Components of a Project Schedule

The Preparation of the Estimate involves planning and consideration of the construction sequence including:

Means and Methods
- Process Methodology & Equipment
- Crewing
- Duration, Sequence and Timing

The Budget
- Enterprise & Work Breakdown Structure
- Productivity and Rate of Production
- Direct Cost by CSI Division
- Indirect Cost / Field Office, Plant and Overhead
- Profit
The process of “Buying Out” the Project Estimate and establishing the Project Budget involves adjustments to the original concepts of planning and execution that are embodied within the Project Estimate.

Details contained in the estimate and subsequent adjustments should be memorialized and clearly communicated to those responsible for scheduling and executing the project.
Formulating the Schedule

Thus, the starting point for the Project Baseline Schedule originates from the project budget, contract, plans and specifications.

The contract documents not only define work scope, they prescribe the responsibilities and hierarchy of the primary Stakeholders, Suppliers, Contractors, Subs and Lower Tier Subcontractors and their respective working relationships.
Components of a Project Schedule

The components of the Baseline Project Schedule include:

- The Work Breakdown Structure
- Work Activity Production Rate and Duration
- “Hard” Logic Relationships driven by physical & resource linkage
- Definition & Identification of Area, Level and Location within Activity IDs & Coding
- Selection of Preferential Sequence “Soft Logic” by Area, Level & Location
Components of a Project Schedule

- Definition of the “Weather” Calendar
- Identification of Key Milestones
- Establishing Design, Procurement and Delivery Activities Leading into Work Activity Startup
- Tabulating and Loading the Schedule with Quantity/Unit, Cost, Crewing/Manpower and Equipment Resources
- The Process and Timing for Updating and Adjusting the Schedule
Goals of Construction Scheduling

To create a “model” of the “Project” embodying scope, defining duration and establishing the optimal sequence and timing of the works to completion in order to:

- Progress Design and Work Activity on Time and Within Budget
- Identify and Optimally Manage Risk
- Minimize Time and Cost / Maximize Efficiency
- Minimize the Impact and Consequence of Change
- Maximize Profit
To accomplish these goals, the Stakeholders must first decide on the primary type of schedule that best fits the characteristics and needs of the project.

It should be noted that more than one scheduling methodology may be utilized to plan and execute a given project.
It is not unusual that the various stakeholders involved in a project will own and utilize scheduling software other than that specified and/or owned by those responsible for generating the schedule. Given the cost of commercial software and familiarity with usage, there is often a tendency by many schedulers to “make do” with the software they possess.
While data can typically be transferred between scheduling software packages, the “exact same” project schedule may produce different results when scheduled in different software. Variances generated in the forward and backward pass using different software is generally due to limitations in the software and differences in algorithms between the respective programs.
While it is possible to identify and “deal with” these variances, there is an element of risk involved which should be recognized and thoroughly considered before the use of software other than that specified and/or directed by the CM’s/GC’s contract is directly or tacitly accepted.
Common Types of Prospective Schedules

• Bar Chart Schedule (Gantt Charts)
• Critical Path Method (CPM) Schedules
• Line of Balance / Linear Schedules
<table>
<thead>
<tr>
<th>WBS</th>
<th>Task Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Define specifications</td>
</tr>
<tr>
<td>1.1</td>
<td>Identify customers</td>
</tr>
<tr>
<td>1.2</td>
<td>Interview 10 customers</td>
</tr>
<tr>
<td>1.3</td>
<td>Interpret requirements</td>
</tr>
<tr>
<td>1.4</td>
<td>Benchmark products</td>
</tr>
<tr>
<td>1.5</td>
<td>Define target PDS</td>
</tr>
<tr>
<td>1.6</td>
<td>Target PDS Released</td>
</tr>
<tr>
<td>2</td>
<td>Generate concepts</td>
</tr>
<tr>
<td>2.1</td>
<td>Review comp products</td>
</tr>
<tr>
<td>2.2</td>
<td>Search patents</td>
</tr>
<tr>
<td>2.3</td>
<td>Brainstorm concepts</td>
</tr>
<tr>
<td>3</td>
<td>Select top 2 concepts</td>
</tr>
<tr>
<td>4</td>
<td>MQ Presented</td>
</tr>
<tr>
<td>5</td>
<td>Profile motor power</td>
</tr>
<tr>
<td>5.1</td>
<td>Design test stand</td>
</tr>
<tr>
<td>5.2</td>
<td>Build test stand</td>
</tr>
</tbody>
</table>

