

Engineering Project Management

By

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Introduction

Project management principles and processes apply to all projects. However, there are unique approaches, tools, and techniques that work better with specific kinds of projects. Such is the case with engineering design projects, which have these unique challenges:

- Stage-gate/phased approach (study, preliminary design, final design)
- Leading a multi-disciplined design team
- Percent complete milestones
- Permitting and code compliance
- Lengthy technical specifications
- Complex systems with performance risks
- Difficult construction cost estimating
- Often no direct return on investment or payback period
- Risks of impact to health and safety of the public

Project managers (PMs), design managers, and engineering leads are expected to achieve the project goals while tackling these challenges. High quality designs are expected in a short time period and at low cost. There is a saying that you can only pick two of three: quality, speed, or cost. But on most projects, all three are expected with specific goals defined for each! Project management is the key to achieving the trifecta: high quality, on schedule, and within budget.

This course focuses on addressing the unique demands of being PM for an engineering design project.

Design Management

For engineering design projects (or the design phase of a project), the term “design management” is often utilized for project management activities. Design management refers to managing design activities for both the overall team (by the PM) and design activities within a discipline (PM or discipline lead). So, design management and project management overlap when referring to the management of the team or multiple disciplines. Design management differs from project management for design tasks such as performing quality reviews, collaborating with other discipline staff, and coordinating with drafters on accurately depicting design details. See Figure 1 for a depiction.

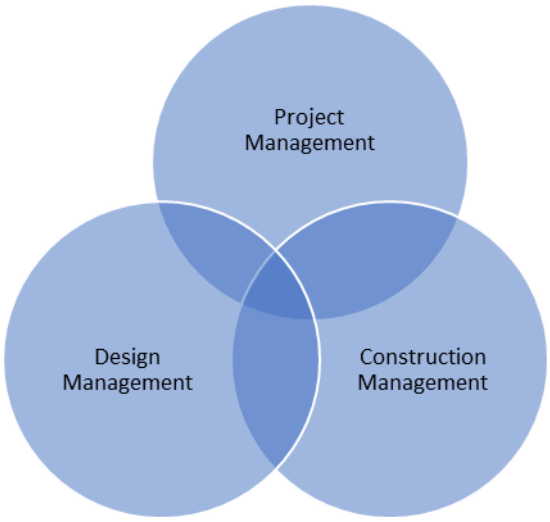


Figure 1: Overlap of Project Management with
Design Management and Construction Management

On some engineering projects, depending on the leadership skills of the design leads, the PM may take on a more active role in design management tasks. The PM and design leads should identify whom will perform certainly overlapping tasks when planning the work.

The majority of project management work is done in planning activities.

PMBOK® Guide

The most widely accepted standard for project management principles is the *Guide to the Project Management Body of Knowledge* (PMBOK® Guide) issued by the Project Management Institute, Inc. (PMI). Fundamental recommendations are provided which are widely accepted across a variety of project types and delivery types. This course makes reference to and is guided by this document.

Five process groups are defined: Initiation, Planning, Execution, Monitoring and Controlling, and Closing. All five apply to each phase/stage of a project, including the design phase.

There are twelve “Principles” for project management, as shown in Figure 2. These principles are foundational attitudes and approaches that guide all aspects of a project. The project manager should embody these principles and live them out each day.

