A Generalized EPC Schedule Tool

T.E. Wolf, Sugar Land, Texas

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**Brief History of the Generalized Engineering, Procurement, and Construction Schedule**

The following graphic is a useful tool to depict an overall management level schedule.

As to the origin of the generalized schedule, over the last four decades I have seen several versions of this generalized schedule, each slightly different in presentation. The variants all are time scaled from 0% to 100%, some start with the start of process development (i.e. modelling and PFDs), some start with P&ID development, they differ in number of tasks (27 to approximately 100), and they differ in the time at which Construction Starts versus Engineering Percent Completion.

I've personally seen Mobil Oil, EXXON, and Fluor versions. James A. Bent’s excellent 1982 book, *Applied Cost and Schedule Control*, has several different presentations and in his Preface gives credit to Mobil Oil, M.W. Kellogg, and Bechtel. No doubt other owner/operator companies and contractors have similar schedules. I have compared three of these by overlaying tasks and durations and there is very close correlation among the presentations. Because these are so closely related, over the years I have also searched for the source document, the original, but to this date without success. From the dates on the documents, ranging from the late 1970s to mid-1980s, it appears the original effort was probably performed in the decade or so following the mid-1960s.

For those interested, I strongly recommend Mr. Bent’s book. He includes several project iterations in Chapter 3, large (master schedule, EPC, engineering, construction) and small (master schedule, EPC), and more in other chapters. The discussions and qualifications included are well worth reading.

That over the many decades with all the many changes in capital project execution (e.g. 3D CAD, electronic process control, increased governmental regulations, improved construction techniques, just to name a few), it is somewhat amazing to me this schedule continues to provide good planning results. Apparently, there is a strong indication there is at least a somewhat natural sequence and relationship among the many tasks required to engineer and construct a capital project.

**Overview of the Generalized EPC Schedule**

This generalized schedule is a time-scaled, one page, overly simplified engineering, procurement, and construction (EPC) Gantt bar chart type schedule. By being overly simplified the schedule allows the user to get a visual of the entire project at one time. The schedule starts at the beginning of Phase 3 (FEL 3), assumes the Conceptual Phase (FEL 1) and Feasibility Phase (FEL 2) having been completed, and detailed engineering and design proceeds continuously upon completion of FEL 3, without a delay between FEL 3 and detailed design.
It is peculiar in at least one way, note the time scale. It is shown in percent of time rather than days, months, and/or years, and the percent of project duration is measured from the start of the engineering to Mechanical Completion, with Mechanical Completion being 100%. Also note the time scale continues beyond 100%.

On the left side the activities comprising the schedule are shown. The task are given identifying numbers (ID No.) and this schedule would be described as containing ‘less than 50 activities.’ These are segregated into three main categories: Engineering tasks, Procurement tasks, and Construction tasks. Relative task start times and durations are shown as gray horizontal bars. If the task is a Milestone, that is, a significant or major activity that is to occur on a specific date, it is shown as a black diamond; see Engineering 95% (ID No. 21), Start Construction (ID No. 30), and Mechanical Completion (ID No. 42).

The duration bars are indicative of the period of major activity for the specific task. The relative start times and durations do not imply staffing start dates nor staffing durations, that is, engineering discipline personnel and construction craft personnel may actually be brought onto the project prior to the shown task duration start and may remain on the project following the shown task duration completion. Also, there is nothing absolute regarding the shown activity start times or durations, there are just too many variations from project to project. However, over the last three to four decades, I have found by overlaying my completed project’s schedule over the generalized schedule, there is very close association. This close association has given me the confidence to continue its use as an early planning tool.

Besides the starting vertical axis, two other vertical lines are shown in heavy grey, these emphasize the Start of Construction milestone date and the Mechanical Completion milestone date. Note the Project Closeout activity (ID No. 22) extends beyond the Mechanical Completion date to approximately 109% of project duration.

Superimposed over the schedule are the engineering and construction progress curves. Note Construction Starts with Engineering at 60% complete and this occurs at approximately 46% of the Project Duration.

The EPC Schedule – Description, Definitions, and Comments

This section will step wise work through each activity starting with Construction and followed by Engineering and Procurement. As the steps are taken a description of the activity, ID Number (ID No.), and related activities will be provided. In many cases there are multiple related activities and the significance of the related activity will be discussed.

