) These calculated performance measures are then used to predict future performance following the basic earned value management (EVM) assumption that future performance can be predicted using an adequate sample of past performance. CPI is a measure of conformance of actual cost of work performed to the budget. It is usually expressed as CPI = EV/AC (short form equation). Equally, SPI is a measure of conformance of actual progress to the schedule and is expressed as SPI = EV/PV (short form equation). CPI/SPI metrics trend reporting consists of graphing those indices over time to show actual performance on the project so far.

Purpose

To provide early warning signs through valuable indication of project performance trending.

Default

After having performed EVA or ESA and determined variance, as well as the SPI and CPI indicators for the present performance period, the values of SPI and CPI should be plotted over time for the purposes of identifying any trends that might require immediate intervention.

Best Practices

The key to proper application of SPI and CPI trending is in defining appropriate thresholds and associated corrective actions. Proper thresholds should be determined based on historical data of projects and their common variances. The common variance threshold area is the region where no particular action is required. Once the trending dives below the common variance area, urgent action is required. Plotting the SPI and CPI trends can also be a good indicator of where to focus current risk processes. So if SPI is constantly lower than the common variance, the risk process should be focused on those time-related sources of risk.

It is highly recommended to plot the performance metrics for the project schedule as a whole and the schedule's critical path separately. The results obtained from such a practice could lead to various performance-related conclusions, depending on the current context.

A full understanding of the drawbacks of some of those metrics should be taken into consideration. These include the known tendency of SPI, when extracted from EVA, to converge back to 1 at the end of the project, regardless of whether the project is in delay or not. In such a case it is more appropriate to use SPI extracted from the earned schedule EVM extension method, which does not appear to have this known defect so far.

Recommended Practice

Use CPI/SPI metrics not only to gauge the general performance of the contractor/project, but also as a health indicator of the risk management process.

Advisories

Running EVM performance indicators on the whole project schedule alone will, in most cases, result in misleading conclusions, due to the fact that non-critical activities with high dollar value tend to positively skew the results.

5.4.2 Earned Value Measurement Forecasting

Guidelines

Definition

Empirical data collected through the usage of earned value on projects seems to suggest that performance trends tend to remain more or less the same until the end of a project. Rarely does the performance improve in a significant manner. Earned value management (EVM) provides the ability to predict, with some certainty, both the total project cost and total project duration from the present trend of the project.

Purpose

Ability to forecast where things might end up if past trends are continued. This aids different stakeholders in planning the way forward and taking pre-emptive measures if necessary so that things are put back into place.

Default Condition

After a schedule update has been performed the basic earned value metrics should be extracted from the update. These metrics usually include budgeted cost of work scheduled (BCWS), budgeted cost of work performed (BCWP), actual cost of work performed (ACWP), schedule variance (SV), cost variance (CV), schedule performance index (SPI) and cost performance index (CPI). The values at hand should then be used to calculate the different estimates allowed by EVM. Some packages do automate the calculation of these forecasts/ estimates.

Best Practices

To accomplish the objectives mentioned above, earned value provides several predictive estimates for projects:

- **Estimated Cost at Completion (EAC):** This estimate attempts to forecast what the project's cost at completion might be. It is usually expressed as EAC = ACWP + ([BAC – BCWP]/CPI). A shorter form of the same formula could be expressed as EAC = BAC/CPI.
  BAC = Budgeted Cost at Completion
- **Estimated Time to Completion (ETTC):** This estimate attempts to forecast what the project's final time of completion might be. This estimate is also expressed in dollar value, making it counter-intuitive for a lot of people. It is usually expressed as ETTC = ATE + (OD – [ATE * SPI])/SPI.
  A shortened version of the same formula is known as ETTC = OD/SPI.
  BAC = Budgeted Cost at Completion
  ATE = Actual Time Expended
  OD = Original Duration
- **To Complete Performance Index (TCPI [BAC]):** This indicates the level of cost performance necessary to complete the project within the initial budget.
  TCPI is usually expressed as TCPI = (BAC – ACWP)/(BAC – ACWP)
- **To Complete Performance Index for Schedule (TCPI [OD]):** Usually indicates the level of schedule performance required to finish the project within the initial allocated time frame.

It is important to understand the shortcomings of the EVM results. The EAC formula provided in the definition above is known to be optimistic. It is a best practice to actually provide three different forecasts/ estimates. In addition to the original EAC definition given above, two other EAC formulas are commonly used as well. The first, labeled the most likely estimate, can be expressed as EAC = ACW + (BAC – BCWP)/ ([0.5 *CPI] + [0.5*SPI]). The third, commonly known as the most pessimistic estimate, is usually expressed as EAC = ACWP + (BAC – BCWP)/(CPI * SPI). SPI also has the known tendency to converge to 1 in specific cases even when the project is in delay.

Earned schedule, a variant of EVM, seems to have solved some of these problems and offers more user-friendly schedule-related performance metrics and forecasting.

Recommended Practice

It is highly recommended that EVM forecasts and risk analysis forecasting go hand in hand. EVM forecasting, being a backwards-looking technique, is complemented by the forward-looking risk analysis technique. One should make sure the EVM forecasting results are augmented by any results provided through risk analysis to account for any future risks EVM cannot possibly account for when looking solely at past performance.

5.4.3 Risk Analysis Forecasting

Guidelines

Definition

Most project schedules today are rather unreasonable. They are built upon deterministic estimates of task durations and do not account for uncertainties. Projects, more often than not, slip beyond completion dates that are initially set in baseline schedules. In addition, the critical path changes during the project life cycle. Rarely does the critical path at the end of the project closely resemble its counterpart in the project baseline schedule. The practice of risk analysis aims to resolve those two main scheduling downfalls.

Risk analysis allows us to identify the most probable completion date at a confidence level most convenient to the client/company. It can also help in identifying those risk factors which are impacting the schedule, and in doing so set the stage for proper risk management processes.

Purpose

To report on confidence levels for project duration and or completion dates. Risk analysis forecasting reports most impacting risk factors in order of priority and their effect on the schedule at the desired confidence level.

Default Condition

The first risk analysis is either performed on a conceptual schedule if the need arises, or most commonly on the contractor's submitted baseline schedule. It is then periodically performed on schedule updates to help forecast a reasonable completion date based on the most current risks, their probabilities, and impacts.

Best Practices

Reporting risk analysis not only involves presenting the results but also the methodology and distributions used, as well as any assumptions made. In practice, such a report could be simply divided into the following main sections:

- **Introduction:** In addition to the usual executive summary found in all reports, this section also introduces the project as a whole, the scope, and the purpose of the report.
- **Methodology/Process:** The role of this section is to explain the methodology and steps followed while performing the risk analysis and chosen for the case at hand.
- **Assumptions:** This section details any assumptions made concerning the project, the schedule, or any other assumptions made about elements which don't presently have a fully defined scope and that might affect the analysis.
- **Risk Analysis Results:** In this section, the results of the risk analysis are presented. A good start is the conventional distribution graph. The distribution graph combines both a histogram view that charts project completion dates or project duration against the number of hits where each of these dates or durations occurred, and a curve illustrating the different percent confidence levels (or cumulative frequencies) for the project completion dates or project durations. This chart is usually augmented with a side table showing different statistics such as the minimum, maximum, and mean and standard deviations. The table also customarily highlights the confidence levels associated with the schedule's deterministic completion date, as well as the completion dates for any desired confidence levels (P80 is normally used).

Depending on the methodology utilized, additional types of useful information can also be presented. If a traditional risk analysis has been performed using the three point estimates, two types of helpful charts can be included:

- **Duration Sensitivity Chart:** This chart indicates which activities are most likely to delay the project and are considered to be highly variable.
- **Criticality Chart:** This chart shows the path most likely to ultimately delay the project.

These two metrics are reported in the form of a tornado chart.

If on the other hand, a method such as the risk drivers method is used, and since the objective of risk analysis is to guide the risk management effort, one should seek to provide information that would be useful to this effort and that helps explain to management:

- How the schedule contingency was generated.
- What risks, sorted in order of priority, have impacted the schedule at the required confidence level.

This information can be reported both in table format and as a chart, if necessary. The risk table would list, in order of priority, each impact risk, the new completion date at the required confidence level after removal of this risk, and the impact expressed both in terms of days and percent of total. The diagram, commonly known as a distribution analyzer report, charts the cumulative distribution S-curves for the schedule after removal of each risk side by side. This helps present the information provided in the risk table in a graphical format.

Recommended Practice

Risk analysis reporting (forecasting) is best mixed with EVM reporting. The contingency presented by the risk analysis of the initial baseline is better included in the BCWS during the IBR process. The forecasting results from the risk analysis should also be used to augment the forecasting performed through EVM, which only bases its forecasting on past performance without proper consideration for any future risks and their related impacts.

Advisories

Two commonly made mistakes in reporting the results of risk analysis is to forget to include the assumptions made or the methodology used in the report. This can be highly misleading to the report reader, who will then be forced to make his/her own assumptions. Another commonly made mistake is to confuse forecasting with fact. This is especially detrimental to the project, when schedule risk analysis is not periodically performed and reported and total reliance is made on the risk analysis initially performed on the baseline schedule.

5.4.4 Written Narratives

The submission of each schedule update should include a narrative report of progress for that given month. The narrative is a status report, the as-built portion of the schedule, and provides the owner with a review of the how the contractor is progressing, as well as providing an update report which explains the plan going forward, the as-planned portion of the schedule. The typical report highlights the status of the project, and often includes the following items:

- Progress relative to the prior approved schedule update and baseline plan;
- Overall review of the project in terms of work started, completed, and in-progress;
- Update on design, submittal, and procurement processes;
- Work coordination;
- Phasing and staging;
- Discussion of problem areas, including current and anticipated delay factors and their impact;
- List of revisions to the schedule;
- Discussion of the project's critical and near-critical paths;
- Equipment usage and limitations;
- Interim milestones and project completion dates;
- Work restrictions, including temperature-sensitive activities;
- Anticipated work hours/day and days/week;
- Calendars; and
- Production data.

The schedule update narrative explains the schedule status and modifications made to create the current schedule. The narrative describes changes made to the schedule, current issues, problems, and related schedule notifications to the owner. It serves as a universally important document typically used by project shareholders, not just the scheduler. One of the primary intentions of the narrative is to inform the owner of current progress and potential delays that may arise, and it allows the owner to act in order to minimize any impact to the project's objectives.

The importance of a narrative accompanying the schedule update cannot be emphasized enough. Both the narrative and the update need to be submitted to ALL stakeholders on a regular basis, which is usually dictated by the project schedule specifications.

Often an owner does not want to receive the update and the narrative or approve it because doing so gives credence to the documents. This is especially true when a project is having its problems and may not achieve the project completion date per the schedule and the contract—especially if it is the owner who may be at fault. The thinking is that if the owner does not approve or accept the monthly narrative and update then he or she can claim that he or she was unaware of a problem.

The general contractor is in a stronger position if he or she submits the narrative and the schedule update at the prescribed times, even if the owner didn't read it and claims he or she was unaware. In a dispute situation, if the schedules were updated regularly with a reasonable degree of care, and used in the management of the project, those schedules will be analyzed in some form.

Along with the narrative report, the contractor is typically required to provide a series of reports generated directly from the schedule update. Reports typically include, but are not limited to: activity listing, early start, late start, total float, predecessor/successor, critical/near-critical material and equipment submittals, and critical path.

Timing/Frequency of Updates

Typically, the schedule update submittal package is provided to the owner monthly and coincides with the contractor's submittal of its monthly pay requisition. Fast-track projects may require close attention to the project controls and more frequent schedule updates. The frequency in schedule updates may be defined by the specifications; however, weekly or biweekly updates are common for fast-track projects.

Owner Involvement

When the schedule update is part of the progress payment process, the owner's representative (construction manager, design team, or both) is usually part of the update process or may have approval authority of the schedule update that may be tied to the contractor's payment.

5.4.5 Reporting Frequency

Guidelines

Definition

How frequently one must report to different project stakeholders is also one of the important ingredients or attributes of proper proactive schedule management, communication management, and ultimately overall project success.

Purpose

The purpose of reporting frequency is the timely release of project status information so that it is still useful to the project stakeholders in making timely, informed decisions that can still influence project outcomes.

Default Condition

It is customary to report project status and progress on a monthly basis for long projects, while reporting on a more frequent basis, such as biweekly, for shorter projects. On the other hand, it is also customary to report on a biweekly or even weekly basis for projects of a more complex nature.

Best Practices

Choose the reporting frequency in light of the following four criteria:

- **Project stakeholders' need to know.** This need to know is usually dependent on general project size, complexity, time span, and sometimes any extraordinary risks. Senior management might need to know how the project is faring on a monthly basis, while the project manager might need some reports on a monthly basis, others on a biweekly or weekly basis, and so on. On-site superintendents and foremen will need information on a daily basis.
- **Current project status and needs.** The present status of the project (healthy, in delay, ahead) and the ensuing needs (more, less, or the same amount of attention).
- **Any emerging triggers.** Any event whose occurrence greatly affects the schedule or the ability to complete on time and requires urgent attention.
- **Reporting frequency.** As dictated by the contract specifications.

It is also a best practice to update and report status on a biweekly or weekly basis for the first 20% of the project; reporting should also occur on a more frequent basis if the project is going through a rough phase, or during the closing out stage of the project, to ensure smooth completion of the work.

