Lessons Learned — Schedule Development Using Primavera P6™

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Abstract: Many contract documents are now requiring the use of the latest version of Primavera software (P6™) because of its enterprise capabilities and its use of latest technologies, including the capabilities to interact other software applications; therefore it is important for the scheduler to understand how to use this software most efficiently in their battle to complete their projects in a timely manner. Primavera's latest release of P6™ contains many features that can assist in developing schedules quickly and efficiently. However, a new or in-experienced user would be overwhelmed in the struggle to prepare the schedule using P6™ and these advanced features without proper training or "basic training." This article will focus on the authors' experiences and their lessons learned regarding the effective use of P6 ™ in the schedule development process as they apply this to the TCM planning and scheduling development processes (TCM 7.2). This article was first presented as PS.11 at the 2010 AACE International Annual Meeting in Atlanta.

A ACE International's **Total Cost Management Framework** (TCM section 7.2) outlines the 12 steps for schedule planning and development as follows:

1. Plan for schedule planning and development;
2. Identify activities;
3. Develop activity logic;
4. Estimate durations;
5. Establish schedule requirements;
6. Allocate resources;
7. Optimize schedule;
8. Establish schedule control basis;
9. Review and validate schedule;
10. Document and communicate schedule;
11. Submit schedule deliverables; and,
12. Develop and maintain methods and tools. [1]

This article will focus on the use of Primavera P6™ to accomplish the first seven steps of the process.

Plan for Schedule Planning and Development

Prior to developing the schedule, the current documented scope basis and technical requirements (including contractual requirements) must be evaluated. The user/scheduler must understand the purpose of the schedule, as well as the specific scheduling requirements contained in the specifications and contract documents. Requirements to consider include stakeholder needs, resource and/or cost loading, structure (Work Breakdown Structure and/or activity coding), reporting, updating, weather considerations, calendars, activity detail (durations, costs, resources), software, and application integration.

Contractual and Internal Organizational Considerations

In the development of an organization's management capabilities of all projects across the enterprise, considerations must be taken which govern integration with outside scheduling systems. These considerations are essential when dealing with varying project environments and across multiple industry sectors. Although scheduling specifications may require the organization's use of Primavera, multiple outside participants with responsibilities that relate directly or indirectly to the process of schedule development (i.e.,

design group, engineering group, subcontractors, suppliers, etc.) may use other scheduling applications to develop timelines for their specific scope development. These scheduling systems will need to be considered, if not directly interfaced with Primavera P6™.

Contractual obligations might require systems integration (conversion to Primavera P3, SureTrak or Microsoft Project) because of client/contractor or third party schedule development and review.

There are several items that must be considered when integrating Primavera P6™ and other Primavera scheduling applications, as well as Microsoft Project. Even integration between differing enterprise structures from one organization's implementation of Primavera P6™ can create technical and data transfer issues.

When transferring data into Primavera P6 an organization must consider the integrity of its own system based upon the implemented structures and reporting requirements. If the goal the company in the use of Primavera P6 is to maintain these organizational structures with consistent reporting and management of projects across its Enterprise Project Structure (EPS), then the organization should consider an alternative to a direct import into the 'production' database.

The initial implementation of Primavera P6 should include the consideration of multiple databases. A 'live' or 'production' database contains the active, most current data, and is used by project schedulers to maintain and analyze up-to-date information. This database allows the organization to maintain, manage, and report project schedule information.

A second database to be considered should be a 'sandbox' or intermediary database from outside sources and the 'production' database. The 'sandbox' database is used for the purpose of 'cleaning' or modifying outside schedules to conform to the company's internal requirements. The schedule is 'cleaned' – global to project settings (calendars, activity codes, etc.) or vice versa, depending on the organizational requirements and then exported/imported into the 'live'

database. Note: There should be a process in place for notification to the outside schedule source regarding any modifications to the schedule. There may be a request and resubmittal process required to comply with organizational requirements. The organization's structures must be clearly defined upfront such that any outside source knows the requirements for schedule submission. This process or requirement should be clearly understood from the beginning of any contract with those developing timelines outside the 'production' database. Original submissions of all outside schedules should be kept as historical records with their original format and data.

A third database, a training database, might also be created for the purposes of training system users outside of the 'production' database. The sample PMDB database provided by Primavera with its sample data is one example of a training database. A large organization might consider duplicating the 'production' database to consist of major programs and project examples for use in a training environment. Some might consider the 'sandbox' database as a source for training. However, this database, over time, will have very little structure that can be used to understand the organizational use of Primavera.

Regardless of the varying databases implemented by the organization, there must be certain considerations when importing data from outside sources. The maintenance of the project schedule and its structures is only one part of the Primavera P6 function. The system's capabilities of maintaining multiple projects both from a project concentric focus, as well as the project management needs of the organization make Primavera P6 a full project management solution. The use of Primavera's global attributes above the project and within the EPS defines the system's ability to manage project requirements across the organization's enterprise or program. It is not recommended to use these global attributes with the focus of a specific project's organization and schedule controls.