The generalized schedule is assumed to have been prepared during Phase 2 (FEL 2) and presented on a one page overly simplified list of activities. During the FEL 3 (ID No. 2) effort a detailed EPC Critical Path Method (CPM) schedule will be developed, along with a forced detail (Budget) Estimate. Both the CPM schedule and the Budget estimate will become basis documents, along with other Phase 3 deliverables, for Detailed Engineering and Design and for project control.

**Construction –**

On the far right side is the vertical grey line emphasizing the Mechanical Completion date. The vertical line passes through the Mechanical Completion milestone (ID No. 42) and is labeled on the time scale axis as being the 100% of Project Duration point. *Mechanical*
Completion (MC) is defined by the contract between the plant owner/operator and the contractor to mean the facility has been erected in accordance with the drawings and specifications, checked and tested by the contractor, and is ready for the Client’s commissioning activities; it is the point in time at which Care, Custody, and Control (CCC) of the facility, that is, legal responsibility, passes from the constructor to the owner. The Client Commissioning Activities are all necessary pre-startup activities the operator’s personnel (not the contractor’s personnel) are required to perform prior to the introduction of feedstock to initiate plant startup.

The contractor’s activities are not normally complete at Mechanical Completion however. Contractor activities that generally do not impede Client commissioning activities continue, these include activities such as paint, insulation, and cleanup (ID No. 43) and these activities are shown extending in time to approximately the 105% point in time; these activities are sometimes referred to as Other Completion Activities and may include other activities than just paint, insulation, and cleanup, as directed or approved by the owner/operator. The purpose for transferring Care, Custody, and Control to the Client in advance of the contractor’s completing all tasks is to allow the operators to get a head start on their commissioning tasks.

In the center of the schedule is another vertical grey line labeled Start of Construction and it passes through the Start Construction milestone (ID No. 30). Start of Construction is a legal term that explicitly defines the point in time that the owner/operator has received all required governmental permits prior to which no physical installation work related to the new facility can begin. Therefore it is extremely important that requests for governmental permits start as early as possible during the first two phases (FEL 1 and 2) so as not to adversely impact the construction start and consequently overall project duration and completion.

Start of Construction usually starts with the civil work of site preparation, grading, and excavation which for this schedule occurs on the time scale at approximately 46%. The major significance of this point in time is that it coincides with Engineering achieving 60% Completion (draw a horizontal line through the intersection of the Start of Construction vertical line and the Engineering Progress curve, and note the horizontal line intersects the left Y-axis at the 60% complete point). This point in time is significant for several reasons:

- To minimize the overall project duration, the point at which construction starts has a direct bearing on the time the project achieves Mechanical Completion.
- Starting later than 60% Engineering completion means more engineering drawings are issued For Construction and more material and equipment have been received at the site, but starting later will generally extend the schedule’s overall duration.
- Starting earlier than 60% Engineering completion implies less engineering drawings are issued For Construction and less material and equipment have been received at the site, but starting earlier suggests a shorter overall duration.
- However, starting earlier than 60% and having less issued For Construction drawings and less material and equipment on the site can have negative consequences that may actually increase overall duration and increase cost.
- These negative consequences may include some or all of the following: increases in engineering errors, increases in construction rework, and increases in construction craft idle, non-productive time waiting for materials.
- There is no magic in the selection of the 60% point, but over time the industry has identified this point to be a good tradeoff between starting too early and starting too late.
Construction must perform several pre-construction activities and this task is known as Mobilization (ID No. 29). **Mobilization** is the collection of activities required to support the construction of the facility. It includes such things, as temporary construction offices, warehousing, laydown areas, craft parking, craft lunch facilities, among others. Notice this activity starts prior to Start Construction and continues just beyond Start Construction; any temporary facilities that are required to be built must have permits in place prior to their erection.

Site preparation, grading, and excavation (informally described as ‘moving dirt’) is shown as the Grading & Excavation (ID No. 31) task, starts at the Start of Construction milestone and as mentioned above implies all governmental permits are in place. Note that engineering activities Site Prep (ID No. 11) and foundation Location Plan (ID No. 13) are complete, thus fully supporting these construction activities.

Once the site excavation has started, installation of Underground (ID No. 32) storm water sewers, special chemical sewers, if required, fire water mains, electrical power, etc. can start. Again notice the engineering activity Underground (ID No. 5), which includes the combined and coordinated efforts of the Piping, Civil/Structural/Architectural, and Electrical design groups, is complete to support these activities. And soon after the underground facilities have started to be installed, the first equipment foundations will start to be formed, reinforcing bar and anchor bolts installed, and concrete poured. These activities are contained in construction task Concrete (ID No. 33) and are supported by engineering activities foundation Location Plan (ID No. 13) and Foundations (ID No. 12).

