Scheduling Best Practices

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In a continuing series of articles on specific aspects of critical path method (CPM) scheduling, Warner examines various facets of the process of preparing, analyzing and utilizing schedules in project management. Warner has worked in all areas of the construction process with owners, contractors and suppliers on all types of projects from residential to power plants. Through this experience, we have accumulated a reservoir of knowledge. This series of articles is designed to pass along observations and insights, highlighting best practices.

The tenth article in the Scheduling Best Practices series is "Relationship Types, Lags and Leads, and How to Use Them". Marco Ferrante, Managing Consultant in Warner's Scheduling Group, is a recognized expert in scheduling and scheduling best practices. Marco Ferrante has over 12 years of experience in the Construction and Information Technology field serving Federal and State Government and Commercial industry. He has applied Project Management skills as a Mission Analyst to deliver an integrated Master Schedule for the largest Intelligent Transportation project in the world. *Mark Anderson, Executive Vice President and Chief Operating Officer*

Relationship Types, Lags and Leads, and How to Use Them
by Marco Ferrante, P.S.P, Managing Consultant

Construction scheduling is intended to give us an understanding of when activities are to start and finish so crews, materials, and equipment can be effectively managed to complete a project on time and on budget. Schedule logic indicates which activity or activities must be completed before another or others can start. Originally, Critical Path Method (CPM) schedules (Activity on Node (AON) and Activity on Arrow (AOA)) had only Finish-to-Start (FS) relationships.

Construction scheduling software manufacturers responded to the need for flexibility in activity relationships in a schedule by creating features permitting construction schedulers to create much more than simple Finish-to-Start networks. Along with the typical Finish-to-Start relationship, other types of relationships (Start-to-Start, Finish-to-Finish, and Start-to-Finish) are available to define the logic between work activities. In addition, these relationships may be customized to further define the relationship between the activities, known as lag or lead time.

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Before we begin the discussion of Best Practices, let's define some of the basic types of activity relationships we will discuss:

- **Finish-to-Start (FS):**
  A relationship between activities in which the start of a successor activity depends on the finish of its predecessor activity.

- **Start-to-Start (SS)**
  A relationship between activities in which the start of a successor activity depends on the start of its predecessor.

- **Finish-to-Finish (FF):**
  A relationship between activities in which the finish of a successor activity depends on the finish of its predecessor.

- **Start-to-Finish (SF):**
  A relationship between activities in which a successor activity cannot complete until its predecessor starts.

- **Lags (or Leads):**
  An offset or delay from an activity to its successor. A Lag can be positive or negative (from Primavera P3).

- **Degree:**
  A positive or negative increment of the unit of time used in the schedule (also known as Lag).

- **Gantt:**
  A bar of Gannt chart is a line graph that depicts activities as bars with length proportional to the duration of each activity. Normally, relationships between activities are not displayed (from Primavera P3).

The simplest of these relationships, is one in which one activity must be completed before the next one can begin. This is known as a Finish-to-Start (FS) relationship.

In a simple, theoretical world, only Finish-to-Start relationships would be necessary. For example, after footings are complete, structural steel can start and once the structural steel is complete, then the building envelope can proceed. Finally, when the envelope is complete, interior finishes can begin. However, this is not the manner in which projects are typically constructed. More typically, the schedule is