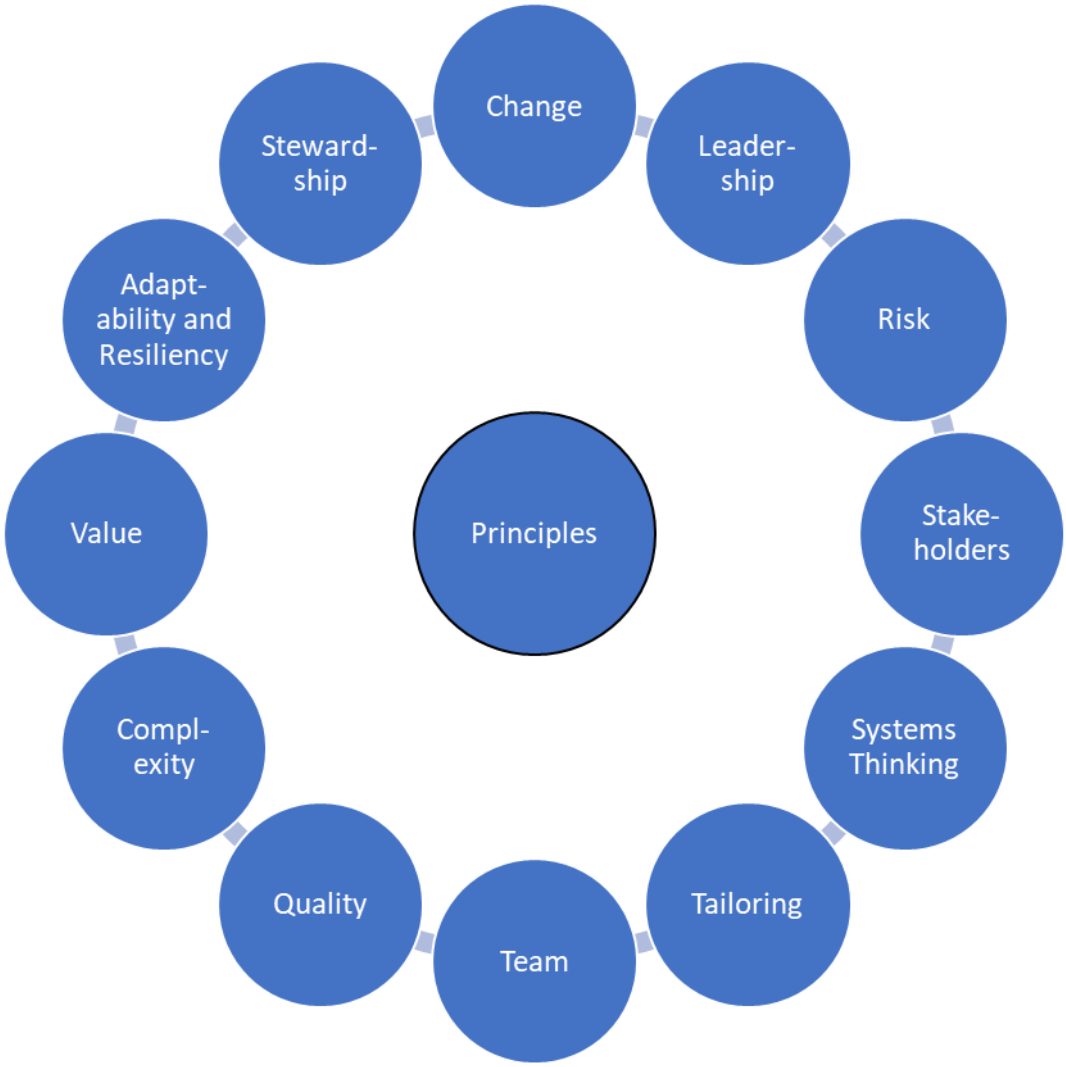


Figure 2: Twelve project management “principles” per the PMBOK® Guide.
Source: Author

There are eight “Performance Domains” for project management, as shown in Figure 3. Performance domains are the areas of activities that help achieve project goals. The domains are ways to put principles into action.



Figure 3: Eight project management “performance domains” per the PMBOK® Guide.
Source: Author

Engineering Projects

Engineering projects, often called capital improvement projects, typically involve the construction of physical improvements to real property or infrastructure. This includes both public property (municipal, special districts, utilities, state, federal, military) and private property (residential, commercial, industrial). Private capital improvement projects are often called capital expenditure projects or CapEx projects.

Engineering projects aim to install or modify physical components as opposed to software development or product development projects. However, controls features and associated programming are often a part of engineering projects. The term engineering project can refer to just the design phase, or both the design and construction phases, with the engineering team providing support during construction. For this course, just the design phase is covered.

Examples of engineering projects in construction are provided in the following figures.





Figure 4: Residential construction examples.

Sources: commons.wikimedia.org/wiki/File:Ilham_Aliyev_viewed_construction_of_residential_complex_built_by_MIDA_10.jpg
commons.wikimedia.org/wiki/File:V%C3%A4stra_gatan_construction_project_01.jpg





Figure 5: Road construction examples.

Source: commons.wikimedia.org/wiki/File:Road_construction_works_-_geograph.org.uk_-_4455596.jpg, Oast House Archive commons.wikimedia.org/wiki/File:Road_building-Hungary-1.jpg, p.d.



Figure 6: Commercial (left) and industrial (right) improvement examples.

Source: commons.wikimedia.org/wiki/File:Construction_of_Hagonoy_Common_Terminal_and_Commercial_Complex_09.jpg, FBenjr123 commons.wikimedia.org/wiki/File:Factory_Aggmax_construction_(6240237708).jpg, Peter Craven



Figure 7: Water and wastewater improvement projects.