This is a good time to introduce some scheduling nomenclature. Notice in the paragraphs immediately above the activities labeled ‘supporting’ activities. These supporting activities are called **Predecessors** in that these activities precede the current activity. Conversely, an activity that follows a current activity is called a **Successor**, as they succeed (follow) the current activity.

Notice the ‘dirt work’, Grading & Excavation (ID No. 31) and Underground (ID No. 32) are finished and the Concrete (ID No. 33), equipment foundations and at least some on site paving, is almost complete prior to Equipment Erection (ID No. 34). Construction management wants to ‘get out of the ground’, that is, stop working in dirt and, more than likely, mud and work on finished surfaces. This is important in that heavy equipment, such as cranes required to erect equipment, and other lighter construction equipment would either disrupt previously graded areas and/or become mired in mud. Also notice, Equipment Deliveries (ID No. 27) started as the construction team was mobilizing (ID No. 29), meaning there were construction personnel and equipment on site to receive, unload, and warehouse or place in the laydown yard all material and equipment.

Once the major equipment has begun to arrive and the foundations have been poured and each foundation allowed to cure (normally 30 days after being poured), equipment can be loaded and moved from the laydown yard to the construction site, lifted by the heavier cranes and placed on their foundations. Once all the equipment has been received (ID No. 27), not only the major equipment, but the smaller equipment, such as pumps, can be set on their foundations, Equipment Erection (ID No. 34). The setting of equipment is of significant
importance in that, pipe spools attach to nozzles on the equipment and Pipe Erection (ID No. 38) starts soon after the initial equipment is set, and obviously pipe erection cannot complete until all equipment is set.

During the foundation installation activities, concrete piers for the major pipe supports and other steel structures are poured, as soon as these are cured, the major Pipe Supports (ID No. 35), known as pipe racks, and Major Structural steel (ID No. 36) are erected and assembled. Erecting the pipe racks are of particular importance in that the rack mounted piping, known as ‘straight run pipe’ or ‘rack pipe’, can be installed. The reason of its importance is that this piping is predominantly straight, requires little to no prefabricated pipe spools, is installed in the rack (called ‘stuffing the rack’) with pipe of double random lengths (nominally 40 feet long) and single random lengths (nominally 20 feet long), and is welded together in place by construction pipe welders. This activity contributes a significant amount of construction progress by getting a considerable amount of pipe tonnage installed in advance of starting the prefabricated Pipe Erection (ID No. 38). Piping other than straight run rack pipe takes longer to arrive at the site due it being prefabricated, see Pipe Fabrication (ID No. 37) and for it to be installed sufficient equipment nozzles must be ready for pipe attachment, as mentioned above.

Before we can address Pipe Fabrication (ID No 37) and Pipe Erection (ID No. 38), Piping Design (ID No. 6) needs to be touched upon. The majority of the duration shown for Piping Design is almost exclusively required to generate isometrics (informally called isos) and iso drawing production does not start until Piping Design is 40% to 50% complete, in other words, even though consuming 50% to 60% of Piping Design’s total duration, it occurs later in their work process. The iso issue curve has much the same shape of any progress curve, that is an ‘S’ shape. This means at the beginning few isos are issued and these are generally fairly simple isos. As time goes on and piping design enters the steeper part of the iso issue curve, more and more isos, and more complex isos, get issued.

As the isos are issued, they are transmitted to the fabricator, who breaks the isos into smaller pieces, called piping spools that can be both fabricated in their shop and transported to the job site. Since there are few isos issued early in the process, the shop fabricator generally waits a period of time before fabricating these spools to build up a backlog of isos to give the shop personnel a more steady flow of work. Without going into more detail, the bottom line is that there is a lag period between iso issue to the fabricator and construction receiving fabricated spools. Unfortunately there is another lag period between receiving fabricated spools and spool installation, generally the early receipt spools are the more simple spools and not the spools needed to match installed nozzles.

With that background, Pipe Fabrication (ID No. 37) follows Piping Design (ID No. 6) by some period, and as soon as the pipe spools are received at the site, Pipe Erection (ID No. 6) occurs.