Recommended Practice

Whenever the need arises, and in accordance with the criteria stated earlier for the reporting frequency to be changed, the planner should make sure to communicate this new information to other stakeholders and act accordingly without any delay.

Advisories

Quite a few people mistake reporting frequency with update frequency. While at times these might be one and the same, this is not always true. A project might status the schedule on a weekly basis, but the client or upper management might not be interested in hearing about progress more frequently than on a monthly basis.

5.5 Float Management

While float is essential to the project, using it poorly will result in failing to meet the schedule. Purposeful use of the float should be a project team decision for the benefit of the project; other use of the float should be limited to unforeseen events.

Guidelines

Definitions

Float management refers to the techniques used to work with and properly use the extra time between activities.

Purpose

Float can be beneficial and destructive to a project at the same time. Successfully controlling how it is used will help the project complete on time, more efficiently, and with less disputes.

Default Condition

Float should be addressed for every schedule. Usually the contract will dictate who owns the float, but if it does not, the project team needs to agree to ownership and the float management technique up front.

Best Practices

The project should own the float and each case in which the float is being used should be discussed as part of the standard project meetings.

Recommended Practice

The regular discussion of float allocation and use keeps the various parties aware of the risks and consequences of consuming the float. Each conversation should distinguish between the use of free float versus total float, discuss how much float is being used, and what can be done to preserve the float. Schedulers are usually aware of the consequences of using all the float and the high risk situation that it leaves the project in. Often, other parties (owners, contractors, suppliers, etc.) feel as if the float can be taken up as they see fit and then they cause problems for any work that needs to follow behind them.

Excessive and/or sparse amounts of float can indicate that the logic is not correct or that resources have not been properly accounted for. In each instance the logic and resources should be reviewed by the team to see if it properly represents the project's plan. If the project review shows that the nature of the project has a high/low level of float, everyone needs to be aware of the fact and know the project team's plan for dealing with it.

Advisories

When the float is gone, everything is critical: this point needs to be emphasized to the project teams. There will be no more room for any errors or unforeseen events.

Never add logic with the purpose of eliminating float. If the logic is wrong, make the correction because the logic is wrong. If the resources are not right, make corrections to the resources.

5.6 Recovery Scheduling (Accounting for Delay)

Guidelines

Definitions

There are two terms that define how to account for a delay to a project schedule, depending on who is at fault for the delay. If the contractor or one of his subcontractors is at fault, the schedule to account for the delay is a recovery schedule. This term is not definitive, in that the industry does not recognize the term "recovery" to indicate contractor fault.

If, on the other hand, the owner of the project is found to be at fault for the delay, the schedule to recover time is called an "acceleration" or "mitigation schedule."

There is also a third classification for the reason for a delay to a project schedule. This classification or reason is due to "force majeure." A force majeure delay is when the project is delayed by forces beyond the control of either the general contractor or the owner. A delay of this type can be due to several factors which can include but are not limited to unforeseen conditions, weather, war, civil unrest, and "acts of God." The schedule to recover time in this event is also called a recovery schedule.

The process of accounting for the delay, tracking the delay, and the ultimate fix to attempt to get the project back on schedule (if possible) is the same for recovery and acceleration/mitigation schedules. See Section 5.7, Change Management, for how to account for delay. Following is the process for recovery scheduling

- The distinction may seem trivial, but it is important to both of the parties mentioned. When the prospect of a delay to a project arises, all stakeholders become concerned about who will ultimately be found at fault. The reason is pretty straightforward: The person at fault ultimately has to pay for it.
- If a general contractor or one of their subcontractors is found to be at fault, it is up to the general contractor and/or one of their subcontractors to do whatever is necessary to try to bring the schedule back on track, to recover lost time, including adding more resources, working overtime, and the purchase of additional material and/or equipment to get the job done. The general contractor is responsible for all costs to accelerate.
- If the owner is found to be at fault for the delay, all costs incurred by the general contractor to accelerate the schedule are on the owner. Owners become concerned about this if the delay to the project forces the project completion date to move out or take longer than the contractual end date. That usually means the owner has to dig deep into their own pockets to pay for it.

Purpose

The purpose of accounting for a delay is to determine its impact on the project. Some delays can be absorbed by the project schedule and/or be concurrent with other delays or scope of work. Others create such a significant impact that a whole new way of looking at the project is required to lessen the impact of the delay.

Default Condition

If a project never had a delay of any kind during its life cycle, it would not be necessary to account for any delay in the construction schedule. Of course, the opposite is also true. If a delay—any delay—is making itself evident, incorporating that delay to assess its impacts on the project schedule must be included in that schedule.

Best Practices

No matter who is at fault, either a recovery schedule or an acceleration schedule is required, usually by contract, to be built and presented as soon as the delay is known. At the time a delay is discovered or becomes evident, it is not necessarily known who is at fault. Despite that, the general contractor needs to create and include the delay in the current schedule to begin tracking it in order to assess the ultimate consequences of the delay on the project.

Recommended Practice

Since the whole idea and philosophy behind the creation of a project schedule is to create a plan for how the project will be constructed, and to tell the truth, the incorporation of a delay, no matter who may be at fault, is paramount to relating the truth about what is going on with the project. The project schedule is the vehicle for recording the delay.

Advisories

Failing to produce either a recovery or an acceleration schedule should be avoided at all costs, no matter who is ultimately at fault for the delay.

5.7 Change Management

Guidelines

Definitions

Change management, as it pertains to scheduling, is the process of accounting for a change to a project, and the project schedule, that significantly forces a change to the original plan (baseline) of the project. That change could be an added or subtracted scope of work, a delay caused by the owner, a delay caused by the general contractor, or a force majeure delay.

Purpose

If a project encounters a situation which forces a rethinking of how it is going to complete, change management is the process of deciding how that change is going to affect the project and how the project team is going to deal with it.

Default Condition

If an ongoing project suffers a delay or change of scope, as soon as the delay or scope change is known tracking of the delay or scopes change should start immediately, even if the full impact or reason for the delay or change is not fully known. Start tracking what you know and what you project to be the potential effect to the project and the project schedule.

Best Practices

All changes to a project and its schedule need to be incorporated into the schedule as soon as the project team is aware that there is a change, be it a delay or change of scope. Not all delays or changes necessarily impact the schedule, but if those changes are not included in the schedule the project team will never know if in fact they will or will not impact it.

If the delay or change of scope is a major event, the possibility exists that the schedule and the original plan to execute the project will have to be rethought. Once the plan is rethought to account for the delay or change of scope, those changes will have to be added to the schedule. The effects of those changes will ultimately tell the project teams what the impacts of said changes are to the project.

Recommended Practice

The cause of the change—no matter the reason or who is at fault—should be dealt with as soon as it becomes evident.

Advisories

The project team should not bury their heads in the proverbial sand and deny that a change has occurred and that it has to be dealt with. Start reporting any changes as soon as they become evident.

5.7.1 Scope Change—Identification and Documentation

Guidelines

Definitions

A change of scope means that there is a significant addition to or subtraction from the project's original scope of work. A change in scope is usually directed by the owner of the project. The general contractor is not going to add or subtract scope of work on his own because then he or she would be in default of the contract. An owner can decide (usually after the project has already started) that he or she doesn't like a certain aspect of the original scope or wants to add/change that scope. The reason makes no difference. The bottom line is that the change is significant enough that the general contractor has to rethink how the project is going to come together based on the new scope of work.

Subtractions of work are also created by the owner, but in this case it is usually economics that drive a reduction. The owner is running out of money, or the market now doesn't require the need for a swimming pool, for instance. Again, the reduction of scope requires a rethinking of how the project is going to complete based on new information. Note that a change in scope usually requires official notice from the owner that a change is coming, which will also create the need for new pricing and scheduling, and thus a new contract or change order directing the general contractor to make the change.

Purpose

The purpose of accounting for a scope change should be obvious because now the original scope of work and the original plan to execute it are changed and thus no longer valid. The schedule will have to be changed to account for the change in scope.

Default Condition

If a project does not experience a significant change in the scope of work, there is no need to worry about or track it. If, however, there is a significant change, it must be accounted for.

Best Practices

Once the general contractor is made aware that a change in scope is on the horizon, and once they have enough general information about what that change is, a what-if schedule can be created which will be derivative of the current working schedule. The new information, which will be a summary level add on the first go around, can be added and then become more detailed as new information becomes known and available. Of course, the new scope of work also has to be plugged into the current logic. Doing so will allow an analysis of the impact of that added scope on the critical path and the end date of the project. Once all of that is known, the end result may be a total rework of the schedule in order to account for the additional work and still maintain the original end date. That may or may not be possible, but the scheduler/planner should make the attempt, because the owner will require it. In many cases, especially on design/build projects, an owner will want the general contractor to add the work without any added compensation.

Once the change of scope is priced and the impacts to the schedule known and approved by the owner by a change order or some other official mechanism, the what-if schedule will become the official schedule. This schedule will usually become the new baseline because the significant changes made to the original schedule will require it. The project now has a new plan, so tracking the new one against the original one will no longer make any sense to anyone.

Recommended Practice

A soon as enough is known about the projected change in scope, ALL the steps to account for it— whether it is an addition or a subtraction of work—need to be connected to their proper predecessors and successors through logic relationships. See Section 5.7 for further information. Start adding information into the schedule as soon as you know some or enough of the details to do so. At first the information will be summary in nature and a guess as to activity description, duration, and logic, but tone must start somewhere. Start as soon as you know it so you can determine the possible impacts on the schedule. If you wait until you know all the information and then add that information/scope of work into the schedule in order to determine the impact, you will more than likely shock the project team and stakeholders. It is better to let the team know the possible impacts early on. Then, as more new information is made available and that information is included in the schedule, the effects of that added information on the schedule will be easier for the stakeholders to take.

Advisories

Avoid the shock factor of late reporting of impacts to the schedule—any impact. Start reporting them as they become evident.

Changes should not be made to the schedule, or work begun on the scope change until you have it in writing to do so. Do not do anything on verbal direction from the owner.

5.7.2 Delays—Identification and Documentation

Guidelines

Definitions

A delay is any impact to a schedule that could affect the critical path. There are three types of delays: those caused by the general contractor or one of his subcontractors, those caused by the owner, and force majeure delays.

1. A delay caused by the general contractor or one of his subcontractors could include a lack of production by one of them due to lack of manpower or materials, poor planning, subcontractor insolvency, unforeseen conditions, or a number of other factors. Note that the general contractor is responsible for all of his/her subcontractors and their performance. If a subcontractor is found to be the reason for the delay to a project, it is the general contractor's responsibility to try to recover lost time. That usually means it is going to also cost more money to recover. Once the delay is accounted for and hopefully mitigated, the general contractor usually then goes after his/her subcontractor to recover any costs incurred during the recovery. Also, the schedule to recover lost time due to the delay is called a recovery schedule.
2. A delay caused by the owner can be due to a lack of timely decision making, poor planning of owner responsibilities, a change of scope, a change order, financial difficulties, or a change of market considerations, to name a few. If a project suffers an owner-caused delay, the mechanism to get the project back on track is the creation of an acceleration schedule. Even though the owner caused the delay, he or she will still want the project to come in on time per the contract and to accomplish that, he or she will direct the general contractor to accelerate the work in order to recover lost time. That cost to accelerate will be attributed to the owner. The hope is that the delay can be mitigated by acceleration of the work.
3. A force majeure delay is also called an "act of God" delay. It is a delay beyond the ability of anyone to foresee. These delays can include above and beyond normal weather (floods, earthquakes, tornadoes, hurricanes, and extreme wind), fire, union strikes, war, and civil unrest. If a force majeure delay is encountered, the effect of the delay to a project could be miniscule or major depending on the severity of the delay event. If the delay affects the critical path, forcing the project to take a longer time to complete, any additional cost to complete is the owner's responsibility. The general contractor will get the additional time, but will not be allowed to collect the additional general conditions to complete the project.

Purpose

The primary purpose of tracking and accounting for a delay is to allow the project team to assess the impact of the delay on the project. The secondary purpose is to figure out who is responsible for the delay and who will then have to pay for it.

Default Condition

As soon as either the general contractor, one of the subcontractors, or the owner is aware that a delay exists or is imminent, the delay must be accounted for in the project schedule to assess its impact. Any delay to a project or potential delay needs to be dealt with as soon as it is known that it exists in order for all stakeholders of the project to be able to react to it and hopefully mitigate it before it ends up on the critical path.

Best Practices

One of the objectives of a project schedule is to relate the truth of how the project was planned (the as-planned condition) and how it was actually built (the as-built condition). That being the case, when a delay is encountered, the incorporation of that delay into the project schedule, no matter who is at fault or responsible for it, needs to be addressed and accounted for to assess its impact on the project's critical path. So as soon as a delay is encountered the steps to mitigate it must be included and added to the schedule.

At first, the actual steps (activities) and durations may be a guesstimate and summary in content. As time goes by, more will be known about the steps to mitigate the delay, and the summary activities will become more detailed and the durations and logic more realistic. The tendency in construction projects is to hide the delay and/or delay the reporting of it to the project team because no one wants to admit that they are responsible for it. The general thinking by those responsible is that if they delay reporting it maybe they can mitigate it, and they hope that no one will notice that it ever occurred. This is not a recommended practice. The delay should be reported as soon as it becomes known so that the project team can react to it immediately, thereby giving them the greatest amount of time to mitigate it. This is true for all three types of delay. There will be plenty of time to assign responsibility later.