Source: commons.wikimedia.org/wiki/File:New_water_tank_working_progress.jpg, Sheetal joshi72
https://commons.wikimedia.org/wiki/File:Dhulikhel_CW_under_construction_(4975036180).jpg, SuSanA Secretariat

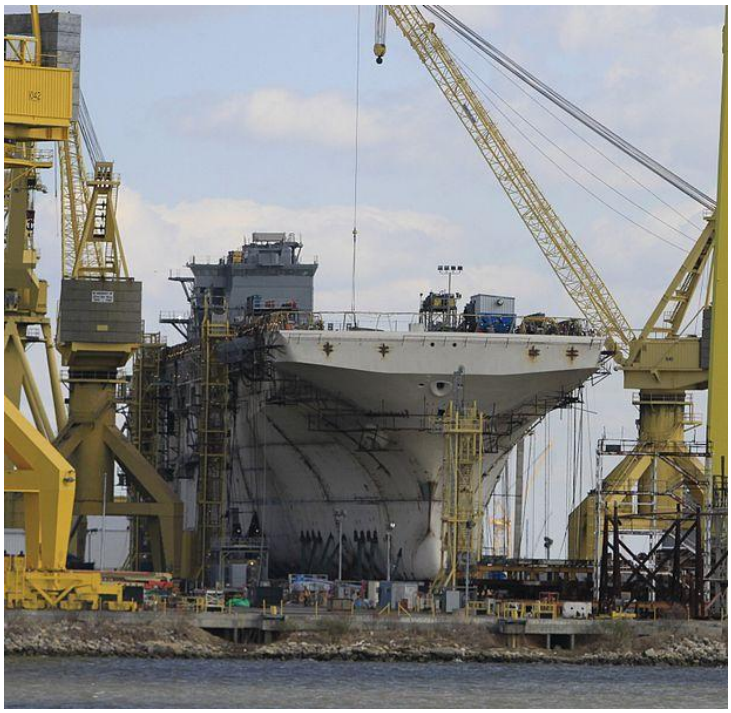


Figure 8: Miscellaneous high-profile improvement projects.

Source: commons.wikimedia.org/wiki/File:World%27s_Tallest_Shiva_Statue_in_construction_phase_at_Nathdwara,_Rajasthan.jpg
commons.wikimedia.org/wiki/File:LHA-6_USS_America_under_construction_at_Ingalls_Shipbuilding_October_19_2001_mg_0184.jpg

Staff Organization

A staff organization chart helps define the roles of each team member and subconsultants.

Basic staff organization charts are provided in Figure 9 for a design project and Figure 10 for a design-only project. The PM is in red. In reality, there will be many more staff involved, including a client services manager, cost estimator, administration assistant, accountant, document processor, drafters, surveyor, permit specialist, etc. Design staff assignments and titles vary greatly based on the project, delivery type, and organizations involved.