WBS Code	WBS Name
4769-1	Memorial Hospital Project
4769-1.01	Design and Engineering
4769-1.02	Procurement
4769-1.03	Sitework
4769-1.04	Foundation
4769-1.04.01	Excavation
4769-1.04.02	Form Work
4769-1.04.03	Concrete
4769-1.05	Structure
4769-1.06	Mechanical/Electrical Systems
4769-1.07	Elevator
4769-1.08	Plumbing and Electrical
4769-1.09	HVAC

Table 1—The Advantage of Different Subcontracting Structures [6]

Using the import templates available in P6 for both Microsoft Project and P3 can help reduce data redundancy for both existing projects and for project creation from outside sources. Accessing these templates is found within the file menu, import option.

The Microsoft Project (MSP) template initially defines the use of summary tasks with the MSP schedule and their possible conversion to P6 WBS summary tasks (to be discussed in detail later). Unlike MSP milestones, P6 milestones cannot have resource/cost assignments. The template allows for the reallocation of these milestone resource costs to either task dependent activities (to be discussed in detail) or start milestones with expenses. Resource structures within P6 are hierarchical based on the organizational requirements. The template defines how resources transfer from MSP to the organization's resource dictionary. The use of activity IDs and their significance differs between Primavera P6 and Microsoft Project, therefore the template defines how activity IDs will be developed based on task structures from MSP. Additional template considerations are notes from MSP tasks to P6 notebook topics and custom data fields transfer. Project calendars or working times imported from Microsoft Project are imported as project specific calendars.

Based on project group structures within P3 and SureTrak (project group type) the P3™ import defines how these structures will be imported into P6. Similar to the MSP template, resources must be imported into the existing resource dictionary based on the organization's existing resource structures and activity logs or notes from P3 must be assigned to notebook topics within P6. The remaining portion of the import contains the specific template configurations for importing data and how that data will conform to or modify existing project data. An item of caution when importing from P3 and SureTrak (project group schedule types), project calendars are imported as global calendars.

Identify Activities
Define Work Breakdown Structure (WBS)

The initial effort in the identification of work items or activities is the development of overall planning with high-level planning structures including work breakdown structures (WBS) and activity codes and determining the role of each. Most organizations use the work breakdown structures (work breakdown structure window) within P6 to define a project's phased or logistical structures. However, because of the rollup capabilities and earned value role of the WBS, many contracts define the project's work breakdown to cost structures and measureable budgeted
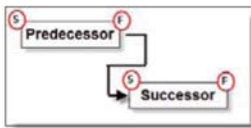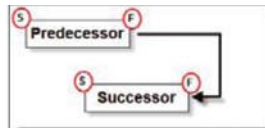
Figure 2 —Finish to Start Relationship

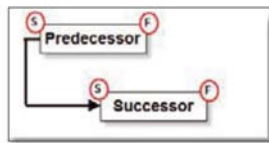**Figure 2 —Finish to Finish Relationship**

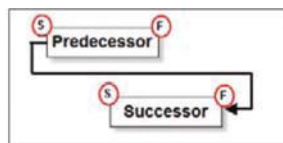**Figure 4 —Start to Start Relationship**

Figure 5 —Start to Finish Relationship

quantities. This requirement can limit the project's needs for structure and also the organization's needs in its use of internal enterprise wide management. In this case, the activity codes can be used to develop project phasing or logistical layout of the project. Be aware that when exporting to P3, the WBS will export based on numerical outline, and the activity codes will be exported in the order created in P6.

If the contract does not define usage of WBS, then this hierarchical structure should be the overall organizational breakdown of the project either by scope breakout (i.e., phase, area, location, etc.) or by budget of quantities. The WBS by default is project specific with the project at its highest level. To create a project WBS, open the work breakdown structure window in P6 and add the lower levels below the project. Using the arrows in the command bar, define the hierarchical structure. This structure will define the overall layout of the project.

Other than the usage of predefined project start-up templates, there is no direct correlation between varying project structures in P6. There is, however, an option of coding WBS levels by using WBS categories (the nomenclature can be modified). These global phases are set by the system administrator (admin menu, admin categories, WBS categories) and assigned in the WBS window (WBS categories column). WBS categories can then be used to group activities across the enterprise based on the activity's associated WBS regardless of the project specific WBS nomenclature.

Define Activity Codes

Activity codes within Primavera P6 (enterprise menu, activity codes) are a means of 'tagging' activities with shared or common attributes across the project, the program (enterprise levels), and the organization (globally).

To create activity codes (enterprise menu, activity codes option) specify the code type: global (enterprise-wide), EPS (program wide), or project (project specific). Click the modify button to add the code. Once the code is added, values for each code will need to be created. Hierarchical structures can be defined for each activity code value listing (ex. CSI divisions and CSI codes) using the arrows located to the right of the activity code values list.

As the name implies, these activity code values are then assigned to individual activities (activity details, codes tab). Once assigned, activity codes can then be used for formatting schedule information (i.e., grouping, filtering, and sorting activity data) in conjunction with or apart from the project's WBS. The user should keep in mind that although project level activity codes are copied with the project and or baseline schedule, formatting within layouts will most likely need to be recreated.