Recommended Practice

A soon as enough is known about the projected delay, then ALL steps to account for it—whether it is an addition or a subtraction of work—needs to be incorporated into the schedule and hooked up to proper logic. Start adding information into the schedule as soon as you know some or enough of the details to do so. At first the information will be summary in nature and a guess as to activity description, duration and logic, but you have to start somewhere. Start as soon as you are aware so that you can determine the possible impacts to the schedule. If you wait until you know all the information and then add that information/scope of work into the schedule in order to determine the impact, you will more than likely shock the project team and the stakeholders. It is better to let the team know early on about the possible impacts. As more new information is made available and that information is included in the schedule, the results of that added information on the schedule will be easier for stakeholders to take.

Advisories

Avoid the shock factor of the late reporting of delays to the schedule—any delay. They should be reported as they become evident. The last thing you want to do is keep the delay hidden or avoid letting the stakeholders know that a delay is happening, or on the horizon. If the impact of the delay to the project schedule is not communicated to stakeholders early, the stakeholders' expectations will not be managed effectively, and problems will arise. Good communication requires early notification of any impacts to the project schedule.

5.7.2.1 Prospective Time Impact Analysis

Guidelines

Definitions

There are many definitions for time impact analysis and they all are valid. Following is a listing of some of those definitions:

1. Prospective Time Impact Analysis is the official term for accounting for the delays mentioned in Section 5.7.2, Delays—Identification and Documentation.

2. Per AACE International *Recommended Practice No. 52R-06* (AACE, 2006) –"Time Impact Analysis as applied in Construction":
   a. "Provides guidelines for the project to assess and quantify the effects of an unplanned event or events on current project completion."
   b. "The TIA is a 'forward looking,' prospective schedule analysis technique that adds a modeled delay to an accepted contract schedule to determine the possible impact of that delay to project completion."
3. In their book, *CPM in Construction Management*—6th Edition, James O'Brien and Fred Plotnick (2006) define time impact evaluation as "Use of a Fragnet or sub network to evaluate the impact of an event such as a change of order or unusual occurrence on the baseline schedule; known as TIE. This is also known as time impact analysis (TIA)."
4. From his paper, *Preparing & Analyzing a Prospective Contemporaneous Time Impact Analysis*, Chris Carson (2007) cites contemporaneous perspective
   - Performed to "look ahead" during the project
   - Performed at moment of start of impact
   - Called Contemporaneous Time Impact Analysis (TIA)
   - Compare the predicted completion of the schedule just prior to the date of the "delay event" to the predicted completion of the schedule after inserting a fragnet of impact activities into the schedule

Purpose

The reasons for use are:

- A time impact analysis (TIA) is the best methodology for determining the extent of impact from a potential delay event.
- When done in a prospective or forward-looking manner, a TIA can promote negotiation and ultimate settlement of any ramifications of a delay event.
- Sometimes a TIA is mandated in the project contract specifications.
- A TIA is the best way to evaluate expected impacts resulting from changed conditions.
- A TIA supports negotiation of time extensions due to changed conditions.
- A TIA enables the sharing of risk.
- A TIA helps to keep the project on track with an accurate schedule.

Here are reasons why a TIA would be performed on a project:

- The project is experiencing a delay or one is looming.
- You have to determine what the impact of the delay event is going to be on the project, especially the critical path.
- The delay event has been inserted into the current schedule and all of the appropriate logic has been hooked up. You may have to assume some durations may have to be assumed in the beginning, but as you know more the details work themselves out and the delay event can be adjusted accordingly.
- You compare the schedule prior to inserting the delay event and note the changes.
- You report out the results of the insertion of the delay event into the schedule to ALL of the stakeholders and let the team assess the meaning of it all.
- The delay event may push the overall duration of the project, which will get everyone's immediate attention as to the seriousness of the delay.
- There will be a lot of discussion as to what can be done to mitigate the delay.
- Hopefully and eventually everyone will come to a decision as to how to handle it.
- The risk associated with the eventual decision will be shared; no one is going to accept it all unless it is shown that there is only one stakeholder responsible for the delay.
- The schedule will be accurate and tell the truth about how the project is going to be completed.

Default Condition

Situations for Use—Excusable Delay Events

- Late notice to proceed
- Undisclosed conditions
- Unknown site conditions

- Request for proposal
- Constructive change directive or change order
- Field order
- Scope change
- Contractor delay
- Owner delay
- Force majeure

Best Practices

Preparing for a TIA:

a. Verify the current schedule.
   - Test for reasonableness. Is it an accurate schedule, depicting the proper scope of work for the project in sufficient detail for proper tracking of the work? Does the schedule tell the truth?
   - Ensure that the schedule logic models the actual project sequencing.
   - Check for constraints. If constraints exist, remove them by inserting the proper logic. A properly built schedule should have only two constraints: An early start constraint to kick the project off, and a late finish constraint at substantial completion or final project completion. All the activities in between should be hooked by logic with a minimum of one predecessor and one successor. Note: The use of a constraint on an interim milestone is allowed if the interim milestone is contractual or driving.

b. Update the current schedule. Use the update date through the date that will reflect the situation immediately prior to the beginning of the changed condition.

c. Do not make any logic changes after the update.

d. Calculate the schedule and set the data date immediately prior to the beginning of the changed condition/delay event (to match the update data).

e. Document the completion date.
   - Be consistent and use a common activity such as "substantial completion" or an interim milestone for the point of comparison.
   - Use the early finish dates for the entire project.

f. Identify the reason for preparing the TIA.
   - Changed condition
   - Potential delay situation
   - Force majeure

g. Create a copy of the reference schedule for use in the analysis, so the reference schedule can be used as a target schedule.

h. Determine the scope of work required to document the changed condition or delay event. List the assumptions:
   - Scope of work—not just the physical work, but also any redesign, permitting, approvals, procurement, etc.
   - Manpower and resources
   - Sequencing rationale
   - Note any questionable assumptions—especially in the very beginning of documenting the event; a lot of it may be guesswork depending on the severity of the event.
   - Provide a narrative on how the work will be done.

i. Create a fragnet of activities.
   - Estimate the durations of the activities that make up the fragnet and document.
   - Determine the appropriate logic to tie the new fragnet into the schedule.
   - Insert the new fragnet into the schedule with the appropriate logic.
   - Calculate the schedule.
   - Note the completion dates.
   - Recalculate the schedule.
   - Again note the completion dates.
   - Compare the completion dates: the completion date with the delay fragnet durations set to zero versus the completion date with the estimated durations.

- Review the critical path changes and shifts.
  - Identify the critical path in the schedule prior to the insertion of the TIA.
  - Identify the critical path after the insertion of the TIA.
  - Compare and review the changes.
- Create a narrative and write-up of the conclusions and disseminate them to the stakeholders.
- Be prepared to discuss and defend.

j. After the TIA is submitted and reviewed by the stakeholders:
- Negotiate a time extension, if any. Remember: this will only happen if all the stakeholders believe the results of the analysis of the TIA.
- Document any decisions.
- Incorporate the TIA into the official schedule. Do this whether the TIA is accepted or not. Just because there are those who don't want to accept or approve the TIA, it doesn't mean it is invalid and that the delay event isn't going to occur and impact the project. The schedule should always reflect the truth.
- Publish the revised schedule and distribute to all.
- Provide a change order showing settlement, if applicable.
- Ideally, a TIA resolution should include any known delay issues or impacts to date. This may require that more than one TIA be performed.

k. The benefits of TIAs:
- Benefits to the owner
  - Participates in decisions that affect budget and completion
  - Can negotiate requests for time and costs prior to work
  - Encourages cooperation
  - No lingering potential claims issues. In other words, work out problems and issues early, come to an agreement, and then move on
  - Budget and completion information will always be current and reasonably accurate after agreement is reached
  - Allows owners to take advantage of pacing opportunities
  - Reduces or eliminates the need for unilateral modifications
  - Shares performance and cost risks

l. Benefits to the contractor:
- A prospective TIA is a relatively simple analysis compared to an after-the-fact retrospective TIA and a claim.
- Receives timely time extensions.
- Builds good documentation even if the TIA is rejected.
- Allows negotiation prior to spending money or doing work.
- Minimal memory problems compared to old issues. Documenting and creating a TIA while it is in progress is a lot easier than doing it after the fact, and maybe years after the delay event occurred.
- Allows for pacing of the other trades.
- Fair preparation of a TIA builds credibility.
- Builds in understanding of risk and pricing.

m. Disadvantages of using TIAs:
- The process requires scheduling personnel with more analytical experience, skills, and knowledge.
- Some added time burden to those preparing the TIA, but a lot less than building a claim after the fact.
- Less attorney and consultant revenue, which is mainly a disadvantage to the attorneys.

Recommended Practice

There is no other way to determine the impact of a delay event to a project and its schedule other than by performing a prospective time impact analysis. TIA methodology is typically used and supported in litigation.

The following sources can provide more information on the use of TIAs:

1. Construction Law Library, *Construction Scheduling, Liability, and Claims*, by Wickwire, Driscoll, Hurlbut, & Hillman, Aspen Publishers, 2003.
2. AACE, *Recommended Practice – 52R-06* (AACE International, 2006)

Advisories

Avoid the shock factor in the late reporting of delays to the schedule. Start reporting them as they become evident. Where a change in scope is usually directed by the owner, a delay could be the responsibility of the owner and/or the general contractor. If the delay is the fault of the owner, the cost of acceleration is borne by the owner as well.

5.7.2.2 Claims Avoidance and Monitoring

A schedule is an essential vehicle and document for a contract that forms a basis of communication and understanding of the project plan and objectives in relation to time. Since changed conditions are not uncommon in projects, particularly in construction, claims are a means of evaluating, analyzing, and agreeing on the impact of these changes. The level of documentation, communication, and control through the life of a project makes schedules a live form of agreement from initiation to close-out phases. Adverse conditions in a claim arising out of poor documentation, contract conditions, or interpretation of rights can end up in expensive legal disputes and litigation.

Application of claim prevention measures in project documentation, planning, stakeholder review, and peer review of contract language can significantly help in the reasonable and equitable resolution of claims and avoid expensive disputes. In addition, these avoidance techniques also make the project a positive experience in problem solving.

Guidelines

Definitions

Any deviation that significantly affects the contractor's or owner's assumptions in profitable execution of the contract forms the basis of a claim.

Default Condition

Claims from the contractor commonly arise for the following reasons:

- Owner-initiated changes;
- Differing ground conditions;
- Poor contract documents;
- Natural causes or force majeure;
- Access restraints or limitations from interfacing contracts that impact the contractor's ability to perform the project efficiently;
- Failure of the owner to make timely decisions; and
- Failure of the owner to provide owner-purchased material on a timely basis.

Claims from an owner can arise for the following reasons:

- Poor contract documents;
- Failure of the contractor to meet the schedule; and
- Failure of the contractor to provide the necessary resources (manpower and material) to meet project requirements.

Contract schedule objectives are typically defined by milestones. A typical contract will have at least two key milestones: start (notice to proceed) and finish (contract completion). Depending on risk assessment, intermediate objectives like delivery of a major equipment or completion of design phase could also be identified as key milestones in a contract. In addition, some of these milestones may carry contractual penalties for delays to cover risks. For example, a client may determine that the delivery of a milestone mandated by federal consent decree is a high-risk contract objective and hence will carry assessments of per diem liquidated damages in case of delay to this milestone.

A schedule delay analysis, in case of a claim, can involve a complex process in interpretations and entitlement under the contract provisions. Since aggravated claims can lead to legal disputes, prevention and avoidance techniques should be carefully formed in consultation with project legal advice. This *Best Practice Guide* should only be used as a guide in the formulation of a project framework in schedule documentation and claim avoidance techniques. Delay claims involve appropriate interpretation of these key concepts under the contract:

- **Excusable delay:** Entitles the contractor to an equitable extension of time.
- **Non-excusable delay:** A delay for which the contractor has to either mitigate or bear penalties.

- **Compensable time:** Delays that legitimately impact the profit margins of the contractor and eligibility for additional compensation.
- **Ownership of float:** Floats can be client-owned, shared for first use, or contractor-owned.
- **Resource constraints:** Assumptions of resource availability that may be contractually binding. Associated claims could arise for loss in productivity or acceleration.
- **Liquidated damages:** An excusable delay may or may not entitle a waiver of liquidated damage based on contract conditions.

Best Practices

The primary premise of any claim rests on deviation from a baseline contract condition. Hence, the best practice in claim prevention and facilitating just and swift resolution is:

- Documentation
- Validating baselines
- Monitoring variances
- Tracking changes
- Maintaining periodic updates
- Settlement of time impact analysis
- Communication and configuration
- As-built and close-out

Recommended Practice

Conduct Planning Reviews

The old adage about prevention is timeless for a reason. Some of the biggest claim issues often get embedded into a contract with little recourse for prevention after the start of the contract. These claim issues stem from the development of unrealistic milestone dates during initiation or planning phases. Issues also arise from poor contract conditions or poor feasibility of execution. From a scheduling standpoint, recommended practices translate to:

- **Independent expert review of contract documents, drawings, and specifications for high-risk projects.** These reviews help an independent expert review the integrity of documents and its intent to the contractor. These reviews are helpful in identifying potential conflicts, verifying consistency in requirements, and verifying coordination and cross references within the contract documents. For example, the delivery of key equipment on-site could have been set at 180 days in special provisions as a milestone for the general contractor, but allow for 240 days in lead time for a preselected vendor in the specifications pertaining to the equipment. Independent reviews obviously add burden to the project budget and are particularly useful for contracts with significant interfaces with other contracts or that involve complex integration of design from various sources.
- **Constructability reviews including review of milestones and associated risk assessments**. This practice particularly applies to the construction industry. Constructability reviews involve rigorous evaluations of high-level schedule assumptions. These reviews can make careful assessments of the risks from ambitious milestones, difficult interfaces, or phase assumptions in a project.
- **Pre-tender stakeholder and peer review of contract documents.** A scheduler's review of contract documents, particularly sections that impact the schedule, can help with including relevant contract conditions that help in validating, maintaining, and controlling a quality schedule.