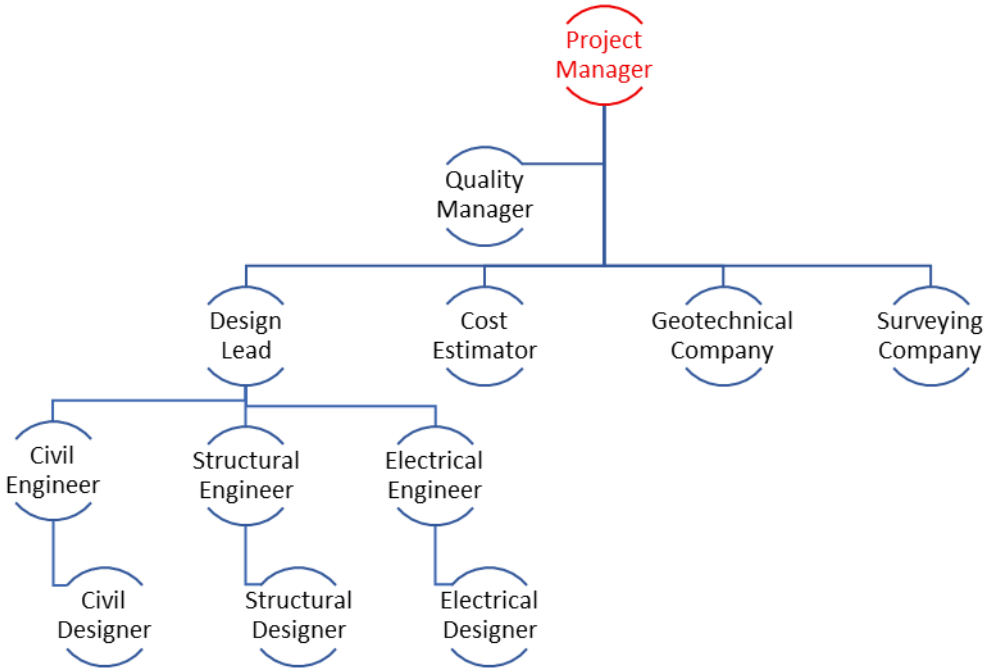


Figure 9: Example Staff Organization Chart for a Design Project

Source: Author

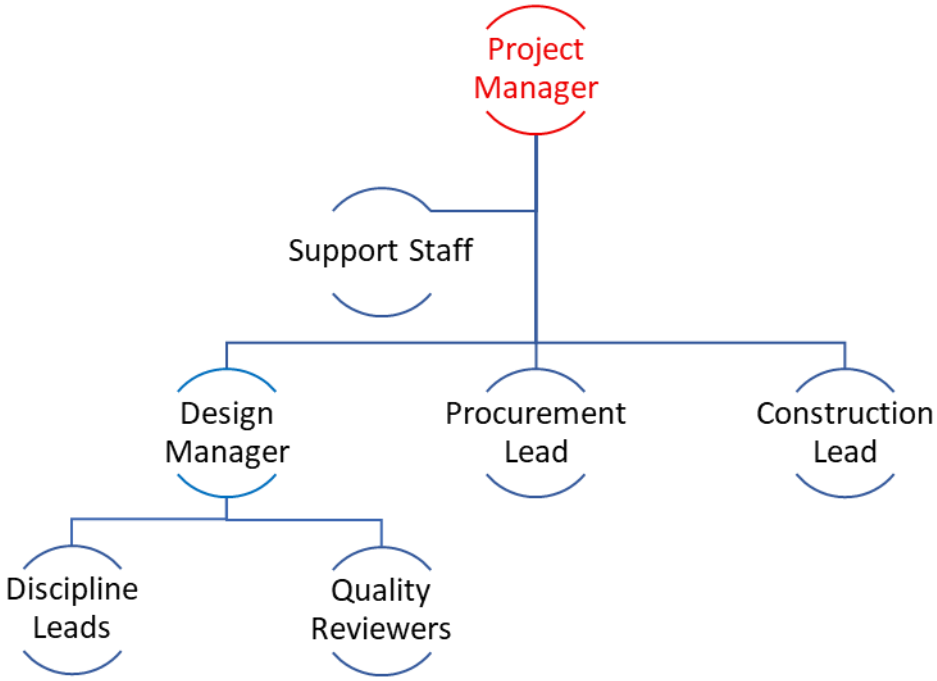


Figure 10: Example Staff Organization Chart for a Design-Build Project

Source: Author

In Figure 10, there is a “Design Manager” assigned to manage the engineering work by all disciplines. This is common on large design projects, in which it is helpful to assign a single individual as responsible for leading the design process. Below are common titles assigned to this individual:

- Design lead or leader (DL)
- Design manager (DM)
- Design coordinator
- Design director
- Engineering lead
- Principle engineer
- Engineering manager

Scope of Work

The scope of work describes the planned improvements and defines the deliverables required to complete the project. It is essential to have an accurate and detailed scope of work to meet schedule and budget goals.

Contract Agreement

Normally the scope of work starts as a section in the proposal for services, which then becomes part of the contract agreement. Each contract is unique depending on the parties involved and the nature of the improvements. Options for incorporating the scope of work include:

- Copy-paste scope of work text into body of the contract
- Insert scope of work pages as an attachment
- Reference the proposal in the contract
- Re-write the scope of work into the contract in owner preferred terms

A typical contract includes the following parts:

1. General Information:
    a. Company information, project name, number, location, etc.
    b. Very short purpose of project or summary or work
2. Scope of Work
    a. See the next page for details
3. Schedule
    a. Exact dates or weeks from notice to proceed for each task completion
    b. Often called milestones
4. Cost
    a. Cost breakdown by tasks
    b. Total cost
5. Terms of Payment
    a. Lump sum, time & materials, shared savings, etc.
    b. Invoice monthly, with each deliverable, or other intervals
6. Assumptions and Exclusions
    a. Sometimes part of the scope of work section
7. Dispute Resolution and Termination (fine print)
8. Signature Page:
    - Names, titles, signatures, notary signatures, corporate seals

Internal Design

The project may not need a contract if the design is to be done **within** the organization that will own the improvements. This is called “in-house design” or “internal projects”. The scope of work, schedule, and budget are normally documented and approved by an authorized person or group in the organization.

