Scheduling From a Designer's Perspective

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In the past, project schedules were often simply hung on the jobsite trailer and seldom used for the planning and control of field activities. Now, most projects require a detailed schedule that provides the baseline for managerial control of the project.

On most projects, the designer must review the submitted schedule to determine if the planned approach to the construction will meet the design intent and contractual requirements. Thus, the designer must be able to identify any potential problems that might develop during its implementation.

Concrete projects offer a unique challenge. A placement can involve mix design approval, formwork preparation, formwork and falsework installation, installation of reinforcement and imbedded items, placement, testing, form removal, reshoring, and curing before the concrete can be put to use. Without a realistic schedule, the project can be delayed and critical items overlooked.

A schedule is the timetable that acts as a roadmap for the successful implementation of a project. Typically, a project is divided into discrete activities. The scheduler will determine the amount of time needed to complete each activity and arrange these activities in sequential or overlapping order. It shows the project duration (defined by the critical path), non-critical activities (activities with float or time leeway), and the delivery dates of key equipment and material.

By updating the schedule on a periodic basis (weekly, biweekly, monthly), the status of the project can be ascertained. This would permit corrective actions to be taken to mitigate potential delays. The schedule is also used as the key document in the resolution of delay claims and for the collection of historical data on the project.

Developing a schedule

A schedule is a model of how and when the various tasks of a project are going to be accomplished. The following steps are taken in developing a schedule:

1. Break the project down into discrete activities (e.g., excavation, concrete foundations).
2. Quantify each activity (e.g., excavation: 3000 yd^3 of soil, concrete foundations: 200 yd^3 of concrete).
3. Apply production rates to each activity to establish durations (e.g., at a placement rate of 200 yd^3/day, the duration of concrete foundations will be 1 work day).
4. Establish a work sequence (or predecessor/successor relationships) between activities. Typically, this consists of asking the question: Which activities must be started or completed before a particular activity can start?
5. Develop a rough diagram of the schedule using the preceding information. From this point, the schedule calculations can either be done manually or by using a computer and a scheduling software program. The data required for generating a computerized schedule are: a) activity number; b) a short and abbreviated description of the activity; c) activity duration in work days; and d) the successor or predecessor relationship between activities.
6. Perform schedule calculations and establish the critical path — the minimum time to complete a project.
7. Examine the project duration, critical path, activity durations, relationships, and floats for accuracy, reasonableness, and constructibility.
8. Make the necessary corrections and refinements to the schedule.
9. Produce the schedule graphics and reports.

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Evaluating the schedule

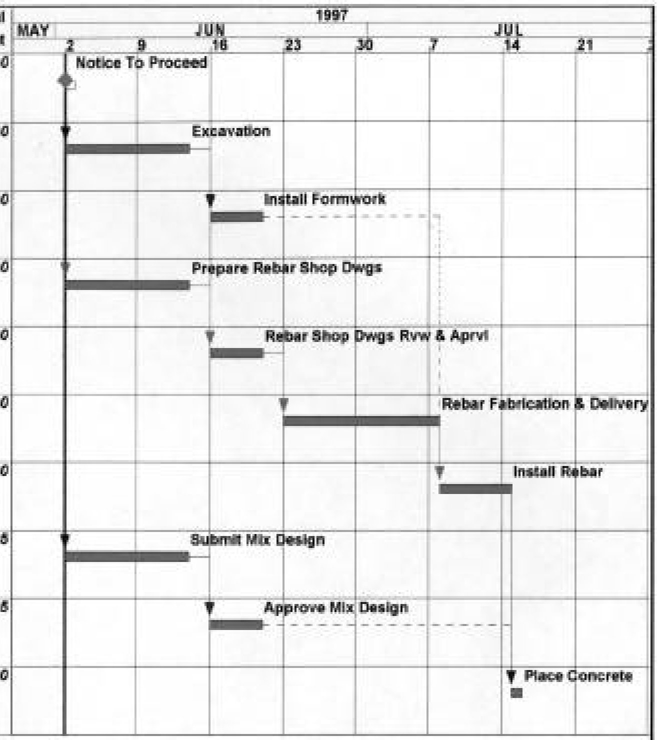
The process of developing a schedule is best understood by examining the schedule for a concrete foundation project for the XYZ Construction Co. (Fig. 1). In this example, the scheduler first determines that the project will have 10 activities. The decision was arbitrary; the scheduler could have had more or fewer activities.

The next step is to determine the duration of each activity. An activity can have a range of durations depending on the production rates applied. The scheduler then has to organize the activities into sequential steps: the shop drawings for the reinforcement must be completed before the review process, review must be done before fabrication, reinforcement fabrication must be done before installation, etc. The logical sequencing of activities into a network is an essential aspect of scheduling.