Validate the Baseline Schedule

A baseline schedule is a key document for establishing an as-bid contract plan. In case of claims, the baseline schedule is generally accepted as a legal basis for measuring variance and contractor performance. The preparation of a baseline schedule and its validation are key processes that help in claim prevention. Typically, baseline schedule preparation and review require careful review and inclusion of applicable contract conditions. A baseline schedule should:

- Contain no progress;
- Have a closed CPM;

- Identify all key milestones;
- Have a well-defined WBS that agrees with project breakdown of scope of work;
- Have a well-defined responsibility for the scope of work either by use of Organizational Breakdown Structure (OBS) or coding;
- Include resource assignments, cost load, and activity coding to the group; and
- Manage and communicate schedule information to all stakeholders.

Ensure documenting the basis of planning adopted for the baseline schedule. Validating a baseline requires a critical and expert review from an experienced scheduler. It should ensure that:

- All contract conditions are satisfied;
- All milestones and key assumptions including subcontractors are identified;
- Float suppression techniques and lags are audited;
- Superfluous predecessor and successor relationships for reducing float are audited; and
- Resource-based relationships are carefully reviewed and conditionally accepted.

A well-established baseline makes the resolution of a claim simpler and helps the overall project health.

Maintain an Updated Contemporaneous Schedule

A schedule updated at a specific interval that is specified in the contract or required by the client is a contemporaneous record of an updated project plan. An updated schedule should include:

- Verified and agreed progress values for activities. If the project uses an earned value process, ensure that applicable progress measurement rules are used to evaluate progress.
- Auditing out-of-sequence progress and modifying logic, where required, to reflect revisions to sequence of work. Update the project plan document or include a narrative with the progress report to document changes and update the project plan represented in the schedule.
- Addition and updating of activities for approved changes.
- Updated WBS, OBS, cost accounts, and codes, as required, to be consistent with project configuration.
- Updated resource planning.
- Addition and tracking of risk issues, including suspension and resumption of work, potential weather days, or delay in access.
- Identification of any potential delay issues, notifications sent for potential time impact, and what-if analysis provided for the projected delay. It may be noteworthy that a contemporaneous schedule update shall not always trigger potential delay. An activity displaying float may already be on a critical path due to a potential change that is awaiting settlement of negotiation. If the change requires additional duration before the activity can be started, the impact can only be seen in a what-if analysis. It is not a recommended practice to track all potential changes in approved schedule updates to maintain the sanity of schedule and cost projections, yet it is imperative to perform what-if analysis separately for significant changes and document its potential impacts in updates.

Review of schedule updates should additionally include:

- Analysis of schedule performance and variances.
- Assessment of responsibility for projected delay. In case of contractor delay, a recovery schedule should be requested to mitigate and arrest further delays. In case of delays not attributed to the contractor, a time impact analysis should be requested from the contractor.
- Communication of updated schedule and performance reports to stakeholders in accordance with the project communication plan. Good communication facilitates better control and timely intervention for swift resolution of claims.

Keeping a schedule current and acceptable to all parties is not only helpful in claims prevention, but also helpful in efficient management of resources and cost control, as well as better spending projections for fiscal planning. These in turn help in the prevention of secondary claim—like productivity losses and costs.

Update Recovery Schedules and Perform Time Impact Analysis

The schedule updates should indicate the health of milestones with current approved changes. Recognition of delay can be made during the update processes. Typically, a progress review meeting is an appropriate forum to discuss all schedule issues related to the update. If the delay is triggered by reasons that are solely attributed to the contractor's performance (also termed as inexcusable delay), a recovery schedule should be requested that shows the contractor's plan to mitigate delays. It is not uncommon to have low productivity periods followed by higher productivity to make up the delay. However, the recovery plan to improve productivity in the next period should be captured and documented. It is an important legal foundation to record that the contractor has made efforts to mitigate a delay.

A recovery schedule should be treated as a revised baseline schedule. Recommendations for the development and review of a baseline also apply to a recovery schedule.

Where a recognized delay has a cause beyond the contractor's control, a time impact analysis (TIA) is an appropriate means for evaluating the impact, analyzing it, and agreeing on the recourse. While there are various methods for evaluating a time impact analysis (TIA), the contemporaneous method is a widely adopted practice. A TIA typically involves development of a fragnet (a small section of a CPM network) that includes a network of activities resulting from the change or incident. This fragnet is inserted into a contemporaneous schedule to evaluate projected delays. TIAs are effective tools in claim resolution and help in the determination of excusable, concurrent, and inexcusable delays. These analyses form the basis for recommendations on time extensions and waiver of liquidated damages.

Create an As-Built Schedule

An as-built schedule is a validated record of actual progress and accomplishment of activities. It becomes a record document in evaluating case history for claims. Validating actual dates during schedule updates is recommended for maintaining a working as-built record.

It becomes a valuable document for close-out.

Advisories

It is always advisable to consult the legal team to adopt a claim prevention technique that is suitable for the project. Claim prevention techniques can help with the easier resolution and settlement of claims, but not necessarily prevent a claim.

Suggested Additional Reading:

AACE International (2009). *Recommended Practice No. 45R-08*. Retrieved from www.aacei.org

AACE International. (2009). *Recommended Practice No. 48R-06.* Retrieved from www.aacei.org

Jensen, D. Jr., Murphy, J.D. Jr., and Craig, J. (1997). "The Seven Legal Elements Necessary for a Successful Claim for a Constructive Acceleration." Project Management Journal, March, 1997.

McLaughlin, G. T. (2011). *Lessons learned from recent, large and complex construction projects.* Paper presented at the PMI Scheduling Community of Practice Conference, San Francisco, CA.

Mirza, M. A. (2005). *Construction claim management.* Paper presented at the PMI Global Congress, Asia Pacific Proceedings. PMI, Newtown Square, PA

SECTION 6

Appendix

6.1 REFERENCES

AACE International. (2004). "Developing Activity Logic," *Recommended Practice No. 24R-03.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2006). "Documenting the Schedule Basis," *Recommended Practice No. 238-06.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2006). "Time Impact Analysis," *Recommended Practice No. 52R-06*. Morgantown, WV: retrieved from www.aacei.org

AACE International. (2006). In J. Hollman (Ed.), *Total Cost Management Framework* (TCM Framework). Morgantown, WV: retrieved from www.aacei.org.

AACE International. (2007). *Recommended Practice No. 23R-02.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2009). "Documenting the Schedule Basis," *Recommended Practice No. 38R-06.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2010). "Cost Engineering Terminology," *Recommended Practice No. 10S-90.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2010). "Schedule Level of Detail as Applied in Engineering, Procurement and Construction," *Recommended Practice No. 37R-06.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2012). "Determining Activity Duration," *Recommended Practice No. 32R-04.* Morgantown, WV: retrieved from www.aacei.org

AACE International. (2013). *Certified Scheduling Technician Primer*. Morgantown, WV: retrieved from www.aacei.org

The American heritage® dictionary of the English language (4th ed.) (2009). Boston, MA: Houghton Mifflin.

Association for Project Management. (2006). *APM body of knowledge* (5th ed.). High Wycombe, UK: APM Publishing.

Association for Project Management. (2002). *Earned value management: APM guidelines*. High Wycombe, UK: APM Publishing.

Carson, C. (2007) *Preparing & analyzing a prospective contemporaneous time impact analysis.* Presented at PMI Scheduling Conference, Chicago, IL.

Carson, C., & Boe, M. (2007). *CPM time analysis on contract changes.* CMAA report. Retrieved from www.slideshare.net

CIOB (2011). *Guide to good practice in the management of time in complex projects.* Chichester, UK: Wiley-Blackwell.

The Construction Industry Institute Pre-Project Planning Research Team. (1995). *Pre-project planning handbook (Special Publication 39-2).* Retrieved from www.construction-institute.org

Drigani, F. (1989). *Computerized project control*. New York, NY: Marcel Dekker, Inc

Galway, G. (2004). *Quantitative risk analysis for project management, a critical review.* Working Paper, The RAND Corporation. Retrieved from www.rand.com.

Goldratt, E. (1997). *Critical chain.* Great Barrington, MA: North River Press Publishing Company.

Interstate General Contactors vs. United States, 12 F.3d 1053 (Fed. Cir. 1993)

Lukas, J. (2008). *Earned value analysis—Why it doesn't work*. Paper presented at AACE International Transactions, Toronto, Canada, p. 3. Retrieved from www.aacei.org.
O'Brien, J., & Plotnick, F. (2005). *CPM in construction management* (6th ed.). New York, NY: McGraw-Hill Companies, p. 275.
Plotnick, F. (2008). RDM, relationship diagramming method (doctoral thesis, Drexel University, Philadelphia, PA), p. 37.
Ponce de Leon, G. (2008). *Project planning using logic diagramming Method.* AACE Transactions, PS.05.
Ponce de Leon, G. (2012). *Forensic scheduling body of knowledge (FSBOK).* Detroit MI: PMA Consultants LLC.
Pritsker, A. (1966). *GERT: Graphical evaluation and review technique. Memorandum RM-4973-NASA.* The RAND Corporation, p. 2. Retrieved from www.rand.com.
Project Management Institute. (2004). *A guide to the project management body of knowledge (PMBOK® Guide)* – Third edition. Newtown Square, PA: Project Management Institute.
Project Management Institute. (2006). *Practice standard for work breakdown structures* – Second edition. Newtown Square, PA: Project Management Institute.
Project Management Institute. (2007). *Construction extension to the PMBOK® Guide* – Third edition. Newtown Square, PA: Project Management Institute.
Project Management Institute. (2008). *A guide to the project management body of knowledge (PMBOK® Guide)* – Fourth edition. Newtown Square, PA: Project Management Institute.
Project Management Institute. (2011a). *Practice standard for earned value management* – Second edition. Newtown Square, PA: Project Management Institute.
Project Management Institute. (2011b). *Practice standard for scheduling* – Second edition. Newtown Square, PA: Project Management Institute.
Project Management Institute. (2013). *A guide to the project management body of knowledge (PMBOK® Guide)* – Fifth edition. Newtown Square, PA: Project Management Institute.
Wickwire, J., Driscoll, T., Hurlbut, S. & Groff, M. (2003). *Construciton scheduling, liability and claims.* New York, NY: Aspen Publishers.
Winter, R. M. (2008). "Schedule update review—as applied in engineering, procurement, and construction," *Recommended Practice 53R-06 Schedule Update Review.* AACE International Transactions, p. 15. Morgantown, WV: AACE International.
Woolf, M. (2007). *Faster construction projects with CPM scheduling.* New York, NY: McGraw Hill.

6.2 Index

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6.3 Glossary of Terms

This section provides the definitions of the many terms and acronyms used within this best practice guide book.

Accelerated Schedule: A schedule implementing adjustments to the original project schedule, accelerating the project completion date in order to meet the contract or owner's stipulated finish date.

Acquisition: The obtaining of supplies, services, or property to meet the needs of a project.

Act of God: See *Force majeure.*

Activity: A basic unit of work as part of the total project that is easily measured and controlled. It is time and resource consuming. Also called Task.

Activity Codes: These are codes within the scheduling program (MS Project, Primavera, etc.) used to group authority and responsibility of an activity.

Activity Coverage: The scope of work of an individual schedule activity, the sum of the scopes of the list of activities, ideally, equivalent to the project scope of work.

Activity Description: A short phrase or label used in a project schedule describing the type of work in this activity. In many cases, it also references location of work and/or other information pertaining to the work in this activity. For example: Concrete placement, suspended slab, 16th floor.

Activity Duration: In a schedule, the time associated with any discrete scope of work enumerated in a single activity on a schedule.

Activity ID: A unique identity given—by the scheduler or scheduling program—to each activity in the schedule. It is usually made of numerical, alpha, or combination characters. For example: ASD4230.

Activity Identification (ID): An alphanumeric tag or reference which provides a unique identifier for each activity of a schedule.

Activity ID Coding: Considered to exist when the assigned alphanumeric identifier follows a specific scheme in order to provide information about the nature of each schedule activity such as work location, responsible party, WBS classification, project phase, etc.

Activity on Arrow (AOA) Network: A network diagram showing a sequence of activities in which each activity is represented by an arrow connecting between two nodes (circles), each node representing an event.

Activity on Node (AON) Network: A network diagram where activities are represented by a node (box) linked by lines representing logic dependencies.

Activity Percent Complete: A completion percentage of the work in an activity based on a chosen method of measuring work progress.

Actual Cost (AC): See Actual Cost for Work Performed (ACWP).

Actual Cost at Completion: See At Completion Total Cost.

Actual Cost for Work Performed (ACWP): Total costs (direct and indirect) incurred in performing work during a given time period.

Actual Cost This Period: Actual cost incurred since last data date till current data date.

Actual Cost to Date: Actual cost incurred from start of work throughout current Data Date.