Here are internal design examples:

- The Engineering Department at the County of Chopter performs a design for road widening for a new bike lane on County Road BB. An agenda item with a scope of work, budget, and schedule was approved by the County Commission. The project is funded from the annual budget for road improvements.

- The Army Corps of Engineers designs flood protection improvements on government property. A feasibility study was performed, a scope of work written, and project approval obtained from the legislative authority and local agencies.

- A large manufacturing company uses the in-house engineering department to perform the design for production equipment improvements. The plant manager submitted a CapEx request with a written scope of work and budget. The project was approved by the CFO and Director of Engineering.

Scope of Work

The following are typical components of a written scope of work:

- Description of improvements
- Design criteria (sizes, materials, flow rates, utilities, etc.)
- Specifications, codes, and regulations to be followed
- Tasks with work details, for example:
  - Task 1: 30% Design – Perform a site survey, create an existing conditions plan and site plan in AutoCAD
- Deliverables for each task, for example:
  - Task 1 Deliverables: design report, preliminary drawings & cost estimate
- Assumptions and Exclusions
  - List of work not included or by others:
    - Examples: surveying, geotech report, utility locates, permitting, landscaping, 3D renderings, etc.
  - Costs like permit fees
  - Software to be utilized

Add Clarity

A clear scope of works sets up a project for success. A vague or inconsistent scope of work makes the project goals a blurry moving target which is hard to hit. Also, a vague scope makes it difficult to gain approval for additional funding for any changes (change order approval) because it can be argued that the supposed change should actually be part of the original scope.

The best time to add clarity to the scope is during the proposal development. Once the proposal is accepted and contract executed, adding clarity to the scope of work can be done officially by documentation such as a change agreement or internally as part of the work plan development.

The following are ways to add clarity to a scope of work:

- List design criteria
- Define disciplines included and excluded
    - For example:
        - Included: Architectural, Structural, HVAC, Electrical
        - Excluded: Civil, Geotechnical, Landscaping, Plumbing
- Reference or attach previous studies or reports that describe the proposed improvements. Be sure to describe how the report applies to the scope of work.
- Attach preliminary drawings, sketches, or 3D model images
- Attach drawing list or define estimated number of drawings
- Attach specifications list or estimated number of specification sections
- Clarify if hardcopy documents are provided and the quantity
- Indicate the maximum number of review iterations to limit updates
- Describe permitting scope (see next subsection)
- List known manufacturers or vendors for complex equipment or structures. Sometimes a change in vendor mid-design and cause significant rework.
- List sizes and quantities of major components such as buildings, tanks, equipment, pumps, pipelines, roads, etc.
- Indicate any use of existing drawings, surveys, or utility locates
- Maximum number of travel days, onsite on weekdays or weekends, etc.
- Maximum number of meetings and who will record meeting minutes
- Indicate level of accuracy and detail for the cost estimate
- List any subconsultants and consider including their proposals as attachments
- List assumptions and exclusions

Permitting Scope

Gaining regulatory agency approvals (known as permitting) is a major part of the design effort. Permitting issues are often responsible for project delays and costly redesign. These risks can be minimized by developing a permitting strategy and describing it in the scope of work.

Key permitting elements to include in the scope of work:

- List of planned regulatory agency submittals,
- Number of resubmittals in scope,
- Estimated agency review times,
- Assumed number of review comments,
- If any zoning variances are predicted,
- Any anticipated public presentations or hearings,
- If Owner or Consultant will be the main contact and applicant, and
- Whom will pay permit fees.

Here is an example list of permits in a scope of work:

1. Watershed Authority – Stormwater Design Approval (2 rounds)
2. Fire Marshall – Conceptual Approval (2 rounds)
3. Industrial Wastewater Discharge – Industrial User Survey (1 round) and Permit Application (2 rounds)
4. City Planning Department - Site Plan Approval (2 rounds)
5. Building Department – “Dry Run” Building Permit Comments (1 round only)

Example Problem 1

Project Manager Silas writes the following draft scope of work for an engineering services contract. What key element is missing?