Define Activities

The next step in the process of activity identification is to define the details within the schedule. Activities or individual deliverables will need to be added within the WBS. Defining activities is the process of identifying the specific actions to be performed to produce the project deliverables [2]. To prepare schedules, information from the documents that define the scope must

first be translated into identifiable, manageable activities and tasks [1].

Create Activities

To create activities in P6, open the activities window and insert each activity. If grouping by WBS, then highlight the WBS level to which the activity applies, then click the add button in the command bar or click the insert key on the keyboard. Note: To see the entire WBS structure, make sure that the 'hide if empty' box is un-checked in the group and sort window (view, group and sort, group by options).

Activity ID

Each activity should have a unique alphanumeric identifier. The activity IDs should be capable of 'smart' or 'intelligent' activity identification in which unique activity identifiers are systematically organized to relate to various groupings for schedule activities [3]. Examples of smart IDs would be using the Construction Specifications Institute (CSI) division as part of the activity ID, or in the case of a logistically defined project, such as multi-story building, using an location or location identifier, (i.e., floor level) as part of the activity ID. It is important for the scheduler to be aware of character limitations for the activity ID; in P6 the activity ID can have up to 20 alphanumeric characters. In P3 there is a limit of 10 alphanumeric characters. Therefore, if the contract requires that the schedule be downloadable/transferable to P3 or SureTrak, the scheduler should limit the activity ID to 10 characters. The maximum ID length can be set by the system administrator (admin menu, admin preferences, ID lengths tab). Keep in mind that all settings defined under the admin menu are global, meaning that they affect all projects across the enterprise.

In P6 each project has a defined default numbering convention set within the projects window, project details, defaults tab. The activity ID is defined by a required prefix (consider a unique project identifier – used in advanced tracking layouts) as well as a required suffix. Activity IDs are then, by default, incremented based on a numerical value
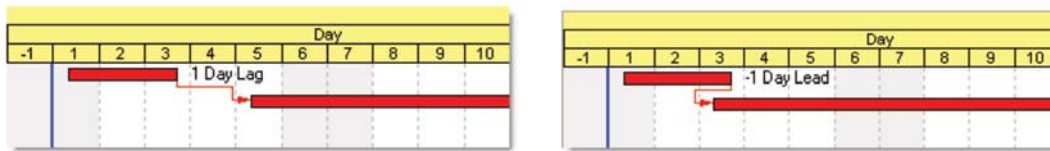
Figure 6 —Lag and Lead

Figure 7 —Viewing Relationship Ties

of 10. This incremental value may be increased to allow for activity insertion and maintaining sort/precedence ordering to maintain organizational or contractual requirements. P6 uses these defined project settings when new activities are added or the user can specify to base a newly inserted activity ID on an existing selected activity.

Activity ID definition can be altered at any time by defining the structure of existing IDs. By first highlighting multiple activities, then selecting the edit menu, renumber activity IDs option, the user is prompted to redefine the activity ID using three options: increment activity ID based on selected activities, auto-number, replace beginning characters. The first option, increment activity ID based on selected activities, adds a user defined value to each selected activity suffix. The second option, auto-number activity IDs option, restructures the activity ID prefix, suffix, and allows for a user defined value to increment remaining selected activities. The third option, replace beginning characters, replaces the activity prefix, left to right, based on the number of characters specified by the user.

In previous versions of P6, using a global change option was necessary to alter large quantities of activities in relation to both the activity name and ID. This option can be found in the tools menu, global change allows the user to add to the existing activity ID and prefix and/or remove/replace the existing activity ID. This option is still available, but may no longer be necessary with the ability to renumber activity IDs in the latest release of P6.
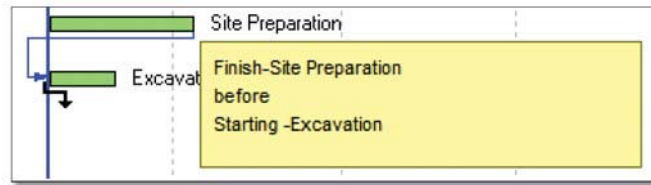
Activity Name

The activity name in P6 (activity description) should be concise and clearly defined such that all using the schedule understand the scope of work that the activity represents. A deliverable or quantifier in the activity description, such as a dimension, quantity or a physical demarcation, is generally a good way to communicate the activity scope. (Percentages are not good quantifiers.) [3].

Keywords in the activity name (left to right in order) should be used to enable sorting and finding activities in the P6 schedule easier. These keywords will also be valuable in relationship assignment by using the search fields in both the predecessor and successor windows.

The user should be aware that P6 has a limit of 120 characters for the activity name, whereas P3 is limited to 48 characters. If the contract requires that the schedule be downloadable/transferable to P3 or SureTrak, the activity description should be limited to 48 characters in P6.

Activity Type

Once the activity is added, its role will need to be defined. In P6, there are several different activity types including task dependent, resource dependent, WBS summary, level of effort and milestones. The activity type is set to each activity in the activity details, general tab, and governs the activity's 'role' within the schedule. It is important to understand what these activity types mean and when you should use them.