![Bar Chart Schedule (Gantt Chart)](image-url)
From Wikipedia; A **Gantt chart** is a type of **bar chart**, developed by **Henry Gantt** in the 1910s, that illustrates a **project schedule**. Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a **project**. Terminal elements and summary elements comprise the **work breakdown structure** of the project. Some Gantt charts also show the **dependency** (i.e. precedence network) relationships between activities. Gantt charts can be used to show current schedule status using percent-complete shadings and a vertical "TODAY" line as shown here.

Although now regarded as a common charting technique, Gantt charts were considered revolutionary when first introduced. In recognition of **Henry Gantt**’s contributions, the **Henry Laurence Gantt Medal** is awarded for distinguished achievement in management and in community service. This chart is also used in **information technology** to represent data that has been collected.
Bar Chart Schedule (Gantt Chart)

Strengths

• Familiarity, The Most Common Schedule
• Uses “Common Sense” Logic
• Quick Determination of Gross Progress
• Simplicity
Weaknesses include:

- Limitations to level of scope & definition
- Severe limitation to logic which can be shown
- Difficult to determine project status
- Does not address relative sensitivity/flexibility
- Doesn’t contain sufficient detail for planning and executing complex work activity
- The Critical Path is not defined
Critical Path Method Schedule (CPM)
The essential technique for using CPM is to construct a model of the project that includes the following:

A list of all activities required to complete the project (typically categorized within a work breakdown structure), The time (duration) that each activity will take to completion, and the dependencies between the activities

Using these values, CPM calculates the longest path of planned activities to the end of the project, and the earliest and latest that each activity can start and finish without making the project longer.
This process determines which activities are "critical" (i.e., on the longest path) and which have "total float" (i.e., can be delayed without making the project longer).

In project management, a critical path is the sequence of project network activities which add up to the longest overall duration. This determines the shortest time possible to complete the project.
Any delay of an activity on the critical path directly impacts the planned project completion date (i.e. there is no float on the critical path).

A project can have several, parallel, near critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.
What is CPM Scheduling?

• Critical Path Method
  – the longest chain of sequential activities to complete the project
• Planned activities in a logical order with defined duration based on quantity, crew and production
• A sequential network of appropriate proper relationships
• A tool to identify and monitor progress against the baseline
**Critical Path Method Schedule (CPM)**

**Strengths**

- Time Scaled Logic / Logical Graphic Display allows for grouping by WBS and/or Codes
- Facilitates Alternative Planning
- Displays Critical and Near Critical Path(s)
- Allows Sorting and Graphic Portrayal of Key Data
- Quick Summary and Milestone Plots
- Relative Ease of Resource & Cost Loading
Weaknesses

- Computer Software is essentially mandatory
- Personnel resources are required for data entry
- Must be monitored, maintained and updated
- Is subject to manipulation by numerous methods
- Algorithms for resource leveling, etc. are typically built into the software and are not disclosed
- Menu driven format “limits” flexibility
Weaknesses

- CPM does not readily discern nor identify the distinction between “hard” logic links and “soft” logic links. Soft logic can be used to distort and/or hide available flexibility (float) within the construction program.

- CPM does not readily graphically portray potential “conflict” between trade crews, work area & locations within the construction sequence.