Scope of Work

Design a new circular driveway to replace the existing straight driveway.

Design Criteria

- Bituminous type pavement with a seal coat
- Turn around circle for a large pickup truck
- Follow DOT standards where applicable

Task 1 – Preliminary Design

- Perform a topographical survey
- Create a site plan
- Determine pavement and subgrade thicknesses
- Create a cost estimate with accuracy range of 60% to 180%.

Task 2 – Final Design

- Create final drawings including an existing condition plan, demolition plan, site plan, and typical details.
- Create a cost estimate with accuracy range of 80% to 140%.

Exclusions

- Permitting, permit fees, geotech, landscaping

Solution:

Upon comparing the above Scope of Work with the recommended “Key Elements to a Scope of Work” above, the “**Deliverables**” are missing for Tasks 1 and 2.

Project Plan

Question: What is the first step in an engineering project?
Answer: Creating a project plan and holding a kick-off meeting. Often the project plan is presented to the design team during the kick-off meeting.

The project plan, also called a project management plan or work plan, guides the design team in how to achieve the project goals. A project plan for a design project may include the following elements:

- Basic project information
- Project goals and objectives
- Contract information
- Summary of work
- Deliverables
- Work breakdown structure
- Milestone dates and/or schedule
- Budget with breakdown by staff or discipline
- Staff list or organization chart
- Software and CAD standards
- Management plans for risk, quality, communications, and stakeholders

To keep the document short and readable, key documents can be attached or hyperlinked, such as the Contract, Proposal, Project Schedule, Budget, Management Plans.

Example Problem 2

Continuing Example Problem 1, Silas creates the following simple work plan for the driveway design project.

Circular Driveway Design Project
Work Plan

Project Name: Circular Driveway
Internal Project Number: 04-4832
Client Project Number: PMN-392
Site Location: 221 Lucy Hills Rd
Client Contact: John Doe

Project Goals: Produce design documents for the replacement of the existing straight driveway with a new circular driveway.

Contract:

- Design Only
- Lump Sum
- Notice to Proceed
- See Executed Contract saved here: G:/Projects/04-4832/Agreements

Change Orders:

- See Change Order Log saved here: G:/Projects/04-4832/Changes

Summary of Work:

- Design a new circular driveway to replace the existing straight driveway.
- Task 1: Preliminary Design
- Task 2: Final Design
- Exclusions: Permitting, permit fees, geotech, landscaping
- See Section “Scope or Work” in Contract for additional details.

Deliverables and Milestones:

- Task 1 (due 10 weeks from NTP):
  - 30% Drawings
  - Specifications List
  - 30% Cost Estimate
- Task 2 (due 20 weeks from NTP):
  - Final Drawings, digital signed
  - Final Specifications, digital signed
  - Bid-Ready Cost Estimate

- Format:
  - All digital submittals in PDF format (no hardcopies)
  - Size 11x17 drawings
  - Native AutoCAD Civil 3D files

Staff List and Budgets:

Project Manager	Silas B.	$5,000
Civil P.E.	Mike G.	$8,000
CAD Designer	Lisa Y.	$9,000
Estimator	Kris A.	$5,000
Quality Reviewer	Jake T.	$2,000
Admin	Brandon P.	$2,000
Expenses		$3,000
Survey (by Subconsultant)		$3,000
Contingency		$3,000
Total		**$40,000**

Attached:

- Risk management plan
- Quality management plan

Staying on Time

Managing a project means being responsible for the work being completed **on time**. This is traditionally done by developing a schedule and focusing the team on completing critical path work. The initial schedule is called the "baseline schedule".

Here are steps to develop a baseline schedule:

1. List major tasks and deliverables
2. List activities required to complete each major task
3. Sequence activities
4. Estimate durations for activities
5. Create Gantt chart (MS Project, Excel, Primavera, etc.)
6. Identify the critical path
7. Allocate float
8. Assign resources (discipline or staff names) to each activity

For Step 7 (Allocate float), there are several options for adding float, also called slack, to a schedule:

- Include all float at the end (see Figure 9).
- Assign float in small increments throughout the schedule.
- Add float to specific activities, especially activities at high risk of delay.
- Each activity can have an early finish date (no float utilized) and late finish date (all float utilized).

Example Problem 3

Continuing Problem 2, Silas must create a schedule for Task 1, Preliminary Design.