Actual Duration: The number of time units consumed to complete an activity, if completed, or consumed on the activity so far, if not completed yet.

Addenda: Plural of Addendum.

Addendum: A document describing an addition, change, correction, or modification to contract documents. An addendum is issued by the design professional or owner to all bidders during the bidding period, but prior to the award of contract. Addenda become part of the contract documents.

Alternate Dispute Resolution (ADR): Any procedure or combination of procedures voluntarily used to resolve a dispute without going to court. These procedures may include, but are not limited to, assisted settlement negotiations, conciliation, facilitation, mediation, fact-finding, mini-trials, and arbitration.

Application for Payment: See Payment Request.

Arbitration: The process by which parties agree to submit their disputes to the determination of a third, impartial party (referred to as the arbitrator), rather than pursuing their claims before a judge and jury in a court of law. Parties often agree in advance to binding arbitration of disputes, either as a clause in the contract or at the occurrence of a dispute. This method of avoiding litigation can save both time and money.

Arrow Diagramming Method (ADM): See Activity on Arrow (AOA) Network.

As-Built Schedule: A schedule prepared after the project has started and that reflects work occurrence as it actually happened in reality, rather than what was planned to happen. Activities are plotted by their actual start and actual finish, disregarding any logic.

As Late As Possible: A constraint in some computer scheduling programs that forces the maximum delay in starting an activity without delaying succeeding activities. Also called the Zero Free Float constraint.

As-of Date: See Data Date.

As-Planned Schedule: The schedule submitted by the contractor—as usually required by the contract—and approved by the owner before the start of the project (and sometimes before the signing of the contract).

At Completion Duration (ACD): The duration of an activity after its completion. For activities not started yet, at completion duration is same as the original duration. For in-progress activities, at completion duration is equal to the summation of actual duration and remaining duration. For completed activities, at completion duration is equal to actual duration.

At Completion Total Cost: Total costs (direct and indirect) incurred in an activity, group of activities, or the entire project throughout the completion of the overall assigned work.

Backward Pass: The process of going on a network from finish to start, calculating late dates for all activities. Backward pass starts with the imposed finish date of the project, if given. If not, it starts with the finish date calculated by the forward pass. Dates calculated by the backward pass, along with those calculated by the forward pass, help identify the critical path and calculate float for all activities.

Backward Resource Leveling: Leveling resources, starting from project finish and going (backwards) through all project activities, fulfilling their resource requirements, and maintaining the total resource usage within the set limits. With such restrictions, the project may take more duration than originally allowed, and project start may have to occur before the scheduled date.

Bar Chart: A graphical representation of project activities shown in a time-scaled bar line with no links shown between activities. Originally developed by Mr. Henry L. Gantt in 1917. Also called a Gantt chart.

Baseline: The original approved plan for a project, including approved changes. It usually includes baseline budget and baseline schedule. It is used as a benchmark for comparison with actual performance. See Project Control.

Baseline Budget: The project's original approved budget, including any approved changes.

Baseline Design: The process of determining the structure of the schedule based on project requirements. The detailed baseline design is a refinement of the initial baseline design.

Baseline Schedule: A schedule prepared by the contractor before the start of the project, and usually approved by the owner, typically used for performance comparison.

Beginning-of-Day Convention: When any date mentioned for an activity means the start of the day. Usually used only by computer software for start dates.

Beneficial Occupancy: The use of premises (or a portion of it) for its intended purpose, even though the project work may not be complete. This term is almost the same as Substantial Completion. (See also Certificate of Substantial Completion.)

Beta Distribution: A continuous probability with a probability distribution function defined on the interval [0, 1]. It is used in PERT with three time estimates for the completion of an activity: the optimistic duration, the most likely duration, and the pessimistic duration. Using these three durations, the beta distribution allows the calculation of the means and variances of activity completion times. The beta distribution also has an advantage over the normal distribution, in that it can be skewed right (toward the pessimistic duration), or left (towards the optimistic duration), or it can be symmetrical.

Budget at Completion (BAC): The sum of the total budgets throughout the completion of work on an activity, group of activities, or the entire project.

Budgeted Cost for Work Performed (BCWP): The sum of the approved cost estimates (including any overhead allocation) for activities (or portions of activities) completed during a given period (usually project-to-date). See Earned Value.

Budgeted Cost for Work Scheduled (BCWS): The sum of the approved cost estimates (including any overhead allocation) for activities (or portions of activities) scheduled to be performed during a given period (usually project-to-date).

Buy-in: A theoretical state where the primary, secondary, direct, and indirect stakeholders of a project commit and demonstrate a willingness to contribute to and reach equitable consensus for the development and execution of the project schedule.

Calculated Finish Date: The completion date of the project as calculated in the forward pass of the Critical Path Method.

Calendar: Shows the days on which work activities may be performed.

Calendar Unit: The smallest unit of time used for activity duration and scheduling the entire project.

Central Limit Theorem (CLT): The central limit theorem demonstrates that in large enough samples, the distribution of a sample mean approximates a normal curve, regardless of the shape of the distribution of the population from which they were drawn. The larger the value of the sample size, the better the approximation to the normal distribution.

Certificate of Completion: A written document forwarded to the general contractor by the architect, engineer, or owner stating that construction is complete according to the contract agreement (approved plans, specifications, change orders, etc.).

Certificate of Occupancy: A written document issued by a local governmental agency stating that the building or facility is in a condition to be occupied (i.e., in compliance with public health and building codes).

Certificate of Substantial Completion: A written document forwarded to the general contractor by the architect, engineer, or owner indicating that the project is substantially complete. This document initiates the time period for the final payment to the contractor.

Change Management: The process of accounting for a change to a project and the project schedule that significantly forces a change to the original plan, or baseline, of the project. That change could be added or subtracted scope of work, a delay caused by the owner, a delay caused by the general contractor, or a force majeure delay.

Change of the Critical Path: A partial or complete change in the critical path on a CPM schedule that was caused by a change in the duration of an activity(ies) and/or a change in the logic of the schedule. Practically, the critical path changes if a near-critical path has increased to exceed the original critical path, or if the original critical path has decreased to become shorter than another path in the schedule.

Change Order (CO): Formal written documents, signed by the owner, directing the contractor to make changes from the original contract. A change order can be used for adding, deleting, or substituting work items. A change order usually, but not always, has an impact on the project's cost and schedule.

Claim: A request from one contracting party (usually the contractor) to another party (usually the owner) for additional compensation, a time extension, or both. See Delay Claims.

Combination Relationship: Two activities related (or connected) by two logical relationships, usually start-to-start and finish-to-finish.

Comparison Schedule: Certain scheduling software allows for comparison of one schedule against another—such as the baseline schedule against the current updated schedule. The software allows users to see the like activities of each schedule side by side for a visual comparison of dates, etc.

Compensable Delays: Project delays, caused by the actions or inactions of another party (usually the owner), that entitle the contractor to a time extension, monetary compensation, or both.

Concurrent Delay: A combination of two or more independent causes of delay during the same period.

Constraint: A restriction imposed on the start or finish dates of an activity that modifies or overrides the activity's logic relationships. Constrained dates are sometimes referred to as "imposed" dates.

Constructability: A project management technique to review construction processes from start to finish during pre-construction phase. It is used to identify obstacles before a project is actually built to reduce or prevent errors, delays, and cost overruns. The term also defines the ease and efficiency with which structures can be built. The more constructible a structure is, the more economical it will be.

Constructive Acceleration: Schedule acceleration by the contractor that occurs when a delay takes place beyond a contractor's control, and yet the owner expects the project to be completed by the original contract completion date. The contractor usually files a claim for this acceleration after the completion of the contract.

Contiguous Activity: An activity that cannot be split or paused. Once work starts on a contiguous activity, it has to continue until its completion.

Contingency Fees: Amounts included in the construction budget to cover the cost of unforeseen events that will most likely occur during the life of the project. Such fees are estimated or calculated directly proportional to the risk taken in the project.

Contract: A legally binding agreement that obligates one party (the architect, engineer, constructor, etc.) to offer products and/or services under certain terms (budget, schedule, specifications) and obligates the other party (owner) to pay for these products/services.

Contract Closeout: The completion and settlement of the contract, including resolution of any open items. From a financial management standpoint, closeout involves settling all financial and accounting matters between the contractor and the owner.

Contractor-Created Float: A schedule float that was created as a result of the contractor's work being completed in a shorter than planned period of time. This float may be created by shorter actual durations for performed activities, a change in the logic, different calendars (6- or 7-day rather than 5-day week), or a combination of these factors. This float is not a part of the total float calculated in the original baseline schedule.

Cost Accounting: The process of taking into account all costs associated with the construction of a project.

Cost at Completion: See Actual Cost at Completion.

Cost Breakdown: See Schedule of Values.

Cost-Loaded Schedule: A CPM schedule in which each activity has a cost figure assigned to it. In some software packages, the user may assign resources (labor, equipment, materials) to each activity, then the software calculates the cost using the cost of these resources given in the resource dictionary.

Cost Performance Index (CPI): The ratio of Earned Value of an activity to its Actual Cost. CPI = BCWP/ACWP or CPI = EV/AC.

Cost Ratio: A method of measuring percent complete for an activity (or a project) by distributing (linearly or using other curves) the cost over the duration of the activity (or project). Percent complete = Actual Cost/Total Cost. This method works well for activities with fixed budget and fixed duration such as a salary staff member.

Cost/Schedule Control System Criteria (C/SCSC): A formal planning and control reporting system developed by the U.S. Department of Defense in the 1960s for its contractors to use. It is used for reporting project schedule and financial information. This system was later simplified and modified to what is currently known as Earned Value Management.

Cost This Period: See Actual Cost This Period.

Cost to Complete: See Estimate to Complete (ETC).

Cost to Date: See Actual Cost (AC).

Cost Variance (CV): The difference between the Earned Value of an activity and its Actual Cost. CV = BCWP – ACWP or EV – AC.

CPM: See Critical Path Method.

CPM Organization: The concept for determining the basic minimal schedule layouts, views, and other conventions, to facilitate the use of the CPM schedule by the stakeholders.

Crash Cost: Total cost of a construction project (direct and indirect), including the impact of crashing (maximum compression of) the schedule.

Crash Duration: The least possible duration for a construction project schedule that is usually achieved by maximum Schedule Compression.

Critical Activity: An activity on the critical path. Any delay to a critical activity will result in a delay to the entire project.

Critical Path: The longest path in a network from start to finish, including any lags and constraints.

Critical Path Method (CPM): A scheduling technique using networks for graphic display of the work plan. The method is used to determine the length of a project and to identify the activities that are critical to the completion of the project.

Cumulative Distribution Function: A function used to compute probabilities for a continuous random variable having values up to a certain value x: $F(x) = Pr(X \leq x)$.

Current Finish Date: The current (updated) estimate of the point in time when the project (or a specific activity) will be completed.

Damages: A measure of monetary compensation that a court or arbitrator awards to a plaintiff for loss or injury suffered by the plaintiff's person, property, or other legally recognizable rights.

Dangling Activity: An activity tied from only one end (start or finish). A dangling activity has only a predecessor(s) or successor(s), not both.

Data Date: The date as of which all progress on a project is reported.

Digressing: The process of reversing all progress reflected on the schedule to go back to the starting point. This practice is used when there is no baseline schedule, but there is a need to create one after construction has started.

Delay: An event or condition that results in work activity starting, or project completion, later than originally planned, or an interruption or hindrance to planned progress.

Delay Claim: A claim for extension of time, monetary compensation, or both for a delay caused by actions of another party. Delay claims are classified into excusable, compensable, and non-excusable.

Dependency: See Logic Relationship.

Design Development: The second phase of a designer's basic services (the first phase being schematic design), which includes developing all engineering and architectural drawings, specifications, and cost estimates. This phase may come in stages; each stage is defined by a certain percent completion. For example: DD30 means Design Development at 30% complete. This indicates that about 30% of the information in the design is determined. Potential contractors have to assume the remaining 70% of information. Further stages follow with the percentage increasing, e.g., DD60, DD90, indicating more design information determined. Final design is the third and final phase of the design process. It follows design development.

Direct Cost: Cost that is directly associated with a specific activity or work item. It typically includes labor, materials, equipment, and subcontracts.

Dispute Review Board (DRB): A panel of three experienced, respected, and impartial reviewers organized before construction begins, and who meet at the jobsite periodically. The board is usually formed by the owner selecting a member for approval by the contractor, the contractor selecting a member for approval by the owner, with the two thus chosen selecting the DRB chair to be approved by both parties. The board becomes familiar with the project and its development. It helps prevent and resolve disputes between the contracting parties.

Dissolve an Activity: A function in Primavera software that deletes an activity but assigns its predecessors to its successors so there won't be an interruption in the logic of the schedule.

Documentation: The written account and representation of the thought process and supporting references which support that the schedule basis is factual and true.

Double-Restricted Float: (in Precedence Networks): The amount of time available to delay the rest of work in an activity after it has started, then finish on time without delaying the entire project.

Driving Relationship: All activities have at least one predecessor and one successor except the first and last activities of any schedule. A driving relationship then is one in which on any given activity its predecessor drives it and it in turn drives its successor. If activity B is the one in question, its predecessor—activity A—drives it, and if activity C is its successor, then B drives C.

Dummy Activity: A fictitious activity with zero duration used in Activity on Arrow Networks to maintain correct logic or distinguish activities' identities.

Duration: See Activity Duration.