- With CPM there are many ways to write the logic of the project, and unfortunately can prove to be self-serving for whoever creates the schedule.
Common Scheduling Software include

- Primavera P6 and earlier version P 3.1
- SureTrack
- MS Project
- Safran
- Asta Scheduling
- Spider Project
- Tilos
- Vico
### Common Display of a CPM Schedule

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Name</th>
<th>Original Duration</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTD</td>
<td>Pump Station Renovation</td>
<td>341</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WTD.1</td>
<td>Project Management</td>
<td>16</td>
<td>11-Feb-09</td>
<td>04-Mar-09</td>
</tr>
<tr>
<td>WTD.1.1</td>
<td>Definition (Scope)</td>
<td>10</td>
<td>11-Feb-09</td>
<td>24-Feb-09</td>
</tr>
<tr>
<td>WTD.1.2</td>
<td>Planning</td>
<td>5</td>
<td>25-Feb-09</td>
<td>03-Mar-09</td>
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<td>WTD.1.3</td>
<td>Authorization</td>
<td>1</td>
<td>04-Mar-09</td>
<td>04-Mar-09</td>
</tr>
<tr>
<td>WTD.2</td>
<td>Design</td>
<td>130</td>
<td>05-Mar-09</td>
<td>04-Sep-09</td>
</tr>
<tr>
<td>WTD.2.1</td>
<td>Procure Design Services</td>
<td>10</td>
<td>05-Mar-09</td>
<td>18-Mar-09</td>
</tr>
<tr>
<td>WTD.2.2</td>
<td>Preliminary Design (15%)</td>
<td>15</td>
<td>19-Mar-09</td>
<td>08-Apr-09</td>
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<tr>
<td>WTD.2.3</td>
<td>Design (30%)</td>
<td>25</td>
<td>09-Apr-09</td>
<td>13-May-09</td>
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<tr>
<td>WTD.2.3.1</td>
<td>Design Document</td>
<td>10</td>
<td>09-Apr-09</td>
<td>22-Apr-09</td>
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<tr>
<td>A1060</td>
<td>Develop 30% Design Document</td>
<td>10</td>
<td>09-Apr-09</td>
<td>22-Apr-09</td>
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<tr>
<td>WTD.2.3.2</td>
<td>Estimate</td>
<td>10</td>
<td>23-Apr-09</td>
<td>06-May-09</td>
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<tr>
<td>A1070</td>
<td>Prepare 30% Cost Estimate</td>
<td>5</td>
<td>23-Apr-09</td>
<td>29-Apr-09</td>
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<tr>
<td>A1080</td>
<td>Document Cost Variance from 15% Submission</td>
<td>5</td>
<td>30-Apr-09</td>
<td>06-May-09</td>
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<tr>
<td>WTD.2.3.3</td>
<td>Quality Control &amp; Assurance</td>
<td>5</td>
<td>23-Apr-09</td>
<td>29-Apr-09</td>
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<tr>
<td>A1090</td>
<td>QC / QA Review 30% Design</td>
<td>5</td>
<td>23-Apr-09</td>
<td>29-Apr-09</td>
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<tr>
<td>WTD.2.3.4</td>
<td>Team Review / Comment</td>
<td>10</td>
<td>30-Apr-09</td>
<td>13-May-09</td>
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<tr>
<td>A1100</td>
<td>Peer Review of 30% Design</td>
<td>5</td>
<td>30-Apr-09</td>
<td>06-May-09</td>
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<tr>
<td>A1110</td>
<td>Address Review Comments</td>
<td>5</td>
<td>07-May-09</td>
<td>13-May-09</td>
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<tr>
<td>WTD.2.4</td>
<td>Design (60%)</td>
<td>30</td>
<td>14-May-09</td>
<td>25-Jun-09</td>
</tr>
<tr>
<td>WTD.2.5</td>
<td>Design (90%)</td>
<td>40</td>
<td>26-Jun-09</td>
<td>21-Aug-09</td>
</tr>
<tr>
<td>WTD.2.6</td>
<td>Final Design (100%)</td>
<td>10</td>
<td>24-Aug-09</td>
<td>04-Sep-09</td>
</tr>
<tr>
<td>WTD.3</td>
<td>Permits</td>
<td>160</td>
<td>14-May-09</td>
<td>31-Dec-09</td>
</tr>
<tr>
<td>WTD.3.1</td>
<td>SEPA</td>
<td>30</td>
<td>14-May-09</td>
<td>25-Jun-09</td>
</tr>
<tr>
<td>WTD.3.2</td>
<td>Building Permits</td>
<td>90</td>
<td>24-Aug-09</td>
<td>31-Dec-09</td>
</tr>
<tr>
<td>WTD.4</td>
<td>Construction</td>
<td>105</td>
<td>04-Jan-10</td>
<td>26-May-10</td>
</tr>
<tr>
<td>WTD.4.1</td>
<td>Procure Construction Services</td>
<td>45</td>
<td>04-Jan-10</td>
<td>05-Mar-10</td>
</tr>
<tr>
<td>WTD.4.2</td>
<td>Pre-Purchase Long Lead Items</td>
<td>30</td>
<td>08-Mar-10</td>
<td>16-Apr-10</td>
</tr>
<tr>
<td>WTD.4.3</td>
<td>Replace Equipment</td>
<td>30</td>
<td>08-Mar-10</td>
<td>16-Apr-10</td>
</tr>
<tr>
<td>WTD.4.4</td>
<td>Replace 2,100ft Main Pipe</td>
<td>60</td>
<td>08-Mar-10</td>
<td>28-May-10</td>
</tr>
<tr>
<td>WTD.4.5</td>
<td>Install New 325ft Influent Pipe</td>
<td>20</td>
<td>08-Mar-10</td>
<td>02-Apr-10</td>
</tr>
<tr>
<td>WTD.5</td>
<td>Closeout</td>
<td>10</td>
<td>01-Jun-10</td>
<td>14-Jun-10</td>
</tr>
</tbody>
</table>
Time Scaled Logic Diagram Example
Line of Balance/Linear Scheduling