Each project will begin with a key event that signals the beginning of work or phase of work as well as a key event signaling the completion of work or phase of work. P6 uses both start and finish milestones for such events. Milestones, whether start or finish, have no duration and can have no resource/cost assignments. P3 flags are not an option in P6.

Activities, by default, are scheduled according the work period or calendar associated to the activity. P6 gives two options that determine which calendar(s) will be used in the calculation of each activity. A task dependent activity is scheduled according the activity's main or base calendar. A resource dependent activity is scheduled according the calendar(s) of its assigned resource(s).

The last two types of activities are summary or 'high-level' activities whose durations are determined by their logical predecessor(s) and successor(s) or by the total duration of the level of the work breakdown structure in which the activity is added. A level of effort activity
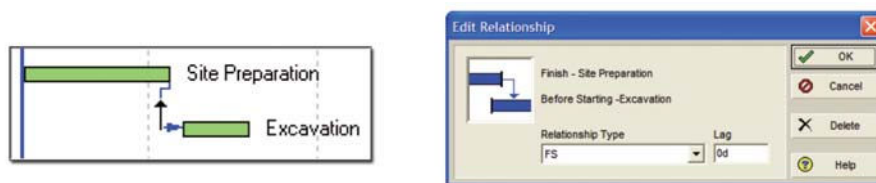

Figure 8 —Editing Relationship Ties

Figure 9 —Assign Predecessor and Successor Windows in P6

has a duration total based on its predecessor(s) and its successor(s) ties. Unlike P3 and a hammock with its required start-to-start predecessor, finish-to-finish successor, the level of effort is not limited in the relationship type available to its predecessor or successor, including lag. LOE activities can be used to measure resource total durations across multiple activities (i.e., tower cranes, rental equipment). They can also serve as resource/cost loaded lump sum activities for overhead or general costs. A WBS summary activity has a duration based on the level of WBS in which the activity exists. This type of activity requires no relationships but requires instead a defined work breakdown structure. Both of these types are useful in loading overall costs or possible overhead costs by phase, area, division, etc.

Develop Schedule Logic

Once the activities have been defined, the next step is to sequence the activities. Sequencing activities is the process of identifying and documenting relationships among the project activities [2]. Logic addresses the sequential dependencies between activities, and similar issues such as programmatic, procedural, and physical requirements and constraints, and preferential sequencing in consideration of cost or resources [1]. Recommended practice is that logic development is an iterative planning process. This process is further refined during the schedule development and optimization [4].

Every activity and milestone in the schedule (except the first and last) must have at least one predecessor relationship and one successor relationship.

Relationship Types

There are four types of relationships that can be assigned in P6, finish to start (FS), start to start (SS), finish to finish (FF) and start to finish (SF). Each of these relationships can also be assigned a lead or lag duration. In P6, the scheduler can assign what calendar is used for defining the relationship lag (schedule, options).

The following four relationship types (listed by their default order in P6) are used to schedule activity dates:

- **Finish to Start** (FS) – typically used in planning the majority of work and for maintaining time contingency in the plan. Primavera uses this tie as its default. This type of relationship indicates that the successor's start is dependent on the predecessor's finish.

- **Finish to Finish** (FF) – typically used when overlapping work. This type of relationship indicates that the successor's finish is dependent on the predecessor's finish.

- **Start to Start** (SS) – typically used when overlapping work. The type of relationship indicates that the successor's start is dependent on the predecessor's start.

- **Start to Finish** (SF) – an unconventional method for controlling a successor's finish date. This type of relationship indicates that the successor's finish is dependent on the predecessor's start.

- Lag is time variance between the start/finish dates of predecessors and successors to the current activity. Lag duration is, by default, based on the predecessor's calendar, unless specified in the scheduling options. (Lead is negative lag.)

Finish-to-start logic will give you the longest total project duration and is the most common logic type. The start-to-start and finish-to-finish logic can be used to compress (shorten) the schedule. This compression is often used in the execution phase of the project to accelerate work.

Assigning Relationships

In P6, there are three methods for assigning precedence relationships to an activity. The first method can be performed in either the Gantt Chart or the Network views by dragging the mouse from the predecessor to the successor to create the relationship tie. Check the yellow box to verify the type of relationship being created. Always begin from the predecessor and 'draw' to the successor to create the desired relationship.

When viewing relationship ties, editing can be performed by double-clicking on the tie in question.

The second method uses the relationships tab(s) or predecessor/successor buttons (located in the command bar) to assign the current activity's predecessor(s), successor(s).

Use the Search field to locate activities by either their IDs or by the activity names. Click the display bar (located at the top of each window) to group activities by WBS (to locate activities in other areas of the project) or view a list of activities. Filter activities by either those critical to the project or by milestones. Modify the columns displayed by either status, dates (e.g., activity start/finish), or resource and click the column headers to change the sort. These settings are retained for the user in working in the database. By default, when creating relationships using this option, a finish-to-start tie is the default tie created to activities other

than milestones. The second tie is finish-to-finish, third is start-to-start, and fourth is start-to-finish.