Early Completion Schedule: The schedule which indicates the earliest time at which a project can be completed, based on a Forward Pass computation of the schedule. The term may indicate a need for the contractor to complete the project early.

Early Finish Schedule: A schedule that completes before the planned completion date as defined in the baseline schedule and the contract.

Early Dates (for an activity): The Early Start date and Early Finish date of an activity.

Early Finish (for an activity) (EF): The earliest date that an activity can finish within project constraints.

Early Finish Constraint: A restriction imposed on an activity or task that limits the earliest time that an activity can finish. Also called a "finish no earlier than," or FNET.

Early Start (for an activity) (ES): The earliest date that an activity can start within project constraints.

Early Start Constraint: A restriction imposed on an activity or task that limits the earliest time that it can start before the next activity. Also called a "start no earlier than," or SNET.

Earned Value (EV): See Budgeted Cost for Work Performed (BCWP).

Earned Value Analysis: Analysis of project progress where the actual money budgeted and spent is compared to the value of the work achieved.

Earned Value Management: A method of integrating scope, schedule, and budget for measuring project performance. It compares the amount of work that was planned with what was actually earned and what was actually spent to determine if cost and schedule performance are as planned.

Effort-Driven Activity: See Resource-Driven Activity.

End of Day Convention: A convention adopted by most scheduling books assuming that when a day (date) is mentioned, it implies the end of that day. An end of a day is equivalent to the beginning of the next day. For this reason, network calculations start on day 0 (i.e., end of day 0) which practically means the beginning of day 1. Using this convention, the duration of an activity is equal to the difference between its finish date and start date.

Estimate at Completion (EAC): The expected total cost of an activity or project when the defined scope of work is completed. EAC = Actual Cost (AC) + Estimate to Complete (ETC).

Estimate-Generated Schedule: A list of project activities, along with their durations, generated by the cost estimating software. The list does not form a CPM schedule because it lacks logic links (relationships) and other schedule attributes. It may help form the foundation of a schedule.

Estimate to Complete (ETC): The projected cost to complete the activity or project from its present state.

Event: A point in time marking a start or end of an activity. Contrary to an activity, an event does not consume time or resources and, while statusing (updating) a project, an event can be statused as "not started" or "complete," but not "in progress." In computer software, events with significance can be created as Milestones, and they are either Start Milestones such as "notice to proceed" or Finish Milestones such as Substantial Completion.

Excusable Delay: A delay that entitles the contractor to additional time for completing the contract work. Excusable delays usually stem from reasons beyond the contractor's control.

Exemplary Damages: See Punitive Damages.

Expected Duration: The expected duration of an activity is the duration expected to take (in PERT calculations), taking into account the different possible values (optimistic, most likely, and pessimistic durations) and their weights.

Fast-Track Projects: Starting the construction process on a project while design is still underway (i.e., overlapping design and construction of a project).

Finish Milestone: An event marking the completion of an activity(ies) with special significance, such as Substantial Completion of construction.

Finish-Restricted Float (in Precedence Networks): The amount of time the start of work of an activity can be delayed, or the rest of it if work has started, then finish on time without delaying the entire project.

Finish-to-Finish (FF) Relationship: A logic restraint that does not allow for the completion of one activity (the successor) until another activity (the predecessor) is completed.

Finish-to-Start (FS) Relationship: A logic restraint that does not allow the start of one activity (the successor) until another activity (the predecessor) is completed.

Float: The maximum amount of time an activity can be delayed without violating certain conditions, depending on the type of float. See the specific type of float for the exact definition. Float is sometimes called Slack or leeway.

Force Majeure: An event or effect that cannot be reasonably anticipated or controlled; usually entitles the contractor to relief from a contractual obligation, usually an extension in time for the completion of the project.

Forecast Cost Variance (FCV): The expected Cost Variance (CV) of an activity or a project after its completion, assuming the continuation of productivity and job conditions do not change.

Forecast Schedule Variance (FSV): The expected Schedule Variance (SV) of an activity or a project after its completion, assuming the continuation of productivity and job conditions do not change.

Forward Pass: The process of going on a network from start to finish, calculating the early dates for each activity and the project's completion date.

Forward Resource Leveling: Leveling resources, starting from project start and going through all project activities, fulfilling their resource requirements and maintaining the total resource usage within the set limits. With such restrictions, some activities have to be delayed until resources are available and the project duration may be greater than planned, causing the finish date to occur later than originally scheduled.

Free Float: The maximum amount of time an activity can be delayed from its Early Start date, without delaying the early start of the succeeding activities.

Frequency of Updating: The time interval between two regular schedule updates.

Front-end Loading the Cost: Overestimating early work activities and underestimating the later work activities while maintaining the same overall contract sum.

Gantt Chart: See Bar Chart.

General Overhead: See Indirect Cost.

Global Calendar: Scheduling software providers typically include a global calendar in their software package as a default calendar. It is then used as a template to create the project calendar or any other calendars that may be used by the project during its life cycle. The global calendar, for example, is used to create the workweek calendar (typically either a 5-day or 6-day per week calendar). The global calendar typically already reflects a 5-day workweek with no holidays or non-work periods defined.

Graphical Evaluation and Review Technique (GERT): A network analysis technique that allows for conditional and probabilistic treatment of logical relationships (that is, some activities may not be performed).

Historical Data: Sources of objective, factual information recording actual information, such as weather conditions, from professional organizations.

Hammock Activity (summary activity): In a project schedule, groups related activities over a segment of the project's life. Hammock activities can be filtered out in a separate report that will minimize the total number of activities that are displayed. Hammock activities report information that is time dependent and lasts from the earliest start date to the latest finish date of the activities it encompasses. It is recommended that hammock activities be a Start-to-Start relationship, with the first activity as a predecessor and a Finish-to-Finish relationship, with the last activity as a successor.

I-J Method: See Activity on Arrow (AOA) Network.

Impact Schedule: A schedule similar to the original (usually As-Planned) schedule, but incorporating the causative factors (factors allegedly causing the schedule delays). By comparing the two schedules (original and impact), the contractor hopes to prove that the delay was caused by the alleged factors.

Imposed Finish Date: The project's completion date, as specified in the contract or stipulated by the owner.

Inadvertent Early Completion Schedule: The submitted As-Planned Schedule which shows an earlier completion of the interim or substantial completion milestone than contractually allowed or mandated and that was not done in an intentional manner to attempt to finish the project early. Generally, an inadvertent submission is due to the contractor's failure to adequately develop the schedule.

Independent Float (Ind. F): The maximum amount of time an activity can be delayed without delaying the early start of the succeeding activity(ies), and without being impacted by the allowable delay of the preceding activities.

Indirect Cost: An expense that cannot be directly associated with a specific activity or work item such as overhead, profit, or insurance. If the expense can be attributed to a specific project, it is considered job overhead, otherwise it is general overhead.

Initial Baseline Design: The process of determining the structure of the schedule based on project requirements.

Interfering Float (Int. F): The maximum amount of time an activity can be delayed from its Early Start without delaying the entire project, but causing delay to the Early Start of the succeeding activity(ies). It represents the part of the Total Float that remains after deducting Free Float. Mathematically speaking, Int. F = TF – FF.

Interruptible Activity: An activity that can be performed in two or more separate segments. It is an activity that can be interrupted or paused.

Inventory Buffer: A theory in materials management that calls for all materials to be purchased, delivered, and stored on-site prior to installation.

Job Overhead: See Indirect Cost.

Just in Time: A theory in materials management that calls for delivering materials at time of installation only, thus, not having any materials stored on-site.

Lag: A minimum waiting period between the finish (or start) of an activity and the start (or finish) of its successor.

Late Finish Constraint: A restriction imposed on the finish date of an activity that modifies or overrides the activity's logic relationships so that the activity will have negative float if the calculated date is past the constrained date. Also called a "finish no later than," or FNLT.

Late Finish (for an activity) (LF): The latest date that activity can finish without extending the project duration.

Late Start (for an activity) (LS): The latest date that activity can start without extending the project duration.

Late Start Constraint: A restriction imposed on the start date of an activity that modifies or overrides the activity's logic relationships. Also called a "start no later than" or SNLT.

Lead: A modification of a logical relationship that allows an acceleration of the successor activity. (*PMBOK® Guide* – Fifth Edition)

Least Cost Duration: The duration of an activity associated with the Least Cost Schedule.

Least Cost Schedule: A CPM schedule accelerated to reach the point where the total cost of the project (direct and indirect) is minimum. If the duration of the schedule increases or decreases, the total cost will increase.

Level of Effort (LoE): LoE is a type of activity that reports on a fragnet of activities over a period of time. An LoE activity's duration is dependent on the time frame from its earliest predecessor and latest successor activities. The term level of effort is also known as Effort Activity or Effort Driven Activity.

Linear Scheduling Method (LSM): A scheduling method that consists of a simple diagram showing location and time at which a certain crew will be working on a given operation. It is most suited for construction projects with few linear activities (usually with large quantities) that have to be done in the same order or sequence. For example, heavy construction projects such as roads, earthwork, or utility piping.

Line of Balance (LOB) Method: See Linear Scheduling Method.

Liquidated Damages: A contract clause that defines a monetary amount that must be paid by the contractor if the contractor fails to satisfactorily complete the project by the contract finish date. Liquidated damages are usually assessed per day of delay, and they may increase after a certain amount of days, e.g., US$1,000 per day for the first week, then US$1,500 per day for the second week, and on.

Litigation: The process of carrying on a legal contest by judicial process. The parties submit their disputes to the jurisdiction and procedures of federal or state courts for resolution.

Logic Loop: A circular logical relationship between two activities in a network, i.e., each one is a predecessor and a successor to the other one. A loop is an error that must be corrected or else CPM calculations (whether manually or by computer) will halt.

Logic Network: A diagram showing project activities and their logical relationships (interdependencies).

Logic Relationship: The interdependency of the activities in a network: One activity (the Predecessor) has to finish (or start) before another (the Successor) can start (or finish), with or without a Lag. There are four types of logic relationships: Finish-to-Start, Start-to-Start, Finish-to-Finish, and Start-to-Finish.

Logical Relationship: A dependency between two project activities, or between a project activity and a schedule Milestone. The four possible types of logical relationships are: Finish-to-Start, Finish-to-Finish, Start-to-Start, and Start-to-Finish.

Look-Ahead Schedule: A segment of the overall schedule that includes only activities that have work planned during a certain period of time, such as the next month or the next two weeks. Project managers may use Look-Ahead Schedules to focus on the immediate future activities.

Loop: See Logic Loop.

Mandatory Finish: The mandatory finish constraint sets the Early Finish date equal to a specified date. Any imposed mandatory finish constraint sets the early date for all paths leading to that activity, making it a zero float event and thereby forcing it onto the critical path. Also called a "must finish on," or MFO constraint.

Mandatory Start: A restriction imposed on the start date of an activity that modifies or overrides the activity's logic relationships and sets the Early Start date equal to a specified date, making it a zero float event and thereby forcing it onto the critical path. Also called a "must start on" or MSO constraint.

Man-Hour Ratio: A method of measuring percent complete of an activity (or a project) by distributing (linearly or using other curves) the budgeted man-hours over the duration of the activity (or project). Percent complete = Actual Man-Hours/Total Man-Hours. This method is similar to the cost ratio method, except for using man-hours instead of money.

Master Schedule: A CPM schedule that includes more than one Sub-Schedule. Typically, a general contractor requires his/her subcontractors to submit their schedules then incorporate them as Sub-Schedules in their Master Schedule that shows all work items in the project. Relationships in a Master Schedule may be internal (i.e., within the same Sub-Schedule) or external (i.e., between activities from two different Sub-Schedules).

Materials Management: The planning and controlling of all necessary efforts to ensure that the correct quality and quantity of materials and equipment are appropriately specified in a timely manner, obtained at a reasonable cost, and available when needed.

Mediation: A method of trying to resolve a dispute by the use of an impartial intermediary to suggest ways to settle the dispute, rather than imposing a decision upon the parties.

Milestone: An event marking the start or completion of an activity with special significance. A milestone can be a Start Milestone or a Finish Milestone. Milestones have zero duration. There are two types of milestones: contractual and preferential. Contractual milestones are those that are mandated for a specific completion date or time in the contract documents, and often have liquidated damages associated with failure to meet the milestone requirements. Preferential milestones are those that are used for an arbitrary purpose, not mandated by contract, and may include useful points in the life cycle of the project, such as building dry-in, rough-ins complete, or other phase completions.

Monte Carlo Simulation: The technique used by project management applications to estimate the likely range of outcomes from a complex random process by simulating the process a large number of times.

Most Likely Duration: The duration believed to have more likelihood of occurring than any other duration.

Narrative: A written analytical report relating the results of an update to a schedule (no matter how often it is updated) to any team member who has a vested interest in the telling thereof.

Negative Float: A situation occurring when performing an activity even on its early dates fails to meet the project's imposed finish date or other constraint.

Negotiation: When two or more parties with competing interests discuss an issue with the aim of reaching an agreement. It is the first step toward resolving claims.

Network: A graphical representation of the activities (and events) comprising the project, in a logical and chronological depiction. Network diagrams are basically two types: arrow networks and node networks. Arrow networks are also called Arrow Diagramming Method (ADM), Activity on Arrow (AOA) Network, or the I-J Method. Node networks are also called Activity on Node (AON) Network or node Diagramming Method. Precedence diagrams or Precedence Diagramming Method (PDM) are advanced forms of node networks.