As with piping design, Electrical Design (ID No. 15) precedes Electrical (ID No. 39) installation, and Control Systems (ID No. 18) design precedes Control System (ID No. 41) installation. The last construction activity prior to Mechanical Completion, is Punch List (ID No. 41). Punch List is a process of checking every system, every piece of equipment, every line, ever instrument device, every electrical piece of equipment or device, and every junction box to assure each has been installed in accordance with the P&IDS, drawings, data sheets, specifications, etc. First the contractor makes the check, then the contractor notifies the owner/operator, who then double checks everything. Once the Client is satisfied all is installed correctly, the construction contractor issues a letter stating Mechanical Completion
(ID No. 42) has been attained; this letter is a contractual requirement. And as mentioned previously, Client’s operators start their pre-start up Commissioning activities and the contractor completes painting, insulation, clean up, and ultimately demobilizing.

Note the Construction Progress curve, the lazy ‘S’ shaped curve, called an ‘S Curve’. It start out at 0% complete at the Start of Construction (ID No. 30) and proceeds to and through Mechanical Completion (ID No. 42), and reaches 100% upon completion of Finish Paint & Insulation (ID No. 43).

Before leaving Construction and moving on to Procurement and Engineering, the last construction related activity is Project Closeout (ID No. 22) which begins once engineering has issued the last drawing For Construction. Project Closeout consists of many activities including the receipt and verification of all Certified Vendor Data and Drawings, the subsequent revision to issued For Construction drawings, if required, and engineering support for construction which includes drawing interpretation, modifications to drawings caused by field obstructions and interferences, and errors caused by all sources (engineering, vendors, fabricators, and/or construction). Sometimes the above identified activities are separated from Project Closeout definition and called Engineering Support, Support Activities, or just Field Support. Even after construction has achieved Mechanical Completion and finished other Completion Activities such as completing Painting and Insulation, all vendor’s, supplier’s, and contractor’s invoices must be received, verified, and paid, including insurance claims, backcharges, and change orders, engineering personnel must complete As-Built drawings, and all project records, drawings, and Data Books transferred to the Client. Note, Project Closeout starts with engineering being 95% complete and ends at about 109% of Project Duration.

Engineering – Phase 3

As mentioned above, Phase 1 (FEL 1) and Phase 2 (FEL 2) were previously completed prior to the start of this EPC schedule, with Phase 3 (FEL 3) being the starting point. The schedule assumes no break in execution continuity upon the completion of Phase 3 and proceeding immediately into detail design and engineering. FEL 3 (ID No. 2) is shown starting at Project Duration 0% and completing at approximately 21%. Major activities making up Phase 3 are shown: Process Design (ID No. 3), Equipment Data Sheets (ID No. 4), Plot Plans (ID No. 7), Preliminary Piping Takeoff (ID No. 8), One Line Diagram (ID No. 16), Area Classification (ID No. 17), DCS Block Control Diagram (ID No. 19), Request Supplier Quotes (ID No. 24), and the initiation of Purchase Equipment (ID No. 25).

Process Design (ID No. 3) commences immediately upon project start. This entails Process and Instrument Diagram (P&ID) development, drafting, checking, a consistency review among process, piping, mechanical, and control systems engineers, a second review with the Client, and drawing issue. These issued P&IDs become the basis document for the Phase 3 forced detail (Budget setting) estimate and the starting point for Detailed Engineering and Design. Concurrent with the P&ID effort, the process engineers develop and issue Equipment Data Sheets (ID No. 4). Upon completion of an equipment data sheet, the data sheet is augmented by the mechanical engineers to include mechanical design data and requirements and to include applicable design standards and specifications. These in turn become the technical Request For Quotation (RFQ) package which is given to the procurement personnel for commercial information inclusion and subsequent issue to the suppliers requested to bid on the equipment, see Request Supplier Quotes (ID No. 24).

Also immediately upon starting the project, piping personnel begin Plot Plans (ID No. 7)
development, starting with the existing facilities (locations of piping, utilities, equipment, etc.), if any, and working closely with process, mechanical, civil/structural/architectural, electrical, and control systems engineers and construction personnel to develop, draft, check, review, and issue an efficient plant configuration. This configuration is then reviewed with the Client and upon approval, the Plot Plans are issued becoming another basis document for the forced detail (Budget) estimate and starting point for Detailed Engineering and Design.