![Project Time Diagram]

- **Project Time**
- **Legend**
  - Repetitive Activity
  - (Durations, single-skilled crew, multi-skilled crew)

- **Sections**
  - Section 1
  - Section 2
  - Section 3
  - Section 4

- **Activities**
  - Slabs
  - Beams
  - Columns
  - Foundations
  - Excavation

- **Extensions**
  - (11.7, S1, M4)
  - (6.7, B1, M2)
  - (8.5, C3, M1)
  - (10.7, F1, M2)
  - (12.5, E1, -)
  - (6.1, B1, M2)
  - (10.3, C3, M1)
  - (10.3, F1, M2)
  - (15.6, E1, -)

- **Completion Times**
  - 91.3 days
  - (12.3, S1, M4)
  - (5.3, B1, M3)
  - (9.0, C3, M2)
  - (9.0, F1, M2)
  - (16.6, E1, -)
Line of Balance/Linear Scheduling

- Linear Scheduling Method (LSM) is a graphical scheduling method focusing on continuous resource utilization in repetitive activities, typically dividing work activity by crew and location.

- Linear Scheduling is mainly used to schedule activities in multiple locations as commonly found in repetitive “linear” types of projects such as highway, pipeline, highrise building, railway and tunnel construction projects.
### Line of Balance/Linear Scheduling

- The LSM scheduling method shows start and finish dates, production rates, and logic constraints. It is simple enough to make recording of as-built production rates, projections of finish times, forecasting of conflicts, and delays a daily matter.

- A secondary Y-axis can record cost in work hours. As the actual number of work hours is generated and available from certified payroll, a superimposed histogram on the LSM schedule can serve the dual purpose of resource leveling and manpower/cost determination.
Advantages of Linear Schedules over CPM schedules include these fundamental concepts.