Non-Compensable Delay: A project delay beyond the control and not the fault of the owner, such as unusual weather conditions, natural disasters (earthquakes, floods, hurricanes, etc.), wars or national crises, and labor strikes. Such delays usually do not entitle the contractor to monetary compensation, but most likely entitles him to a time extension.

Non-Driving Relationship: A relationship between a predecessor and a successor that does not affect the current activities' dates. If a non-driving relationship is omitted, the CPM calculations—including all activities' start and finish dates—should not change. However, a non-driving relationship may become driving if network conditions change, such as activities' durations or logic, or if activities were added or deleted.

Non-Excusable Delay: A delay that does not entitle the contractor to either time extension or monetary compensation.

Non-Workdays: Days on which no work is/was performed, such as holidays, rain days, shutdowns, and the like. Non-workdays are two types: known, such as holidays and scheduled shutdowns, and unknown, such as weather days and unscheduled shutdowns.

Normal Cost: The cost of a project that is performed under Normal Duration.

Normal Distribution: A probability distribution forming a symmetrical bell-shaped curve.

Normal Duration: The amount of time it takes to finish the project under ordinary circumstances without any deliberate delay or acceleration.

Open-Ended Activity: An activity without a predecessor, successor or both.

Optimistic Duration: The amount of time an activity is expected to take if everything goes smoothly and efficiently within the realistic (though perhaps not likely) realm of expectations.

Original Duration: The number of time units (days, weeks, months, etc.) estimated to complete an activity that has not started yet.

Out-of-Sequence Progress: The start of a successor to an activity before the logical relationships driving the activity in question have been satisfied.

*Overhead: S*ee Indirect Cost.

Overlapping Activities: Two activities are said to overlap when the successor starts while the predecessor is in progress. Mathematically speaking, the duration of the combination of the two activities is less than the summation of the two activities' durations.

Payment Request (Pay Request, Payment Requisition): A formal written request for payment by a contractor or subcontractor for work completed on a contract and, if allowed in the contract, materials purchased and stored on the job site or in a warehouse during a specified period of time. Subcontractors submit their payment requests to the general contractor, who combines them with his own in one total payment request to the owner. Typically, this process is done on a monthly basis.

Percent Complete: See Activity Percent Complete or Project.

Pessimistic Duration: The duration under almost the worst-case scenario within the realistic (though perhaps not likely) realm of expectations.

Planned Value (PV): See Budgeted Cost for Work Scheduled (BCWS).

Precedence Diagramming Method (PDM): A node network (see Activity on Node Network) that allows for the use of four types of relationships: Finish-to-Start (FS), Start-to-Start (SS), Finish-to-Finish (FF), and Start-to-Finish (SF).

Precedence Network: See Precedence Diagramming Method.

Predecessor Activity: An activity that has to finish (or start) in order for the succeeding activity(ies) to start (or finish). It has also been defined as an activity that has some measurable portion of its duration logically restraining a subsequent activity or activities.

Probability Density Function (PDF): A function used to compute probabilities for a continuous random variable at a certain value. The area under the curve of a probability density function over an interval represents probability (chance of occurrence): $f(x) = Pr(X = x)$.

Probability Distribution: A function or mathematical model that describes all the values that the random variable can take, and the probability (chance of occurrence) associated with each. Also called a probability function.

Probability Universe: The set of the values of all possible outcomes for a random variable.

Procurement: The process of acquiring materials, equipment, and/or services from external sources for use in the project. It is a process that usually starts long before the start of the construction process, and ends with project completion or closeout.

Professional Engineer (PE): An engineer licensed by an authority (usually the government of the state) after fulfilling certain requirements (minimum experience and passing an exam).

Pro forma: A projection or estimate of the cost/benefit ratio or rate of return on an investment. Project owners and investors usually use a pro forma to help them make a decision about whether or not to carry out the project. Typically, a pro forma includes all expected costs (initial, recurring, and occasional) and expected revenues throughout the life cycle of the project, then calculates the rate of return.

Program Evaluation and Review Technique (PERT): An event-oriented network analysis technique used to estimate project duration when there is a high degree of uncertainty with individual activity duration estimates. PERT applies the critical path method to a weighted average duration estimate. It is considered a probabilistic method. The name "PERT diagram" is incorrectly used in the construction industry, sometimes to denote a Logic Network.

Progress Override: An option used in Primavera scheduling software to ignore a logic relationship between two activities after actual work has violated this logic. For example, if activity A is a predecessor (with FS relationship) to activity B, but activity B has started before activity A is completed. See the other option, Retained Logic.

Progress Override: Method in schedule software that instructs the software to ignore the logic leading into the out-of-sequence activity.

Progress Payments: Periodic (usually monthly) payments made by the owner to the general contractor (and from the general contractor to the subcontractors) upon the approval of the Payment Request. Owners usually retain a portion of the progress payment (5–10% typically) until the successful completion of the project.

Progressive Elaboration: The continuous evolution of the project design documents, along with its impact on the project's cost estimate and schedule. Unlike Scope Creep, progressive elaboration is not considered a negative practice since it represents the changes in a project's attributes (cost, schedule) as project scope gets more clarified as a result of the development of the design documents.

Project: A temporary endeavor undertaken to produce a unique product, service, or result (*PMBOK® Guide* – Fifth Edition, 2013).

Project Breakdown Structure (PBS): A task-oriented family tree of activities that organizes, defines, and displays the work to be accomplished. See Work Breakdown Structure.

Project Close-Out: The full completion of a project signed off by all responsible parties, and the finalization of all paperwork and payments.

Project Control: The continuous process of: (1) monitoring work progress; (2) comparing it to baseline schedule and baseline budget (what was supposed to happen or what was planned); (3) finding any variances (deviations from baselines), where and how much, and analyzing the variances to find out the causes; then (4) taking corrective actions whenever and wherever necessary to bring the project back on schedule and within budget.

Project Cost Breakdown: See Schedule of Values.

Project Management Plan: See Project Plan.

Project Management Team: The individuals involved in the management of a project. This involvement can be in different capacities, at different levels, or at different times. The team is usually led by the Project Manager.

Project Manager: The individual responsible for managing a project and its completion within its scope, budget, and schedule.

Project Monitoring: A term sometimes used to mean project control. Technically, it includes the first three functions of Project Control (monitoring, comparing, finding).

Project Percent Complete: A completion percentage of the work in a project based on a chosen method of measuring work progress.

Project Plan: A formal, approved document used to guide both project execution and project control. The primary uses of the project plan are to document planning assumptions and decisions, facilitate communication among stakeholders, and document approved scope, cost, and schedule baselines. A project plan may be summary or detailed.

Project Planning: The process of choosing the one method and order of work to be adopted for a project from all the various ways and sequences in which it could be done. Project planning serves as a foundation for several related functions such as cost estimating, scheduling, project control, quality control, safety management, and others.

Project Tracking: See Project Control.

Punch List: A list made near the completion of a project showing the items of work remaining in order to complete the project scope.

Punitive Damages: Damages awarded by a judge to a plaintiff in excess of those required to compensate the plaintiff for losses incurred. Used to punish the defendant for wrongful conduct and to show the plight of the defendant as an example to potential wrongdoers.

Rain Days: See Non-Workdays.

Re-baselining: The process of adjusting the schedule to reflect a major change to the original plan of execution of a project schedule. The original baseline and plan of execution is no longer valid due to the change, so the schedule is completely redone in terms of reworking the activities that have started but not completed and all of the successors to those activities.

Recovery Schedule: A schedule prepared during the course of construction, after the project had fallen behind (either failed to meet an interim target or showed serious signs of failure to meet its expected completion date), with adjustments made by the contractor to expedite the remainder of the project to ensure a timely finish.

Redundancy: A duplication in depicting logical relationships. For example, if A and B are predecessors to C, but A is a predecessor to B, then the relationship between A and C is redundant. Redundancies often happen when inserting activities after the logic network has been built. Unlike a Logic Loop, a redundancy is not an error and it will not halt CPM calculations.

Remaining Duration: The number of time units (days, weeks, months, etc.) estimated to complete an in-progress activity.

Request for Change (RFC): A request initiated by the owner, or the party representing the owner, authorizing the contractor for a change in the scope of the contract. The request is usually, but not always, preceded by an agreement on the impact of the change on the cost and schedule of the project.

Request for Information (RFI): Solicitation issued to prospective bidders which is used to obtain information relative to how a prospective contractor proposes to perform certain work, its qualifications, and terms and conditions. Not used to obtain price information.

Request for Payment: See Payment Request.

Request for Proposal (RFP): A formal invitation by the owner or its representative to potential bidders containing a scope of work which seeks a formal response (proposal) describing both methodology and compensation to form the basis of a contract.

Request for Quotation (RFQ): A formal invitation to submit a price for goods and/or services as specified.

Resource: Any measurable effort or substance that is required or consumed by work activities in a project. In the context of construction projects, resources are labor, materials, and equipment.

Resource Allocation: The assignment of the required resources to each activity, in the required amount and timing.

Resource Constraint: A type of constraint that subjects the start and continuity of an activity to the availability of required resources. See Resource Allocation, Resource-Driven Activity, Resource-Driven Schedule, and Resource Leveling.

Resource-Driven Activity. An activity where duration is calculated based on availability of required resources. Typically, several activities compete for limited resources and the scheduler has to set the priority rules among them.

Resource-Driven Schedule: A CPM schedule with some or all activities are resource-driven. Logic relationships still apply in addition to resource constraints.

Resource Histogram: A display of the number of units required (for future work) or consumed (for past work) of a specific resource during a specified period of time. The user can view the usage per unit of time or the cumulative usage. The user can compare the resource usage to the resource limit (availability). The histogram may plot the resource usage in terms of number of units or cost.

Resource Leveling: Minimizing the fluctuations in day-to-day resource usage throughout the project. It is usually done by shifting non-critical activities within their available float. It attempts to make the daily use of a certain resource as uniform as possible.

Resource Loading: See Resource Allocation.

Resource Usage Profile: See Resource Histogram.

Restraint: See Constraint.

Retainage: A portion of the eligible Progress Payment that is held by the owner until the contractor fulfills his contractual obligations. The contract usually specifies the amount and conditions of the retainage. In large projects, it is customary to either reduce the retainage percentage to stop retaining any money by the owner after the project reaches a certain completion stage, such as 50% complete.

Retained Logic: The process of maintaining a logic relationship between a predecessor and a successor activity even though the successor has started before the predecessor has finished. In other words, the rest of the work in the successor activity will still have to wait until the rest of the work in the predecessor activity is completed.

Right to Finish Early: The contractor has a right to complete the project early as long as certain conditions are met, starting with the submission of an Early Completion Schedule. Then he or she needs to notify the owner, have the ability to complete early, and be in the position to finish early, and if he or she meets all those conditions, the contractor may be able to limit his or her general conditions to the early completion deadline.

Risk Identification: The development of a list of risks that may affect the project. Risk identification should start with a clear understanding of the project purpose, objectives, benefits to be delivered, success criteria, constraints and assumptions, among others, supplemented by a Risk Management Plan and then identification using an agreed technique or techniques.

Risk Management Planning: Deciding how to execute the risk management activities for a project. Risk management planning should be conducted in the early stages of project planning, to determine how risk management will be conducted.

Roll-up Schedule: See Summary Schedule.

S-curve: A cumulative curve plotting work progress against time. Work progress may be expressed in terms of units of work, budget, man-hours, percent complete, or other. The curve loosely resembles the letter S because work typically starts at a light scale then intensifies towards the middle of the project, and finally lightens up again towards the end of the project. The curve is sometimes called "Lazy S-curve."

Schedule: A display of project activities and events, along with their timing, plotted chronologically against a calendar. A schedule may or may not be based on the Critical Path Method (CPM).

Schedule Acceleration: See Schedule Compression.

Schedule Compliance Analysis: The process of determining whether a general contractor generated project schedule follows the owner generated project schedule specifications as outlined in the project contract at a minimum, and the construction industry scheduling best practices and guidelines at a maximum.

Schedule Compression: Shortening the project schedule without reducing the project scope. Schedule compression usually, but not always, increases project cost and often has physical limitations as to how much it can be shortened.

Schedule Contingency: An amount of time included in the construction schedule to account for the unforeseen events that will likely happen during the life of the project and cause delay.

Schedule Crashing: See Schedule Compression.

Schedule Design: The process of developing the structure and organization for the schedule prior to beginning detailed schedule development. Schedule design is planning for schedule development. It provides a methodical approach to building the schedule, so that when schedule development starts it will advance logically to the end result, and that end result will be what was envisioned from the beginning. Schedule design provides the guidance needed to make sure that the schedule that is ultimately developed is what the stakeholders need to manage the project.

Schedule Detail: Scope of work down to the lowest necessary level so that the schedule can be used to achieve its intended purpose. The level of detail is determined by the amount of information needed by those who will be using the schedule. If a schedule is a preliminary or summary level schedule, then the amount of detail will be limited to a broad brush scope of work that outlines a general plan of how a project will go together. If the schedule is a baseline schedule, then it will be fully detailed to present all scope of work performed by all parties to a level of detail such that the scope of work can be easily tracked for progress throughout the life of the project.

Schedule Finalization and Buy-in: The culmination in the development of a project schedule which occurs prior to establishing a project baseline schedule. The process should involve all of the project stakeholders, including the project manager, key project management staff members, and the owner of the project, to mention a few. The buy-in becomes a milestone for the project where all of the project stakeholders accept and agree to the project schedule.