The user should be careful when assigning relationships using this method since P6 allows for multiple relationship assignments (i.e., finish-to start with a finish-to-finish with a start-to-start with a start-to-finish). Use the undo to delete the last tie created (individual tie only). Use the remove button to delete the 'first' tie created (i.e., finish-to-start with a finish-to-finish. The remove button will remove the finish-to-start whereas the undo will remove the finish-to-finish.

The third method uses the link activities feature to sequence two or more activities in the order selected. Highlight multiple activities in the order of precedence and select the edit menu, link activities option (or right-click in the activity table, link activities). The activities are linked finish-to-start by default. Again, caution should be taken when using the link activities feature to avoid creating multiple relationship assignments; using the undo option (edit menu, undo) will remove the last tie created.

Estimate Durations

The next step in the process is to assign durations to each activity. Estimating activity durations is the process of approximating the number of work periods needed to complete individual activities with estimated resources [2]. The duration of planned activities is estimated to calculate the estimated start and finish dates based on the defined scope of work, estimates of required resources and their availability, and the expected performance (or consumption) rate of those resources [1].

Work Periods and Calendars

When using P6, the user must be aware that the software is always scheduling/calculating in minutes. The user may select how P6 displays activity duration (edit menu, user preferences option, time units tab). Typically duration is displayed in days. However, based on the project plan a day might be 8 hours or 10 hours. In order to define individual durations, work periods will need to be established.

Every project plan revolves around a standard work week or time-period per month and per year. Activity detail must be defined by hours, days, weeks, etc. as work is broken down into measurable units and scope. Primavera uses calendars to define standard periods of work and nonwork (enterprise menu, calendars option). The standard workweek is defined by establishing calendars to measure work and to calculate exceptions to the standard workweek for the project and for individual activities. Specific calendars are then assigned to an activity as a base calendar (activity details, general tab) or to a resource (resource details, details tab). Dependent on the activity type, the activity's duration will be measured based on its base calendar (a task dependent activity type) or on its assigned resources (resource dependent activity type).

In P6 there are three types of calendars: global, resource, and project. P6 uses calendars to define standards globally (available to all activities in database), resource (used by resources to schedule activities), and project (specific to activities within the active project). Global calendars set the standards for creating other global calendars as well as for creating resource and project calendars. The default global calendar is assigned to all new projects. Global calendars can be assigned to activities across all projects within the database. The scheduler using P6 must be aware of the implications of using global calendars instead of project calendars. Any change to a global calendar, such as adding a nonwork day, will affect all activities in the database assigned to that calendar.

The project may begin on a standard workweek (i.e., 5 work days and 2 nonwork days). Most likely not all work days will have production due to seasonal issues or holidays. These days or dates will need to be modified to nonwork to correctly define production days. There may be reason to create a seven-day workweek to measure or account for 365 days of time in order to measure total time durations. There may also be reason to create additional working calendars to measure optional workweek standards (i.e., 6 work days and 1 nonwork day – because of needs for accelerating production). Certain contracts may require calendars to define weather and/or environmental conditions. Refer to the contract for both calendar setup requirements and specific periods of work and nonwork.

To create a new calendar, select the type of calendar to be created (unless managing a program of projects, consider using a project type of calendar). All calendars are created by copying an existing global calendar. Specify the global calendar to be created and name the newly created calendar. When creating a project specific type of calendar consider naming the calendar with a project identifier. This will assist in reporting calendar information across the enterprise. After the calendar is created, it will inherit all holidays and exceptions from its originating global calendar. If the global calendar is changed in future (i.e., workweek is changed or nonwork periods modified), the effect will carry over into all linked calendars. To remove this link (i.e., the calendar is stand-alone), use the pull-down in the lower left corner of the calendar window (inherit holidays and exceptions from the global calendar) and specify <None>.

Because P6 calculates to the minute; review the detailed work hours/day to verify that the day start/finish times are consistent for each work period, as well as with other calendars used in the project and enterprise. Inconsistencies can cause unusual start/finish times in the schedule, as well as unwanted overlapping of days between activities. When modifying existing calendars (i.e., 5 day to 6 day), verify detailed work hours/day for each day of the workweek to remove any inconsistencies. It is recommended that the global calendars be correctly defined initially to avoid these inconsistencies from the start.

After calendars are established they are then assigned to individual activities. Each activity will have an assigned calendar (activity details, general tab). The user should be aware that the use of multiple calendars within one project, although common, can impact float

calculations for the project (i.e., 7 days in a 7 day calendar or 7 days in a 5 day calendar).

Workday Definition

After calendars are assigned to their respective activities, durations for each activity will reflect not only the workweek per activity but any nonwork time associated to the activity's calendar. The user must be aware of the work day definition (i.e., 8 hour workday or 10 hour workday, etc.). In P6 (prior to version 7) the work day was defined at the admin or user level with only one selection available, therefore causing issues when multiple calendars were used. In P6 version 7 (admin menu, admin preferences, time periods), the workday can be defined at the calendar level. The system administrator can define either global hours per time period (day, month, etc.) or set the hours per time period at the calendar level.

The user can modify how durations (i.e., hours, days, etc.) are displayed across the users' projects under the edit menu, user preferences option, time units tab.