• Resources/work activity and associated crews can not overlap nor occupy the same location (conflicts)

• Resources should remain continuously at work

• Resources are NOT unlimited
Line of Balance/Linear Scheduling

- Resource levels cannot practically be
  instantaneously increased and decreased to
  track “unleveled” labor demands
- Interruption of repetitive work activity
  should be minimal
- The focus of LSM is production, not time
- The effect of the “learning curve” should be
  minimized
- Resource utilization should be maximized
Other Names for Linear Scheduling Method

- Location-based scheduling
- Harmonograms
- Line-of-balance
- Flowline or flow line
- Repetitive scheduling method
- Vertical production method
- Time-location matrix model
- Time space scheduling method
- Disturbance scheduling
- Horizontal and vertical logic scheduling for multistory projects
- Horizontal and vertical scheduling
- Multiple repetitive construction process
- Representing construction
- Linear scheduling
- Time versus distance diagrams (T-D charts)
- Linear balance charts
- Velocity diagrams
Current commercial LSM software is predominately provided by programs independent of the major CPM software suppliers. Their use constitutes an additional investment in finance and training as a large number of CPM schedulers are unfamiliar with LSM techniques.

Common commercial linear schedule software programs are written to allow data to be imported from and exported to and from common CPM scheduling software.
On selected projects, the coordinated use of both CPM and LBM methodologies may provide advantage over the sole use of either scheduling methods.

Portions of the CPM schedule can be isolated and tracked in LBM, particularly those which are repetitive in nature and sequence. An example being repetitive typical floors (once reached) in a multi-story high-rise project.
Linear Scheduling Software Graphics Example (from Tilos)
Linear Scheduling Software Example (from Tilos)
Schedule Specifications

Project Startup Review
Prior to implementing schedule specifications and contract execution, the contract and specifications provisions should be reviewed by the Stakeholders and modified as necessary to ensure compatibility with current requirements.
Schedule Specifications

Scheduling Specifications should be tailored to “fit” the size and complexity of project particulars. In scheduling specifications, one size does not fit all. Despite the current trend towards more detailed and extensive scheduling specifications, more is not necessarily better.

Overly cumbersome spec requirements can create a needless burden to those tasked with creating, maintaining and reporting on the project schedule.
Schedule Specifications

The Scheduling Specifications should:

• Designate the scheduling software to be utilized
• Designate any other software desired to be used in conjunction with the above
• Incorporate consistent terminology
• Utilize standardized and consistent numbering system(s)
• Assign “Ownership” of the Schedule to Stakeholders relative to their contractual work scope
Schedule Specifications

- Correctly and consistently identify stakeholder roles and responsibilities.
- Establish standards for naming and coding work activity, defining area and identifying location.
- Establish a uniform schedule for non-work days including anticipated “weather” days and other variables which can be foreseen & anticipated.
- Review and verify requirements related to cost and resource loading.
Schedule Specifications

- Resource Loading
- Manpower (Trade)
- Cost
- Major and Minor Equipment
- Indirect Cost – Plant and Facilities

Every additional resource adds to initial coding complexity, update reporting and ongoing record keeping workload.
Schedule Specifications

- Cost Loaded Schedule
  - Advantages
    - Simplifies billing
    - Appears to tie progress to payment
    - Establishes % Complete from Quantity in Place?
  - Disadvantages
    - Complicates data input
    - Payment needs often lead to manipulation

Using a Schedule for Payment requires additional effort during updates and a higher level of expertise
More is not always better!

Prolific specifications can easily prove overly burdensome, difficult, costly to satisfy and potentially detrimental to success.