Toward the end of plot plan development and using the Process Flow Diagrams (PFD) issued during Phase 2, the piping personnel will layout major piping routes over the plot plan. In this way, the piping forced detail estimate will include very close approximation of line sizes, required lengths, number of bends, and number of valves and fittings required for the major (large bore) piping. Small bore pipe, valves, and fittings are then estimated using historical frequency data. The combined large and small bore estimates are the Preliminary Piping Takeoff (ID No. 8) and becomes the basic part of the Piping material RFQ.

As the electrical power requirements become better defined following the Equipment Data Sheet (ID No. 4) development, electrical engineers review of existing electrical facilities, and other new electrical power requirements, the electrical engineers will develop, draft, check, and issue the electrical One Line Diagram (ID No. 16) to the Client for review. Upon approval the one line diagram will be issued and become a basis document for the forced detail (Budget) estimate and a starting point for Detailed Engineering and Design.

Utilizing the developed Plot Plans (ID No. 7), electrical engineers develop, draft, check, and issue the electrical Area Classification (ID No. 17) drawing to the Client for review. It too is issued and becomes a basis document for the forced detail (Budget) estimate and a starting point for Detailed Engineering and Design upon Client approval.

While the instrument engineers, also called control systems engineers, are assisting in the P&ID development, they will develop, draft, check, and issue the process control DCS (Distributed Control System) Block Control Diagram (ID No. 19). This document sets in block form the overall electronic control scheme for the facility, including physical instrument monitoring and actual process control, required interfaces between the instruments and the controls computer(s), and existing Client plant monitoring and controls systems. Following the Client review of this diagram it becomes a basis document for the forced detail (Budget) estimate and a starting point for Detailed Engineering and Design.

Upon completion of all the above mentioned basis documents including the detailed CPM schedule and the associated material takeoffs for equipment, civil/structural/architectural, piping, electrical, and control systems, the materials are priced and the installation labor estimated to identify the estimated direct field cost, an estimate of the indirect field cost, engineering cost, and the amount of escalation, contingency, and accuracy to be applied, as appropriate, to compile the total forced detail (Budget) estimate. The completed estimate is issued to the Client for review and upon approval becomes the project’s Budget for project control purposes.

Note, this estimate gets its name, ‘forced detail estimate’, from the fact that Detailed Engineering and Design has not even started and the details contained in the estimates are ‘forced’ to be developed based only on the basis documents.

**Engineering - Detailed Engineering and Design**

*Detailed Engineering and Design* is the process of taking the above developed Phase 3
(FEL 3) basis documents, industry codes and standards, project specifications, and data and drawings provided by material and equipment suppliers to produce construction drawings, details, and control documents, including:

- Equipment list, equipment purchase requisitions, and receipt and checking of supplier provided drawings and documentation.
- Piping Underground (ID No. 5) drawings and details, detailed Piping Design (ID No. 6) including piping model, line list, piping tie-in list, piping specialty items list, piping plans and sections, piping isometrics, and once the model is complete and just prior to the start of isometric production, piping extracts a Secondary Piping Takeoff (ID No. 9) from the model which is used to fine tune the piping material and piping fabrication purchase orders. The Underground (ID No. 5) is preceded by the civil engineers completing Site Prep (ID No. 11) drawings.
- Civil/Structural/Architectural (ID No. 10) engineering and design, including Site Preparation (ID No. 11) drawings, civil Underground drawings and details (ID No. 5), paving drawings, foundation Location Plans (ID No. 13), Foundation (ID No. 12) drawings and detailed drawings, Pipe Supports & Structures (ID No. 14) steel drawings, details, and erection plans, purchase requisitions, receipt and checking of supplier provided drawings.
- Electrical Underground (ID No 5) drawings and details, Electrical Design (ID No. 15) including electrical plans and details, electrical equipment list, electrical motor list, junction box drawings and details, grounding plans and details, cathodic protection drawings and details, lighting plans and details, purchase requisitions, receipt and checking of supplier provided drawings and data.
- Instrument Data Sheets (ID No. 20), Controls Systems (ID No. 18) engineering and design, including instrument list, instrument locations plans and details, process control loop diagrams, marshalling cabinet drawings and details, wiring diagrams, purchase requisitions, receipt and checking of supplier provided drawings and data.
- All of which are engineered, developed, drafted, checked, issued for Client review and approval, and subsequently issue For Construction.
- Engineering and Design is considered to be essentially once the last drawing is issued For Construction and this milestone is known as Engineering 95% (ID No. 21) complete.
- As soon as the Engineering 95% milestone is achieved, Project Closeout (ID No. 22) begins.