It is important for the scheduler to understand the different duration types in P6 and the relationship between the duration of the activity and the cost and/or resources assigned to the activity. The scheduler must choose the correct duration type for each activity in the schedule for the schedule model to accurately reflect the project plan.

Establish Schedule Requirements

The next step is to establish the project or contract time limitation requirements and the date constraints within the plan [1]. These can be contract milestones such as fixed dates for substantial completion and phased turnovers. P6 allows for several type of constraints (both primary and secondary constraints are available). The user must understand the use of constraints, their impact on date calculations, and understand which constraint type to use.

Because of contractual requirements and/or time limitations, precedence relationships may not be the driving consideration for specific activities (i.e., contract or project completion, phase startup and/or

completion). In these cases the use of imposed time constraints might be required to reflect the activity's importance within the path of precedence relationships.

When assigning these constraints (whether contractual or internal) (activity details, status tab) the user should consider the level of priority of the date (contract completion over a material date), in other words, a level of priority or process for change should a change in date be required. If a date change is not optional you might choose one type of constraint versus another type.

There are varying types of constraints that can be applied to an activity's start or finish date. Dependent on the type of constraint, the imposed date might affect the activity's early dates or late dates.

A start on or after constraint imposes a restriction on an activity's early start date. This activity cannot start earlier than its constrained start date although precedence relationships might cause the activity to start later. A finish on or after constraint imposes a restriction on an activity's early finish date. This activity cannot finish earlier than its constrained finish date although precedence relationships might cause the activity to finish later.

A start on or before constraint imposes a restriction on an activity's late start date. This activity cannot start later than its constrained start date and will override precedence relationships possibly causing negative float. A finish on or before constraint imposes a restriction on an activity's late finish date. This activity cannot finish later than its constrained date and will override precedence relationships possibly causing negative float.

A start on constraint imposes a restriction on an activity's early and late start dates. This activity cannot start earlier or later than its constrained start date without impacting its criticality, but this constraint will not override precedence relationship. The finish on constraint imposes a restriction on an activity's early and late finish dates. This activity cannot finish earlier or later than its constrained finish date without impacting its criticality, but this constrain

will not override precedence relationship.

Mandatory start and mandatory finish impose restrictions on an activity's early and late start dates and on an activity's early and late finish dates respectively. This activity cannot start or finish later than its constrained date. Unlike other constraints, these mandatory constraints override any precedence relationship.

The as late as possible constraint removes all free float from the activity. The activity moves to its latest possible date without impacting is successor's early start date.

Allocate Resources

Estimating activity resources is the process of estimating the type and quantities of material, people, equipment, or supplies to perform each activity [2]. If the contract documents require resource and/or cost loading, the scheduler must assign resources to the activities. Even if the contract does not require resource/cost loading, it is good practice; by assigning (i.e., loading) resources for each activity, available resources can be scheduled in accordance with resource consumption limitations (i.e., money, labor hours, etc.) by resource leveling or balancing [1].

When considering activity resource development and assignment the determination must be made either contractually or internally what 'types' of resources will be tracked and will costs be associated to each resource or tracked independently. Secondly will resources be updated based on activity work performance and will payment be based on percentage complete. If this is the case, the user and/or project team must consider the amount of time that is required to not only input resource/cost data but the time involved to manage and report resource updates.

Resources in Primavera P6 are global in that a single resource dictionary houses all projects' resources. This dictionary is hierarchical in its structure which allows for controls to be in place for overall resource management. Resources are global in that a single resource (dependent upon user access) can be assigned to multiple activities

within across multiple projects within the EPS.

In P6 cost loading is typically defined at the resource level. Dependent upon the requirements of both the organization and the project contract, cost loading is achieved as either a lump sum nonlabor resource or a price per unit labor/material resource.

Three areas or levels within P6 contain the settings which govern resource allocation, costing, and updating options. It is important that the user be aware of these settings prior to defining the resource and allocating resource units/costs. Once a resource is assigned to an activity, any changes to the resource settings will apply to new assignments only.

The first of the three areas which contain settings governing resource allocation is the resource itself. These default global settings, specific to each resource, affect the resource regardless of the project and the activity to which it is assigned. Secondly, the project also contains default settings which affect all resources within the specific project. And finally the activity specific settings affect the individual resources assigned to that activity.

To control these settings within each of the three levels, a basic understanding of P6™ and each option with its function is required. The first setting is calculate units from costs. By definition, costs are recalculated whenever resource unit quantities are modified. By default, this setting, found at the resource level (resource details, details tab) and at the activity location (activity details, resources tab, columns), applies to any new resource assignment. This option is not used for resources requiring lump sum loading where units/time are not considered.

A second setting that should be understood is auto compute actuals. By definition, resource actual and remaining units, as well as start and finish dates are updated automatically based on the activity's planned dates, budgeted units, and percent complete. This option can only be modified at the resource level (resource details, details tab) and therefore applies to the resource globally across its activity assignments. The nomenclature for this

setting should not be confused with what appears to be the same option at the activity level. Although the naming convention is identical, another setting for updating activity information (found in the columns in the activity window) is used in conjunction with the apply actuals option within Primavera P6.