Various graphical methods such as Arrow Diagram Method, Precedence Diagram Method (PDM), and Program Evaluation and Review Technique are used to represent the schedule logic diagrams. Currently, PDM is the most widely used scheduling method. More information on developing a schedule network using Precedence Diagram Method is available.[1, 2]

Fig. 1 — Construction schedule, concrete foundation project.

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Late Start	Late Finish	Total Float
10	Notice To Proceed	0	02JUN97		02JUN97		0
20	Excavation	10	02JUN97	13JUN97	16JUN97	27JUN97	10
25	Install Formwork	5	16JUN97	20JUN97	30JUN97	07JUL97	10
30	Prepare Rebar Shop Dwgs	10	02JUN97	13JUN97	02JUN97	13JUN97	0
40	Rebar Shop Dwgs Rvw & Aprvl	5	16JUN97	20JUN97	16JUN97	20JUN97	0
60	Rebar Fabrication & Delivery	10	23JUN97	07JUL97	23JUN97	07JUL97	0
70	Install Rebar	5	08JUL97	14JUL97	08JUL97	14JUL97	0
75	Submit Mix Design	10	02JUN97	13JUN97	23JUN97	07JUL97	15
80	Approve Mix Design	5	16JUN97	20JUN97	08JUL97	14JUL97	15
100	Place Concrete	1	15JUL97	15JUL97	15JUL97	15JUL97	0



Project Start	02JUN97	Early Bar
Project Finish	15JUL97	Progress Bar
Data Date	02JUN97	Critical Activity
Plot Date	13AUG97	

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What does the schedule tell us?

The bar chart schedule shown in Fig. 1 is generated in the PDM format using Primavera P3 scheduling software. The data shown in the bar chart are typical of most scheduling graphics.

Project calendar

The calendar (or timescale) is one of the key features of the bar chart schedule and helps provide a quick overview of the start and completion dates of individual activities as well as the overall project duration. The calendar normally used is the standard work week calendar (Monday through Friday, 8-hour day, 5-day work week). Most scheduling programs also allow 6-day and 7-day work week calendars and any number of non-work days. In addition, the standard calendar can incorporate non-work days due to the legal holidays recognized in the United States or other countries.

Typically, a calendar month will have 20 to 22 working days. As illustrated in Fig. 2, the month of June has 21 working days and the month of July which has a holiday (Independence Day), has 22 working days. The start of the project is based on the start date or the date of notice to proceed. In this example, the notice to proceed is 2 June 1997.

Column 1 — Activity Identification (ID)

The activity identification provides each activity with a unique number. For example, excavation is assigned an Activity ID of 20. Scheduling software programs allow up to 10 digits for an Activity ID, thereby making it possible for a schedule to contain several thousand activities. Activity IDs must not be duplicated within a schedule.

Column 2 — Description

The description provides an abbreviated definition of each activity. A description is generally limited to 48 characters or less.

Column 3 — Original Duration

The original duration shows the activity durations in working days. Although it is customary to express the durations in working days, software programs allow multiple calendars so that work units such as hours and calendar days can also be used simultaneously. Thus a work day based schedule can also have some activity durations (e.g., concrete curing: 7 days) expressed in calendar days.

Columns 4 to 8 show dates and values calculated by the software program using the start date of the project and data input shown in Columns 1, 2, 3, and activity relationships.

Column 4 — Early Start (ES)

The early start indicates the earliest possible date a particular activity can begin. For example, Activity #20 (Excavation) can start as early as 2 June 97.

Column 5 — Early Finish (EF)

The early finish shows the earliest possible completion date of an activity. It is derived by adding an activity duration (D) to its early start date. For example, the EF of Activity #20 (Excavation) can be calculated as:

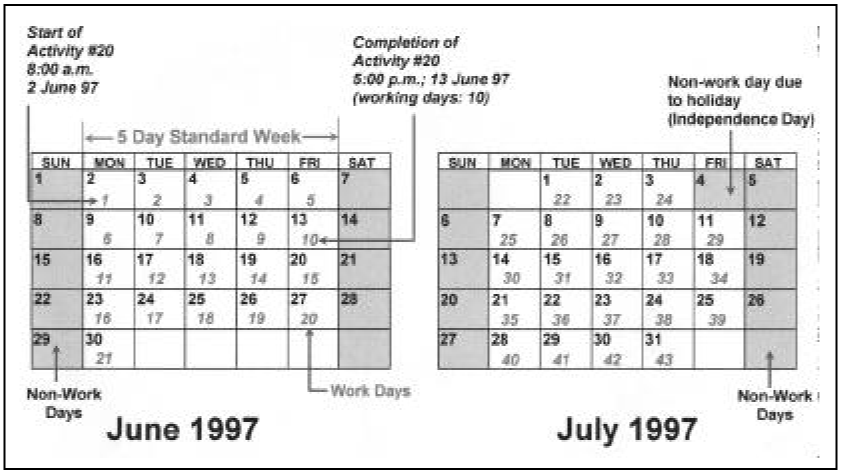


Fig. 2 — Calendar days/work days conversion.