As already mentioned, but included again for its importance, Project Closeout consists of many activities including the receipt and verification of all Certified Vendor Data and Drawings, and the subsequent revision to issued For Construction drawings, if required, and engineering support for construction which includes drawing interpretation, modifications to drawings caused by field obstructions and interferences, and errors caused by all sources (engineering, vendors, fabricators, and/or construction). Even after construction has achieved Mechanical Completion and finished other Completion Activities such as completing Painting and Insulation, all vendor’s, supplier’s, and contractor’s invoices must be received, verified, and paid, including insurance claims, backcharges, and change orders, engineering personnel must complete As-Built drawings, and all project records, drawings, and Data Books transferred to the Client. Project Closeout starts with engineering being 95% complete and ends at about 109% of Project Duration.

Note the Engineering Progress curve, or ‘S Curve’ start out at 0% complete at the Project
Start, time duration 0% of Project Duration and proceeds to and through Start of Construction (ID No. 30) with engineering being 60% compete at approximately 46% of Project Duration, and reaches the Engineering 95% (ID No. 21) at about 73% of Project Duration, then upon entering Project Closeout (ID No. 22), the engineering progress curve becomes a straight line until the end of Project Closeout reaching 100% complete at approximately 109% of Project Duration.

**Procurement**

As soon as process and mechanical engineers start completing Equipment Data Sheets (ID No. 3) and request for quotation (RFQ) technical packages, these get issued to procurement personnel for the addition of the commercial RFQ components, then procurement issues the Request for Supplier Quotes (ID No. 24). As soon as the quotations are received, particularly for long delivery items that might adversely affect construction’s schedule, engineering tabulates the technical information on the bids to determine if the offered equipment meets the required drawings, codes, and specifications, procurement performs the commercial evaluation, and the consolidated bid tabulation is sent to the Client for review and approval. At his point Purchase Equipment (ID No. 25) begins and continues until all equipment have been bid, tabulated, approved, and purchased.

As soon as the P&IDs are approved, the control systems engineers’ start preparing the Instrument Data Sheets (ID No. 20), assembling the technical RFQ packages and forwards these on the procurement to enter the Request Supplier Quotes (ID No. 24), bid, tabulation and approval cycle. This effort culminates with the Purchase Instruments (ID No. 26) activities. The equipment suppliers prepare drawings and data for approval by engineers and Client personnel, purchase materials, start fabrication, and when the equipment is completed, tested, and checked by the engineers and/or Client for meeting requirements, Equipment Deliveries (ID No. 27) begins and continues until all equipment is received at the site. Similarly civil, structural, and electrical materials will be quoted, tabulated, approved, purchased, and delivered to the site.

So much for a tour of the generalized schedule, how is it used?

**Utility of Generalized Schedule**

If you are given the anticipated start date and target Mechanical Completion date, then you can use the generalized schedule to generate an indicative schedule of EPC activities. This ability is useful in several circumstances:

- During the conceptual phase (FEL 1), when little project detail is known
- During the feasibility phase (FEL 2), when process alternates and/or construction alternates are to be evaluated, schedule impacts can be compared visually
- During EPC bid development, when there is a need to verify estimated effort hours for validity, assist in determining when resources may be required
- Starting a new project and providing an overall ‘feel’ of the project staffing needs, relative timing, sequencing, and visualization of possible schedule ‘windows’ (e.g. weather windows, anticipated strikes, vacation periods, shutdowns, etc.)
- After completing a project, comparing actual execution with this benchmarking tool to both visualize and highlight deviations, allowing better insight and analysis of
lesson learned
• After completing a project to continue to identify strengths and weaknesses in the tool itself.

The best way to proceed is to take a couple of hours and build a spreadsheet of the information shown in the generalized schedule. Having a spreadsheet to calculate the many activity start dates and finish dates, and the engineering and construction progress dates is both quick and most scheduling software, e.g. Primavera, MSProject, accept spreadsheet inputs to facilitate quick schedule generation for presentation.

Start the spreadsheet by inserting a table of input cells, there are only two: Project Start Date and Mechanical Completion Date, see Figure 2.