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not developed to a level of detail that permits only FS relationships, nor is it typically feasible to do this. Scheduling mechanical, electrical, and plumbing trades (MEP) on an apartment building is typically done with a SS and lag to the next trade, with the activity defined to a floor or a reasonable number of units. If these trades were scheduled FS, then the detail would have to be far greater in order to allow the trades to perform their work within the contractual time, while not performing work in the same place as other trades. The use of only FS relationships has the potential to increase the number of activities to unmanageable levels.
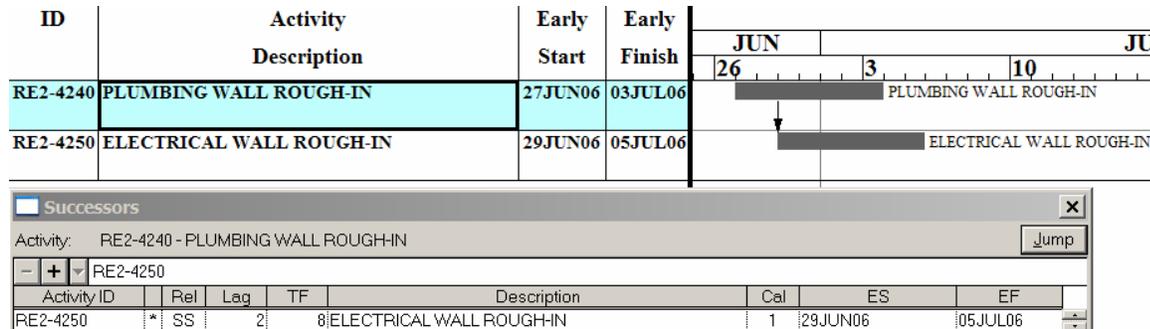
Lags and Leads may be used to customize the schedule logic. A Lag/Lead tie permits a scheduler to link activity relationships in a way that approximates the degree to which one activity must be finished before another can start or the degree to which an activity should precede another. Thus, if the start of one activity lags behind the start of another, or if one must lead the other by a period of time, these relationships can be incorporated into the schedule. This means that the plumbing crew can have a SS relationship to the electrical crew, with a short lag to allow the electrical crew to follow the plumbing crew shortly after they start, instead of waiting for their completion.

The use of Lag/Lead ties is a common software schedule feature used with various types of ties, however, caution must be used to avoid mistakes. One such mistake is the creation of non-overlapping Lags. This happens when a rough schedule is developed or a template is used where Lags exist.

For example, let's use activities with 10 working days as their duration, originally set with a SS relationship and a 5 day Lag. The template came from a large apartment building, and is now used for a small garden apartment complex. The duration is now 4 days for each activity. If the Lag duration was not checked and corrected, the effect of a SS with 5 day lag on a 4 day activity is a FS relationship with a 1 day lag.

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Discussion:

ID	Activity Description	Early Start	Early Finish	
RE2-4240	PLUMBING WALL ROUGH-IN	27JUN06	03JUL06	PLUMBING WALL ROUGH-IN
RE2-4250	ELECTRICAL WALL ROUGH-IN	29JUN06	05JUL06	ELECTRICAL WALL ROUGH-IN

Successors

Activity: RE2-4240 - PLUMBING WALL ROUGH-IN

RE2-4250

Activity ID	Rel	Lag	TF	Description	Cal	ES	EF
RE2-4250	* SS	2	8	ELECTRICAL WALL ROUGH-IN	1	29JUN06	05JUL06

(Graphic from Primavera P3)

Seldom are activities actually planned to start immediately after the start of another activity. Usually one activity should progress to a point where the successor will not be at risk of "having to wait." In the diagram above, Electrical Wall Rough-in could start at the same time that Plumbing Wall Rough-in starts; however, a lag was added so that the plumbing crew will perform enough work to get out of the way of the electrical crew.

Lags are most frequently used with Start-to-Start ties when a predecessor activity must get ahead in their work before the successor can start.   Usually the predecessor will control the entire progress of the successor but a lag can be used when one activity starts several time units after the start of its predecessor. This situation arises where one trade must have some initial time to begin its work before the next trade can begin. An example of appropriately used Lag is when a long trench must begin to be dug before piping can be placed in the trench, but the installation of the piping does not necessarily have to wait for the entire length of trench to be dug before the pipe can start to be placed inside the trench.

Although a Lag may be used with a Finish-to-Start tie this is not the best practice when the Lag is used in lieu of a defined activity. This is because without a defined activity, gaps in time in printouts may appear confusing to people unfamiliar with the hidden structure of the schedule. An example of this is concrete cure time. It is good to show cure time as an activity, so that not only will the time be represented

as an activity rather than a blank space but, in addition, the description of the activity will act as a reminder that little or no other work can proceed during that time.

Relationship ties are not as clear when using Lags because they are generally not shown on a Gantt report print out. Again, this may cause confusion when trying to convey a schedule to people unfamiliar with the hidden structure of the schedule.

In conclusion, the use of various relationship types, and the customization of those relationships with Lags allows a high degree of customization to scheduling. However, a "Best Practices" approach to the use of Lags is to carefully review their use when preparing a CPM schedule in order to avoid their misuse.

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