EF of Activity #20 (Excavation) = ES + D
ES of Activity #20 (Excavation) = 2 June 97
D of Activity #20 (Excavation) = 10 work days
EF of Activity #20 (Excavation) = 2 June 97 + 10
= 13 June 97

In counting the calendar dates of an activity, an activity always starts at 8:00 a.m. on the start date and finishes at 5:00 p.m. on the finish date. By examining Fig. 2, it can be seen that Activity #20 (Excavation) starts on 2 June 97 (work day 1) and finishes on 13 June 97 (work day 10). It is to be noted that 7 June 97 (Saturday) and 8 June 97 (Sunday) are non-work periods and hence are not included in the work day count.

Column 6 — Late Start (LS)

The late start shows the latest date an activity can begin without delaying the project completion date. For example, although Activity #75 (Submit Mix Design) has an ES date of 2 June 97, the start of the activity can be delayed as late as 23 June 97 without delaying the project completion date of 15 July 97.

Column 7 — Late Finish (LF)

The late finish shows the latest possible completion date of an activity without delaying the project completion date. It is derived by adding an activity duratio to its late start date. For example in Fig. 1, the LF of Activity #75 (Submit Mix Design) can be calculated as shown below:

LF of Activity #75 (Submit Mix Design) = LS + D
LS of Activity #75 (Submit Mix Design) = 23 June 97
D of Activity #75 (Submit Mix Design) = 10 work days
LF of Activity #75 (Submit Mix Design) = 23 June 97 + 10
= 7 July 97

It should be noted that 28 June 97 (Saturday), 29 June 97 (Sunday), 4 July 97 (Independence Day), 5 July 97 (Saturday) and 6 July 97 (Sunday) are not included in the work day count.

Column 8 — Total Float (TF)

The total float shows the number of working days that an activity can be delayed without impacting the project scheduled completion date. It is derived by computing the difference between an activity early and late start dates or early and late finish dates.

For example, the TF of Activity #20 (Excavation) can be determined as shown:

TF = LS - ES = 16 June 97 - 2 June 97 = 10 work days or,
TF = LF - EF = 27 June 97 - 13 June 97 = 10 work days

Similarly, the TF of Activity #75 (Submit Mix Design) can be determined from:

LS - ES = 23 June 97 - 2 June 97 =
15 work days, or
LF - EF = 7 July 97 - 13 June 97 =
15 work days.

Float is a very fundamental concept of scheduling and helps in understanding the criticalness of a particular activity in relationship with the other activities in the schedule. Activities with zero float are called critical activities and the critical path defines the overall duration of the project. In the example project, all the activities on the critical path (Activities #10, #30, #40, #60, #70, and #100; represented by red rectangular bars in the software program), show zero total float. Delays on any one of these activities will cause the schedule to extend and result in project delays. On the other hand, non-critical activities (represented by green rectangular bars in the program) have float and can be delayed within their float limits without causing any impact to the project completion date.

For example, a designer responsible for Activity #40 (Rebar Shop Dwgs Rvw and Aprvl) should realize that he/she will be responsible for delays caused in the review and approval of shop drawings if the review/approval process exceeds the 5-day turnaround time. However, Activity #80 (Approve Mix Design) with a total float of 15 working days can absorb delays in approval time up to 15 days.

It should be noted that the total float is shared by several activities along their float path. For example, Activities #75 (Submit Mix Design) and #80 (Approve Mix Design) share a total float of 15 days. If Activity #75 is delayed by 10 working days, Activity #80 will have only 5 days float available. Thus, the understanding and control of float plays an important part in the execution of a construction project.

Bar chart graphics

The bar chart (refer to Fig. 1) is the most widely used scheduling tool and is relatively easy to understand. An activity is represented by a rectangular bar and the length of the bar is (timescaled) proportional to its duration.

The color coding of a bar chart has considerable impact in terms of communication and most software programs permit a variety of colors and graphic symbols. The accepted convention is to show the critical activities in red and the non-critical activities in gray or green. Milestone events do not consume any resources, have zero duration, and are represented by diamonds or flags. The legend in the title block should explain the color and graphic conventions used.

How is a schedule reviewed by the designer?