A third setting that should be understood is link actual and actual this period units and cost. By definition, resource costs/units are updated when either actual or actual this period are updated. This option must be selected when using financial periods and store period performance. Found at only the project level (project details, calculations tab) this option applies to all resource assignments within the project.

Other considerations relating to resource assignments include activity types. As discussed previously, milestones cannot have assigned resources and therefore cannot be cost loaded.

Duration Types

Each activity's duration type defines how resource modifications adjust the activity's duration, its budgeted resource quantities, and/or its resource production by period. When an activity's duration type is fixed duration and units, P6 will recalculate the units per time for each of the activity's resource assignments when either the activity's duration or its budgeted units are updated. When an activity's duration type is fixed duration and units/time, P6 will recalculate the budgeted units when either the activity's duration or production rate (units/time) is updated. When an activity's duration type is units, P6 will recalculate either the activity's duration or production rate (units/time) when the budgeted units are updated.

As mentioned previously, costs are allocated to each activity as either a lump sum resource cost or based on price/unit resources. When cost loading the P6 schedule, financial periods are then used to store actual period performance as opposed to spreading actual work performance across the timeline.

These financial periods are set at the globally across the enterprise by the
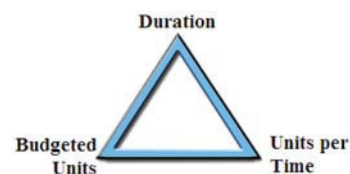
Figure 10 —Three Factors Determining Duration Type

system administrator (under the admin menu, financial periods option). They are set at periodic intervals for cost/production tracking.

Cost Accounts

Cost accounts can be established within P6 (enterprise menu, cost accounts) to identify organizational accounting codes to specific resource/cost times within the schedule and across the enterprise. They are typically created by the cost engineer or controls engineer. This hierarchical structure is associated to each activity at the resource level (activity detail, resources tab, cost accounts column).

Resource Curves and Future Bucket Planning

Resource curves (under the enterprise menu, resource curves option) define how resource units/costs are distributed across an activity's duration. They are associated to each activity's resource (activity details, resources tab, curves column).

Primavera P6 also offers future bucket planning for resource units/cost forecasting, where distributions are manually entered in the resource usage spreadsheet for future resource projections. These manually spread distributions are displayed in the activity details, resource curves column as manual.

Percent Complete Types

When determining the process of updating resources and the contractual and/or internal requirements for resource/payment obligations, the user must consider the means of updating each resource at the activity level. When payment is based on work performance, the user must consider how each activity's update will affect the resource cost/quantities for that activity. Work

performance in P6 is updated automatically (unless specified) in Primavera using percent complete. There are three percent complete types at the activity level: duration percent complete, physical percent complete, and units percent complete.

Duration percent complete is directly associated to the activity's original duration and remaining duration. This default setting within P6 is used to update resource costs/units. However, when payment is based on work performance and stored materials, duration percent complete might not reflect actual costs to date.

Percent Complete = (Original Duration – Remaining Duration) / Original Duration * 100.

(equation 1)

Physical percent complete is a manually entered (or resource entered) percentage of work. This percentage type has no correlation with the activity's duration or units complete. At this time this option cannot be used to update resource costs/units.

Units percent complete is directly associated with the activity's labor and nonlabor resources. This option can be used to update resource costs/units.

Percent Complete = Actual Units / At Completion Units * 100.

(equation 2)

In most instances where work performance in the schedule is directly tied to payment, the use of either duration percent or units percent (when associated with a lump sum activity) cannot be used. The user should be aware that actuals will need to be manually entered at the resource level within each activity.

Optimize Schedule (Simulation and Optimization)

This process step is wherein the scheduler, based on his or her cost engineering judgment and team input and feedback, iteratively modifies the plan and schedule inputs until the most satisfactory schedule is obtained [1].

The scheduler using P6 must have an understanding of the software

Figure 11—Schedule Options in P6

schedule options and the impact each has on the calculation results. Optimization of the schedule requires consistent auditing of resource definition and activity detail during the course of schedule development. Assessment and analysis of critical events within the schedule define the schedule's ability to plan and manage the life of the project. Understanding the rules of schedule calculation which determine these critical activities is fundamental in the early stages of schedule development as well as maintenance of the mature schedule.

P6 provides multiple sources for schedule optimization during the schedule development phase of the project. The schedule log (an option found when updating and/or calculating the schedule) analyzes schedule data based on these predefined CPM rules. As data is entered and the schedule is calculated from the defined data date to project completion and back, a log of schedule analytics can be produced for evaluation of schedule development and overall critical path. The log displays the calculation settings currently in place for the particular project(s) (set within the tools menu, schedule, options). These options define whether the calculation considers purely duration and sequence of work or whether resource leveling (based on resource allocations and limitations) is used for calculation and at

what point. They also allow assignment costs of resources to be automatically recalculated each time the project is scheduled updating activity costs to reflect any new price/unit values modifications.