![Figure 2 – Input](image)

Adjacent to this Input table, calculate the Project Duration by subtracting the two dates; that is,

\[
\text{Project Duration (in days)} = \text{Mechanical Completion Date} - \text{Project Start Date}.
\]

Then start a new table with the first column being the activities as shown in the Task Name column of the generalized schedule, see Figure 3. The second and third columns are the Start Percent of Duration and the Ending Percent Duration of each task as indicated on the schedule, be sure to format these two columns to be ‘percentages’. As examples:

• Foundations (ID No. 12), start percent is approximately 32%, end percent is approximately 43%
• Pipe Erection (ID No. 38), start percent is approximately 64%, end percent is approximately 97%

![Figure 3 – Activities and their Date and Duration Calculation](image)

Just read the start and finish percentages directly from the generalized schedule and enter these adjacent to the task’s names in the second table. The fourth and fifth column are to be the calculation of the Start Dates and the End Dates for each task. With these two columns formatted ‘dates’, the calculation is the percentage times the Project Duration plus the Project Start Date, or using the above examples:

\[
\text{Foundations Start Date} = (0.32\times\text{Project Duration}) + \text{Project Start Date}.
\]
Foundations End Date  = (0.43*Project Duration) + Project Start Date.

Pipe Erection Start Date = (0.64*Project Duration) + Project Start Date.
Pipe Erection End Date  = (0.97*Project Duration) + Project Start Date.

The last three columns of the table will be the activities duration, that is, the difference between the task end date and the task start date, first calculating the durations in days, again using the examples:

Foundations Duration  = Foundations End Date – Foundations Start Date.
Pipe Erection Duration = Pipe Erection End Date – Pipe Erection Start Date.

Having the durations in weeks and months is sometimes useful. If you would like to have the number of weeks available, just divide the tasks duration in days by 7; and if you like to display the number of months, just divide the tasks duration in days by 4.33 (that is, 52 weeks/12 months = 4.33 weeks per month).

The third and last table, see Figure 4, will calculate and tabulate the percent complete curves for engineering and construction. In the first column input the percent complete from 10 to 100% and include 95%. The second and third columns will be the percent of duration read off the generalized schedule as indicated above.

- Engineering is 40% complete at approximately 36% of Project Duration
- Construction is 40% complete at approximately 77% of Project Duration

The last two columns are the calculated dates for the indicated percent completes, calculated as above.

At this point, the data is ready to be plotted or loaded into a scheduling software package. Once plotted, the schedule will be Phase 1 or Phase 2 one page, less than 50 activity, Gantt schedule for a project starting and being Mechanically Complete on the dates of your project with the activities relative starts and durations coinciding with the generalized schedule. But what if there is an up-front known difference in your project from the generalized schedule?

Modifying the Generalized Schedule

Any number of differences between your schedule and the generalized schedule may be known in advance. These differences may include:
- Construction starting earlier or later than Engineering being 60% complete
- Detailed Engineering not starting immediately upon completion of FEL 3 (Phase 3)
- Critical equipment being delivered on a date not within the indicated period
- Construction being subcontracted in defined packages, such as, Civil/Underground/Foundations, Mechanical/Structural/Piping, and Electrical/Instrumentation
- A known weather impediment to continuous construction

The list could go on and on. The facts may be such that you must adjust your Phase 1 or 2 schedule to accommodate your specific conditions. And if necessary, don’t be afraid to adjust the indicated starts, durations, and/or sequences if the facts of your project differ from those on the generalized schedule. Again, there is nothing sacred or absolute about what is shown. Let’s look at an example where Construction is planned to start at Engineering being 40% complete.

**Example – Construction starting at Engineering 40% complete**

In this example, Engineering activities are assumed to have the same start dates, durations, and relative to each other as the generalized schedule. This is a good assumption in that if the generalized schedule’s engineering activities were effective within generally accepted engineering practice (which they are), and therefore no engineering activities are accelerated (which they could be, but schedule acceleration is beyond the scope of a basic project controls document). Procurement and Equipment Deliveries do not change either.

The same assumption will be made regarding the construction activities being the same durations and start dates relative to other construction activities, just the Start of Construction date is moved forward in time. This is not as good an assumption as for engineering, in that accelerating Construction relative to Engineering completion has inherent risks (also beyond the scope of this document). But this assumption will be made, and we will see the impact on schedule upon making these assumptions.

Since Engineering activities and progress are the same as the generalized schedule, there is no change to the Engineering schedule, except the Project Closeout duration is shortened. Engineering reaches 40% complete at approximately 36 percent of original Project Duration. Therefore, the Start of Construction is now to be advanced to 36 percent of original Project Duration, as compared to generalized schedule’s 46%, a ten percentage (10%) point acceleration. With the Construction durations remaining unchanged, the Mechanical Completion is advanced the same ten percentage points. The new construction schedule has been overlaid onto generalized schedule, see Figure 5, with the new Start of Construction and New Mechanical Completion dates shown in heavy black vertical lines, and the revised activity bars shown in black (the Construction progress curve has been omitted to improve the graphic presentation).