Schedule Risk Analysis (SRA): Method used to derive the implications (such as the likelihood of finishing on time, the amount of time contingency reserve needed and the high-priority risks for risk mitigation) for the overall project schedule from the individual risks that may affect the project at the level of detailed activities.

Schedule of Values: A listing of elements, systems, items, or other subdivisions of the work, each of which is assigned a monetary value, the total of which equals the contract sum when multiplied by the estimated quantities. The schedule of values is used for establishing the cash flow of a project and serves as the basis for payment requests. Also called Project Cost Breakdown or simply Cost Breakdown.

Schedule Performance Index (SPI): The ratio of work performed to work scheduled. SPI = BCWP/BCWS or SPI = EV/PV.

Scheduler: A project scheduling professional in charge of preparing and updating a CPM schedule for a construction project. The scheduler is also responsible for producing reports required by the management, pertaining to the schedule.

Schedule Risk Analysis (SRA): Method used to derive the implications (such as the likelihood of finishing on time, the amount of time contingency reserve needed, and the high-priority risks for risk mitigation) for the overall project schedule from the individual risks that may affect the project at the level of detailed activities. Generally, SRA is based on using a Critical Path Method (CPM) schedule. Inputs include risk data such as probability of risks occurring and their impact on activity durations if they do occur, using Monte Carlo style simulation to build a probability distribution of the finish dates in the schedule, including total project finish.

Schedule Sponsorship (SS): The extent of senior leadership in the sponsorship of schedule management practices within the organization.

Schedule Structure: The framework which consists of a set of elements or variables associated with each activity. The particular arrangement of these elements will define how the schedule is organized and presented. Organizational purpose may be for ongoing schedule development, status input facilitation, presentation of results, etc.

Schedule Updating: Reflecting actual performance information on the schedule at time of occurrence and amount (or percentage) of performed work, as well as implementing any changes to the future work on the schedule.

Schedule Variance (SV): The difference between work performed and work scheduled. SV = BCWP – BCWS or SV = EV – PV.

Schedule Variance Analysis: The process of comparing one schedule to another and noting the changes between the two. For example, the analysis of comparing the latest recent schedule update to the last one to note the changes. The changes one would look for, but are not limited to, include any addition of activities; any deletion of activities; or any changes in duration, in logic, in lags, in total float, in the critical path, in the code structure, of calendars, in dates (Early Start (ES), Early Finish (EF), Late Start (LS), and Late Finish (LF)), of activity type, and in resources.

Schedule Management System (SMS): The guidelines and infrastructure that are used to employ schedule management.

Scheduling: The determination of the timing and sequence of operations in the project and their assembly to give the overall completion time. Scheduling takes one part of the planning effort and zooms in on it.

Scope Change: A significant addition or subtraction of work to the original scope of work of a project. A change in scope is usually directed by the owner of the project.

Scope Creep: The continuous and gradual expansion of the scope of a project (size, area, design, materials, etc.) after the contract has been signed, as a result of multiple and successive owner-issued Change Orders. Scope creep usually results from the owner's lack of scope vision, lack of appreciating the impact of changes on cost and schedule, unrealistic expectations, decentralized decision making, or other factors. It usually results in negative consequences to the owner, including the reduction of the value obtained in the project.

Sequestering the Float: Eliminating or reducing the float of an activity or activities by inflating Durations, inserting unnecessary Logic Relationships, inserting unnecessary Lags, or a combination of these procedures. This is a technique practiced by some contractors in order to maintain inconspicuous ownership of the Float. Most owners dislike this practice and disallow it by inserting a "no sequestering the float" clause in the contract.

Settlement: An agreement by which the parties consent to settle a dispute between them.

Slack: See Float.

Soft Logic: See Resource Constraint.

Standard Normal Distribution: A normal distribution with the parameters $\mu = 0$ and $\sigma = 1$. The random variable for this distribution is denoted by Z. The z-tables (values of the random variable Z and the corresponding probabilities) are widely used for normal distributions.

Start Milestone: An event marking the start of an activity with special significance, such as notice to proceed (NTP).

Start-Restricted Float (in Precedence Networks): The amount of time the rest of the work can be delayed in an activity after it has started, without delaying the entire project.

Start-to-Finish (SF) Relationship: A logic restraint that does not allow for the start of one activity (the successor) until another activity (the predecessor) is completed.

Start-to-Start (SS) Relationship: A logic restraint that does not allow for the start of one activity (the successor) until another activity (the predecessor) has started.

Status Date: See Data Date.

Store Period Performance: A function in Primavera software that adds the latest Cost This Period to the Cost to Date then makes Cost This Period zero. This is a practice the scheduler has to do every time there is a schedule update, along with a Payment Request.

Stretchable Activity: An activity with flexible duration that increases or decreases to accommodate the amount of available resources or other restrictions. The activity duration of a stretchable activity is determined by the CPM calculations in presence of the user's resource and/or other restrictions.

Submittal: A sample, manufacturer's data, shop drawing, or other such item submitted to the owner or the design professional by the contractor for the purpose of approval or other action, usually a requirement of the contract documents.

Sub-Schedule: Generally, a sub-schedule is a portion of a larger schedule based on certain criterion such as responsibility, area, phase, period of time, or others. It is a common practice to refer to the schedule reflecting the work of one subcontractor or other single participant in the project as a sub-schedule. A sub-schedule may have a starting date, completion date, and/or duration that is different from the Master Schedule.

Substantial Completion: The point in time when the project is ready for use by the owner for the purpose intended and is so certified. See Certificate of Substantial Completion.

Successor Activity: An activity that cannot start (or finish) until another activity (predecessor) has finished (or started).

Summary Schedule: A schedule (usually a Bar Chart) where activities are summarized (combined) by certain criterion such as responsibility, phase, or area. If Work Breakdown Structure (WBS) is used, it is possible to summarize (roll up) the schedule at any level higher than the individual activity. Summary schedules are usually used to inform upper management about the overall project situation without too much detail.

Sunk Cost: Cost already incurred which could not be avoided even if the project were to be terminated. It cannot be recovered regardless of future events.

Target Schedule: Any schedule that is used to compare the progress of one schedule against another. For example, once the baseline schedule is complete and approved for the project, the use of comparative targets is the process of comparing updates of the schedule to the baseline schedule in order to understand if the project progress is maintaining and tracking to what was planned originally. It also refers to the comparing of one month's schedule update to last month's, or whatever month or schedule one would want to use for comparative analysis. See Baseline Schedule.

Task: See Activity.

Time Contingency: See Schedule Contingency.

Time Ratio: A method of measuring percent complete for an activity (or a project) by dividing actual duration over the total duration. This method works well for activities with uniform work over its duration. The method also has a variety of ways of calculating, mainly using actual or planned durations.

Time-Scaled Logic Diagrams (or Bar Charts with relationships): A bar chart with logic relationships (all or driving) depicted.

Total Float (TF): The maximum amount of time an activity can be delayed from its early start without delaying the entire project.

Units Completed: A method of measuring percent complete for an activity that is made of small, similar, and repetitive units of work. Percent complete = completed units/total units. This method can be applied to the entire project if the project can be divided into similar types of work such as road construction or earthmoving projects.

Unrestricted Float (in Precedence Networks): The amount of time all or part of an activity can be delayed from its early start without delaying the entire project.

Updated Impact Schedule: A method developed by the U.S. Corps of Engineers to help resolve delay claims. The concept is to create an as-built schedule or updated schedule from the start of the project only to the point just before the delay occurred. The original or baseline schedule is updated with progress information, and then compared to the impacted completion date on another schedule on which a delay is included.

Updated Schedule: A revised schedule reflecting project information at a given Data Date, regarding completed activities, in-progress activities, and changes in the logic, cost, and resources required and allocated at any activity level (Popescu & Charoenngam, 1995, p. 566).

Value Engineering (VE): A science that studies the relative value of various materials and construction techniques. Value engineering considers the initial cost of construction, coupled with the estimated cost of maintenance, energy use, life expectancy, and replacement cost.

Work Breakdown Structure (WBS): A task-oriented detailed breakdown of activities which organizes, defines, and graphically displays the total work to be accomplished in order to achieve the final objectives of a project. WBS breaks down the project into progressively detailed levels. Each descending level represents an increasingly detailed definition of a project component. In CPM scheduling, the components at the lowest WBS level are used as activities to build the project schedule.

Workdays: Days on which work was performed or can be performed.

Work Package: A well-defined scope of work that terminates in a deliverable product or completion of a service.

Zero Free Float: See As Late As Possible.

Z-function: See Standard Normal Distribution.

6.4 Leadership Team Members

In addition to providing their support by writing and commenting on this best practice guide, these individuals also supported our initiative as ad hoc members of this SEI team.

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6.7 Acknowledgements

The last two years has been a tremendous effort of alignment, consolidation, coordination and a little blood, sweat and a few tears as we worked on the final edit of this best practice guide. As we look back to late 2003, the charter was formed creating PMI's College of Scheduling (COS), known today as PMI Scheduling Community of Practice. As with any new organization, the first few years were full of growing pains, numerous committees, and very ambitious plans for a series of publications. The early supporters of this effort—Jim O'Brien, Fred Plotnick, Doc Dochtermann, Jon Wickwire, Stu Ockman, Guy Ponce de Leon, Janice Staley, Kristy Tan and Murray Woolf—all had a vision on how this effort could be achieved. In the end, to streamline the process, the Scheduling Excellence Initiative was formed. We thank Laura Williams, who was instrumental in helping to get the early SEI organized, and for her work with the "Smooth Projects" phase of this project. The individuals listed in Sections 6.4 and 6.5 were instrumental in getting this best practice guide developed through their continued participation throughout the years. We also thank Pradip Mehta, who understood the importance of SEI, and provided much needed encouragement to our efforts.

Finally the one individual who understood the need for this best practice guide, who has been our most stalwart champion, for without his unwavering support and commitment, this first publication from the SEI might never have materialized, we thank Chris Carson.

Pete Oakander and Craig Relyea

Introduction

These *Best Practices and Guidelines* are a reflection of the concept which brought together those PMI members in the construction and claims and dispute resolution industries who felt that some sort of order was needed to come to the industry in terms of scheduling best practices and guidelines. The history and occurrence of construction projects that ended up in either litigation, arbitration, or the courts, made those who were a part of that process aware that there was a need for improvement and standardization of the scheduling process.

The *Best Practices and Guidelines* (BP&G) started as a concept to provide a balanced and informative guide to entry level and senior schedulers as well as non-schedulers in management roles. The BP&G was based on the need for conformity, standardization, and the need to document scheduling best practices and guidelines for all schedulers and planners. The Scheduling Excellence Initiative (SEI) Committee's efforts began in earnest in 2005 with a call to the membership of the former PMI College of Scheduling to participate in this rather large undertaking.

The SEI Leadership Team was assisted initially and over the years by a small group of volunteers who took on leadership roles in developing the concept, refining the purpose and structure, and organizing the effort for the SEI projects. These volunteers contributed many long hours in thought leadership that was important to the development of the volume, even if it didn't show in the work product. These leaders are identified to the best of our knowledge in Section 6.4, and this volume would not be published today without the commitment of those leaders in working through the concept.

Members quickly volunteered to be topic leaders using an online collaborative space for other interested members to provide comments. While participation has been sporadic over these past six years, we would not be where we are today without the selfless efforts of the few PMI members who have participated in this effort. These contributors, also listed in Section 6.5, receive the SEI team's most grateful thanks for their perseverance and participation. When the approach to writing changed from a grassroots collaborative effort to an individual topic-leader effort in 2010, the topic leaders who stepped up and wrote draft sections of the BP&G enabled completion of much of the volume in a short period of time. The members listed in Section 6.6 provided commentary to the development process, and their comments were included in the final drafts of the various sections of this book by the topic leaders. The SEI Committee is grateful to them all for their time and contributions, and for sharing their experiences and knowledge with our scheduling community.

While the structure of our community has changed over the years to keep up with changes in technology, member needs, and the growth of the profession, the support of our volunteer leadership for the SEI Committee's work was constant. We would like to acknowledge their legacy of leadership and support, which made this publication possible:

- Stu Ockman, founding Chair of the former PMI College of Scheduling (2002–2010)
- Murray Woolf, Vice-President for Scheduling Excellence, former PMI College of Scheduling (2005–2006)
- Phil Apprill, Vice-President for Scheduling Excellence, former PMI College of Scheduling (2007–2010)
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- Kristy Tan Neckowicz, Knowledge Management Lead, PMI Scheduling Community of Practice (2010–2012); Community Manager, PMI Scheduling Community of Practice (2013–2014)
- Mark "Doc" Dochtermann, Vice-President Publicity, former PMI College of Scheduling (2008–2010); Marketing and Communications Lead, PMI Scheduling Community of Practice (2011–2012)

Finally, the committee would like to extend a special "thank you" to Pradip Mehta, Community Manager, PMI Scheduling Community of Practice (2010–2012), without whose unwavering support for our efforts the SEI project could not have endured.

Scheduling Excellence Initiative Committee

The current SEI Committee consists of a very small group of dedicated individuals whose efforts have been unwavering for years in promoting, managing, participating, and supporting all areas and roles within the SEI project, leading topic organization and development and writing work product, participating in meeting after meeting month after month, as well as facilitating town hall sessions at the annual conferences. This group is responsible for the final structure, compilation, and review of this volume. Without the time and dedication contributed by this group, this volume would not be published today.

Chris Carson, SEI Committee Chair
Pete Oakander, SEI Committee
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