In P6 the user has the ability, if granted access, to sequence activities in one project to activities in other projects based on program requirements. The scheduling options allow the user to ignore these 'inter project' ties to review project specific critical events or to consider these ties, analyzing an overall critical path of the program (multiple projects) where the latest finish date of the latest open project is used as the starting point for the backward pass.

Each schedule will have a 'start' activity (an activity with no predecessor) and a 'finish' activity (an activity with no successor). Other than these two open-ended activities, all activities within the schedule must have predecessor and successor relationships with few exceptions. P6 scheduling rules determine how these exceptions are handled in relationship to its criticality.

As activity precedence relationships are added P6, through its scheduling options, can set the schedule to calculate latest data automatically as changes are made. When developing precedence between activities, the use of lag, and the number of time periods the lag represents is determined, by
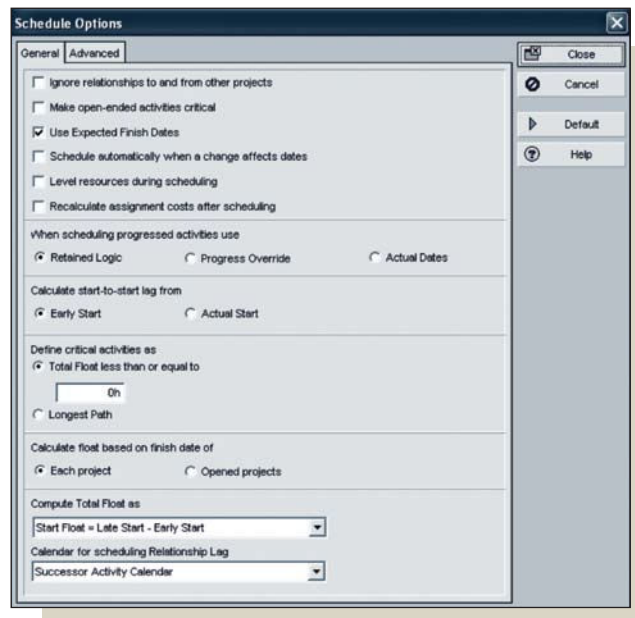
default, based on the predecessor's calendar or work period. The user, through the scheduling options, can choose to use the successor's calendar for lag measurement as well as the project's default calendar (project details, defaults tab), or a 24 hour calendar.

Other calculation rules are defined by determining how P6 displays open-ended activities in relationship to the critical path and whether total float (based on a user defined number of hours) will be used for measuring the critical path or whether longest path will be used.

Under the advanced options tab within the schedule options, the user can select whether P6 will calculate multiple float paths based on either total float or free float. When using total float the application determines, based on the most critical precedence relationships, each critical path. When using free float, the application uses longest path to identify the latest calculated finish date tracing driving relationships backward through the schedule. Based on the specified number of paths to calculate, P6 will store each path within the Float Path field (column).

In P6 there are three options available when scheduling progressed activities: retained logic, progress override, and actual dates. Retained logic maintains the as-built sequence of activities regardless of actual work. The predecessor's inherited driving relationships drive the successor. In progress override the activity as-built sequence can be overridden based on actual work. The direct predecessor activity's dates (remaining early) drive those successor activities which have not started. When the predecessor is assigned an actual finish, the activity's dates (remaining early) are driven by the data date. When the activity has an actual start, its remaining duration drives the remaining early finish. The option actual dates allows for future actualized activity dates to calculate sequence. If the actual dates option is selected, then the predecessor's late finish is set to the time unit before the actual start of the out-of-sequence predecessor. This assignment has the potential of creating negative float [5].

P6 also contains two options on how to calculate start-to-start lag which determines how a predecessor's resume date (when suspended) impacts its successors start date when using a start-to-start tie with lag. The options are early start and actual start. Early start – drives the successor's start date from the predecessor's remaining early start. Actual start – drives the successor's start date from the predecessor's actual start.

Warnings on the schedule log report include open-ended activities, out-of-sequence activities, activities with actual dates on or after the data date, and milestones with invalid relationships. Primavera P6 will allow for milestones to have finish-to-start relationships, although not always recommended because of start and finish times. A start milestone should only have a start-to-start relationship with its predecessor and a start-to-start and/or start-to-finish with its successor. A finish milestone should only have a finish-to-finish relationship with its successor and a finish-to-finish or start-to-finish with its predecessor.

Unsatisfied constraints and relationships are created when a relationship overrides the assigned activity constraint (i.e., start on or finish on) or when a constraint overrides the assigned relationship.

Claim Digger (issued as part of the Primavera P6 software: tools, Claim Digger) allows the user to compare two schedules and evaluate the differences between them, including but not limited to: changes in durations, dates, relationships, added / deleted activities, added / deleted WBS, added / deleted assignments.

P6 also contains many standard tabular reports which can be helpful in analyzing a schedule, such as logic reports.

Many contract documents are now requiring the use of the latest version of Primavera software (P6) because of its enterprise capabilities and its use of latest technologies including the capabilities to interact other software applications. The scheduler should be able to apply the implementation and execution "lessons learned" outlined in this article to develop schedules quickly and efficiently using P6. ◆

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