For Step 1, the Task 1 major deliverables are in the work plan:

1. 30% Drawings
2. Specifications List
3. 30% Cost Estimate

For Steps 2 and 3, Silas makes a list of activities for each deliverable and puts them in sequential order:

1. 30% Drawings Activities:
    - Survey contract, perform survey, CAD setup, incorporate survey data, existing conditions plan, driveway layout, check turn radius, define slopes, add stormwater features, site plan, quality review, submit to client
2. Specifications List Activities:
    - Create specifications list, quality review, submit to client
3. 30% Cost Estimate Activities:
    - Start after "driveway layout" is done, obtain pricing, estimate direct costs, estimate overhead costs, quality review, submit to client

For Step 4, Silas adds estimated durations (working days) for each task:

1. 30% Drawings
   - Survey contract 5 days
   - Perform survey 10 days
   - CAD setup 2 days
   - Incorporate survey data 2 days
   - Existing conditions plan 2 days
   - Driveway layout 3 days
   - Check turn radius 2 days
   - Define slopes 2 days
   - Add stormwater features 2 days
   - Site plan 4 days
   - Quality review 5 days
   - Submit to client 1 day
   - Total 40 days (8 weeks)
2. Specifications List
   - Create specifications list 1 day
   - Quality review 5 days
   - Submit to client 1 day
   - Total 7 days (1.4 weeks)
3. 30% Cost Estimate
   - After “driveway layout" 24 days (delayed start)
   - Obtain pricing 6 days
   - Estimate direct costs 3 days
   - Estimate indirect costs 1 days
   - Quality review 3 days
   - Submit to client 1 day
   - Total 38 days (7.6 weeks)

For Step 5, Silas creates a Gantt chart as shown in Figure 9. Silas made this schedule in excel.

Circular Driveway Design
Project No. 04-4832
PM: Dee B.

Project Start: Mon, 10/2/2023
Display Week: 1

TASK 1 - Prelim. Design	RESOURCE	CRITICAL PATH	PROGRESS	WORK DAYS	START	END
30% Drawings						
Survey contract	PM	X	0%	5	10/2/23	10/6/23
Perform survey	Sub	X	0%	10	10/9/23	10/20/23
CAD setup	CAD	X		2	10/23/23	10/24/23
Incorporate survey data	CAD	X		2	10/25/23	10/26/23
Existing conditions plan	CAD	X		2	10/27/23	10/30/23
Driveway layout	Civil	X		3	10/31/23	11/2/23
Check turn radius	CAD	X		2	11/3/23	11/6/23
Define slopes	Civil	X		2	11/7/23	11/8/23
Add Stormwater feature:	Civil	X		2	11/9/23	11/10/23
Site plan	Civil & CAD	X		4	11/13/23	11/16/23
Quality review	Quality	X		5	11/17/23	11/24/23
Submit to client	PM	X		1	11/27/23	11/27/23
Specifications List						
Create specifications list	PM			1	11/15/23	11/15/23
Quality review	Quality			5	11/16/23	11/24/23
Submit to client	PM			1	11/27/23	11/27/23
30% Cost Estimate						
After "driveway layout"	PM			24	10/4/23	11/6/23
Obtain pricing	Estimator			6	11/7/23	11/14/23
Estimate direct costs	Estimator			3	11/15/23	11/17/23
Estimate indirect costs	Estimator			1	11/20/23	11/20/23
Quality review	Quality			3	11/21/23	11/24/23
Submit to client	PM			1	11/27/23	11/27/23
Key Dates						
NTP	PM			1	**10/2/23**	10/2/23
Due Date (10 weeks)	PM			1	12/11/23	**12/11/23**
Float	PM			9	11/28/23	12/8/23