This example was chosen for a very specific reason, many times and more often than not Construction Start is advanced in an effort to get the plant online and producing valuable product as soon as possible. From a project profitability standpoint this makes very good sense, and because of this, advancing construction is a popular strategy. However, there are consequences that are often overlooked or more likely glossed over at the time the decision is made to advance construction start. There are several consequences that should be carefully weighed during the decision making process that may very well reduce the apparent increased
profitability.
First, let’s look at the schedule itself:

- **Underground** - Underground Construction (ID No. 32) is now shown starting before Underground design (ID No. 5) is complete. This is not an ideal situation since as engineering and design proceeds downstream design features, such as equipment sizing from suppliers may cause movements in plot plan affecting early underground locations, and there are others.

- **Foundations** – Concrete installation (ID No. 33) starts when Foundation design (ID No. 12) is approximately half complete. This too is a less than ideal situation for the same reason mentioned above.

*Figure 5 – Construction Starting at Engineering 40% Complete*
• **Equipment Erection** – Equipment erection (ID No. 34) begins at about one-third through the Equipment delivery (ID No. 37). This is not all bad in that the equipment can be set onto the foundations upon arrival, rather than having to be first off loaded and stored in the laydown area, then loaded and moved to the foundation (double handling). However, Pipe erection (ID No. 38) starts when Equipment deliveries are less than half complete. This can be very disruptive for Construction in that, after pipe rack pipe is installed, equipment nozzles (meaning, equipment must be erected) are required to be in place for piping spools to be installed. The problem here is that it is inevitable that the first piping spools delivered to the site are NOT the piping spools connecting to the in-place equipment nozzles.

• **Piping Erection** – In addition to the above mentioned piping problem, piping fabrication (ID No. 37) starts when piping design (ID No. 6) is just over ±60%. Also a less than desirable situation that can lead to Construction problems and rework.

Another problem with accelerating Construction Start is errors and perceived errors. Errors are a fact in dealing with any human endeavor, we try our best to minimize them but there is no eliminating them. Schedule acceleration only exacerbates the conditions. To meet construction needs, engineering may have to do some things out of sequence, that is, issue a drawing for Construction prior to some downstream engineering is complete. This situation may result in contributes to construction inefficiency, construction rework, engineering inefficiency, engineering rework, a combination of these, or all four. The result is increased cost, and possibly losing some of the reduced schedule and increasing the cost.

Again to meet construction needs Client management, Project management, and Construction management will be focused on the schedule savings and consequently put increased pressure (as if there was not already enough pressure) to speed both engineering and construction work along. The combination of increased speed and pressure generates errors inherently, and errors generate additional errors.

Finger pointing is directly related to errors, in dealing with people it cannot be avoided because no party will want to be the cause of an error. Errors inevitably leads to finger pointing. Construction will point at engineering, who will point at construction, or they will point at a supplier, who will point at construction or engineering, or one engineering group will point at another engineering discipline, or one construction craft at another craft. With the management focus on schedule acceleration, the increased pressure on the entire workforce, increases the tendency to finger point, which in turn increases conflict and distrust of the other party, and everyone on the project team is the ‘other party’. Team disharmony can mount to become extremely disruptive, cost more money, and again threatening the very schedule savings the acceleration was to provide.

The Construction Industry Institute (CII) has an old publication, Publication 6-3, dated April 1987, titled **Model Planning and Controlling System for EPC of Industrial Projects**, there is a paragraph I have reflected upon many times when required to shorten the schedule.

> “The pressures and mistakes associated with extreme fast-tracking can easily strain the relationships among owner, engineer, and contractor and destroy the team atmosphere so essential to success. To the workers, rework and waiting for materials translates into incompetent project management – a major demotivator. In an atmosphere of tension and demoralized workers, quality inevitably suffers.”

I strongly suggest not only reading this entire CII document, but also re-reading every year
or so to reinforce the concepts discussed. I only ask that you, the reader, once you have
attained the management leadership role responsible for having to make the decision to
accelerate the schedule that you at least stop and reflect on these very real issues.

Tom Wolf has over 40 years petroleum and petrochemical experience, including 25 years in project
management. He holds a BS degree in Mechanical Engineering.

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