The designer is often required to review and approve the schedule developed by a contractor after the notice of award. Once approved, it becomes the baseline schedule of the project.

The baseline schedule is an important document in that it represents the contractor's strategy and timetable for the implementation of the project within the specified contract duration, and is considered a legal document for resolution of delay claims. The following is a suggested checklist for use in the review of contractor-submitted schedules:

General

1. Are the project start and completion dates, and the project duration in conformance with the contract documents?

2. Does the project calendar used conform with the specifications in terms of work days/week (5-day, 6-day, 7-day week) and non-work days? Do the non-work days include the weekends, the six standard holidays, and any regional holidays?

3. Has the contractor submitted all the schedule documents (e.g., bar charts, network schedules, schedule reports, and back-up data diskettes) as specified in the contract and by the due date? Most contracts specify that the contractor submit the baseline schedule within a certain time period; generally 21 to 30 calendar days from the notice of award.

Scheduling mechanics review

1. Have all the activities been tied into a network using the specified scheduling format? Ideally, in a properly developed network only the starting activity has no predecessor and the ending activity has no successor. A network with many open ends or dangling activities will result in an erroneous critical path and unrealistically high floats.

2. Does the schedule show any progress? The baseline schedules are prepared at the start of the project and should *not* show any progress.

Schedule analysis and review

1. Mobilization — Has the contractor allowed adequate mobilization time? On most projects, the schedule should allow three to four weeks mobilization time (field office trailer setup, utilities hookup, equipment mobilization, etc.)

2. Construction permits — Has the contractor allowed time for demolition and/or construction permits from local authorities? Are there any permit requirements with regard to traffic rerouting and/or with regard to use of highways and roads by construction equipment/haulers?

3. Activity breakdown — Does the activity breakdown shown in the schedule reflect the intent and scope of work involved in the project? While the number of activities to be included in a schedule is somewhat arbitrary, too few activities will make the schedule less meaningful and too many activities will make it very unwieldy and cumbersome. For example in our illustration, the scheduler could have included additional activities such as mobilization, construction permits, procurement of anchor bolts, and curing of concrete.

4. Activity durations — Are the activity durations reasonable and consistent with their scope of work? Do durations shown for the review and approval cycles conform with the turnaround times provided in the specifications? In the example, both Activity #40 (Rebar Shop Dwgs Rvw & Aprvl) and Activity #80 (Approve Mix Design) show a duration of 5 work days each. The designer, who is responsible for these tasks, should question the adequacy of this short duration, since a considerable portion of this time is likely to be consumed by the transmittal of drawings alone. The designer might also want to question the absence of an activity entitled “Curing” following Activity #100 (Place Concrete).

5. Schedule logic — Are the relationships between activities reasonable? In other words, does the work flow conform to accepted norms of construction practice? For example, excessive number of concurrent activities while resulting in a shorter project duration, can create “stacking” of trades and lead to problems associated with allocation of resources, congested work places, construction safety, and jurisdictional issues. It should also be obvious that activities which cannot normally be executed in severe cold weather such as concrete placement or earthwork compaction should not be scheduled during that period. If these activities must be scheduled during this period, additional time should be allocated to account for the probability of bad weather.

6. Critical path — Since the critical path determines the project duration, it is vital that the critical activities, durations, and the associated logic are valid and reasonable. The designer should also examine specifically the activities for which he/she is responsible and ensure that adequate time is allowed for accomplishing them. In the example, this would be the critical path Activity #40 (Rebar Shop Dwg Rvw & Aprvl) with a duration of 5 work days and zero total float. It is obvious any delay with this activity will extend the project completion date and make the designer liable for associated costs.

7. Float analysis — It is important to identify activities with excessive total float. These are a result of inaccurate logic and/or activities with open ends (not connected to a successor activity). It is necessary to correct these errors so that activity floats are adjusted to more realistic values.

Conclusion

A well-planned and well-structured construction schedule is essential to the successful control and completion of a project. The schedule plays a vital part not only during the implementation phase of a project but also in the resolution of any delay claims that may arise.

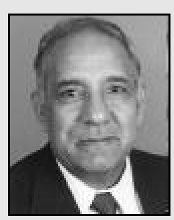
Since the designer must typically review the schedule, it is necessary to understand the concepts and logic that are incorporated into the schedule. Therefore, the designer must learn to understand and appreciate the uses of a schedule so that potential problems can be avoided.

References

1. The Associated General Contractors of America, *Construction Planning and Scheduling*, Publication No. 1107.1, Washington, D.C., 1994.

2. *Primavera Project Planner for Windows Version 2.0*, Primavera Systems, Inc., Bala Cynwyd, Pa., 1996.

Selected for reader interest by the editors.



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