Question if the requirements of the project plans and specifications are commensurate with the size, nature and complexity of the project to which they are being applied! If not, they should be adjusted accordingly.
Project Management Issues as they Relate to Scheduling
Scheduling Issues

Schedules are dynamic, the stakeholders cannot assume the baseline schedule will hold true throughout project. Question whether the current schedule reflects the current plan to complete as of the selected data date.

The schedule is useful in alerting PM to potential problems by using Time Impact Analysis to project and quantify projected impact and/or disruption.

Accurate TIA forward looking schedule projections are necessary for demonstrating the impact of change, loss of flexibility, delay and assessment of contract time extensions in a timely manner.
How to Quickly Spot Problems

- Use comparison software to compare changes made from one update to the next such as Digger™ and Acumen™
- Look for asterisks in duration or date columns – indication of constraint vs. logic
- Look for very large float values – indication of missing successor activities
- Check for inappropriate leads and lags
- Unexpectedly large activity durations are an indication of sequestered float
Scheduling software has become overly user friendly. It is easy to confuse graphics with substance. Keep in mind that skill is not necessarily required to produce a visually appealing graphic representation of a schedule.

Ensure there is sufficient substance, logic and detail to solidly underlay the calculation of the forward and backward pass.
**Inherent Dangers**

- It is very easy to hide flawed logic / durations / constraints if only a hard copy of the schedule is supplied, especially if float and the late dates are not displayed.

- It is very easy to not properly update schedule activity and to enter information on the wrong activity if the description & coding does not distinctly identify area, location and elevation.

- It is very easy to misrepresent project status by the use of subjective % complete vs. physical measurement of quantity of work in place.
Inherent Dangers

- Account for productivity changes for similar work activity in differing conditions. Forecasting using as-planned production rates instead of actual can create unrealistic predictions.

- As a consequence, the PM and Stakeholders can be misled until it’s too late to react.

- Insist that “native” electronic files be provided for expert independent review and analysis.
Regular updates are essential for useful monitoring the critical and near critical paths.

Change logic as appropriate and/or amend the schedule to include current and proposed changes to scope and projected sequence.

Distribute reports quickly to provide PM with time to react.

Update, maintain and chronicle the events & non-events preceding each current update to provide a historical chronology of the project.
Failure of Stakeholder “Buy-In”

Some take the position that “Ownership” of the Project Schedule lies solely with the party that generates and produces the baseline schedule and performs and submits updates.

Over the years, the amount of “self-performed” work by PMs and GCs on construction projects has diminished to the point where the majority (if not all) of work activity on site is performed by specialty subcontractors and their lower tier subs.
Failure of Stakeholder “Buy-In”

As a consequence, Owners, PMs and GCs have come to increasingly depend on the participation of individual specialty subs and suppliers in defining the work breakdown structure, duration, resources, logic, etc. for their contractual work scope and identifying how and in what sequence their work is linked to that of others. When a sub fails to participate and contribute to the process, the party responsible for generating the schedule (usually the PM or GC) is left to unilaterally “fill in the gaps” on their behalf.
Other Common Errors to Avoid

Failure of Stakeholder “Buy-In”

While subs that follow this tactic may believe that not participating in creating and/or updating the schedule releases them from ownership of what is produced on their behalf, such is not normally the case.

Most commercial contracts and subcontracts require substantive participation from all involved parties in the scheduling process. Failure to do so may constitute a failure to perform and thus form a basis for breach of contract.
Other Common Errors to Avoid

Failure of Stakeholder “Buy-In”

In reality, all of the stakeholders performing work on a project have ownership of their scope within the project schedule. The success of an individual party in a project is in reality seldom extricated from the success of the other parties involved. Taking the position that “it’s not my schedule” is impractical.

It is an extremely detrimental attitude which may well prove the basis for the offending party to contractually assume the negative consequences of taking such a position.
Other Errors to Avoid

- Project personnel not possessing sufficient skills and knowledge
- Inadequate software
- Manipulation
- False reporting
- Failure in communication
- Failure to notify