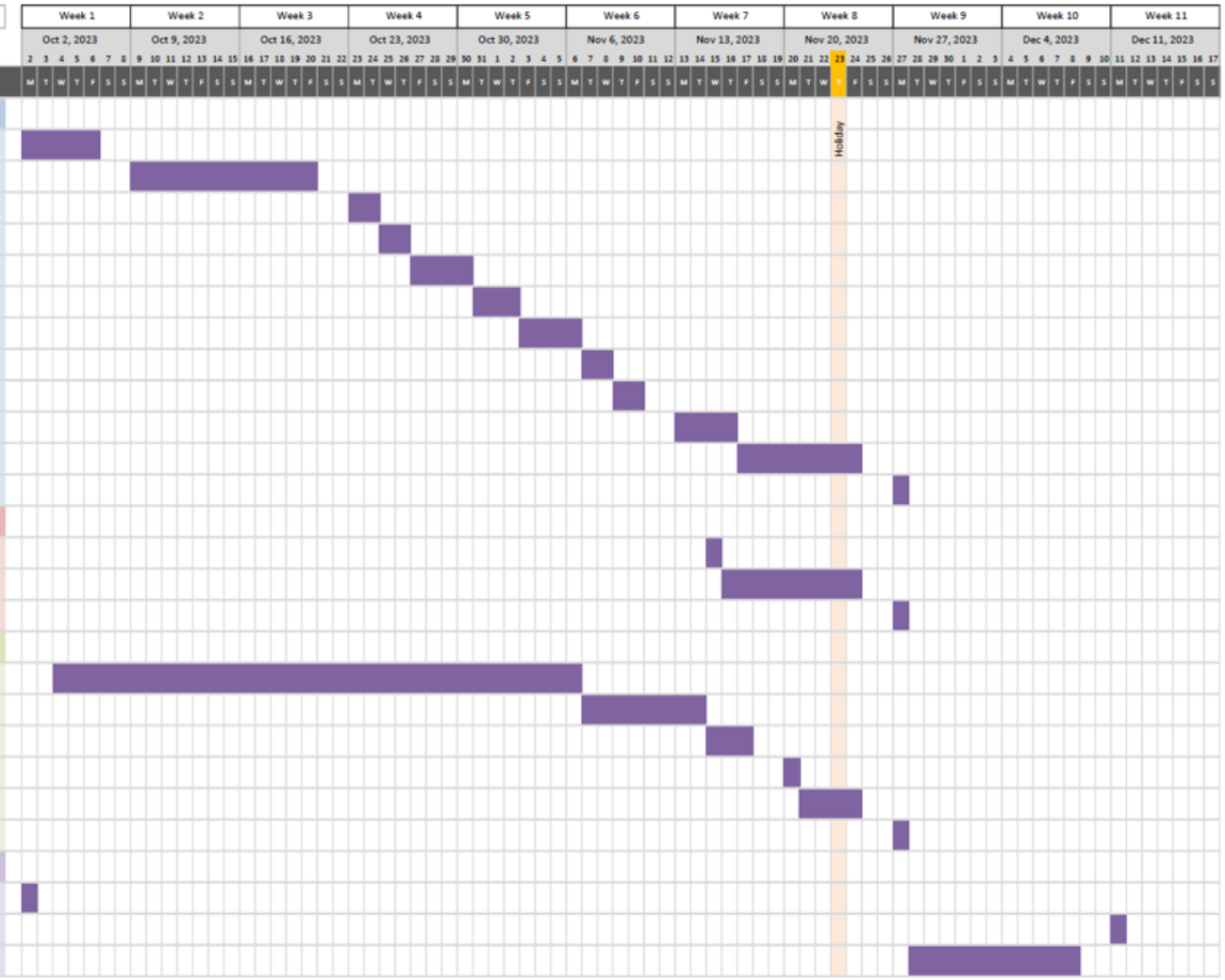


Figure 9: Gantt chart for Example Problem 3. As work progresses, percent completes are added in the Progress column.
Source: Author

For Step 6, Silas identifies the critical path as being all the activities for 30% drawings. An “X” is added in the Critical Path column in Figure 9.

For Step 7, the contractual due date is 10 weeks (70 calendar days or 50 weekdays). The earliest finish time is 41 weekdays (40 workdays plus 1 holiday) from the notice to proceed (NTP). There are 9 weekdays between the contractual due date and the earliest finish time (50 minus 41), with no holidays in the time period. Therefore, the project has 9 days of float (also called slack) which Silas added as the last row in Figure 9.

For Step 8, Silas assigns resources for each activity and adds the discipline name to the Resource column in Figure 9.

Progress Schedules

The Gantt schedule should be periodically reviewed to visually understand if work is progressing ahead or behind schedule. A vertical line is drawn for the current date. Activities to the left of the line should be completed.

The schedule can be revised as a “progress schedule” or “current schedule”. Activity durations and start dates can be adjusted based on the actual work completed and the latest projections for future work. The original “Baseline Schedule” should be saved for reference.

Percent Complete

Percent complete comparisons are a mathematical approach to determine if individual activities and the overall project is ahead or behind schedule. This is done by comparing the “scheduled percent complete” to the “actual percent complete”, as depicted in Figure 10.

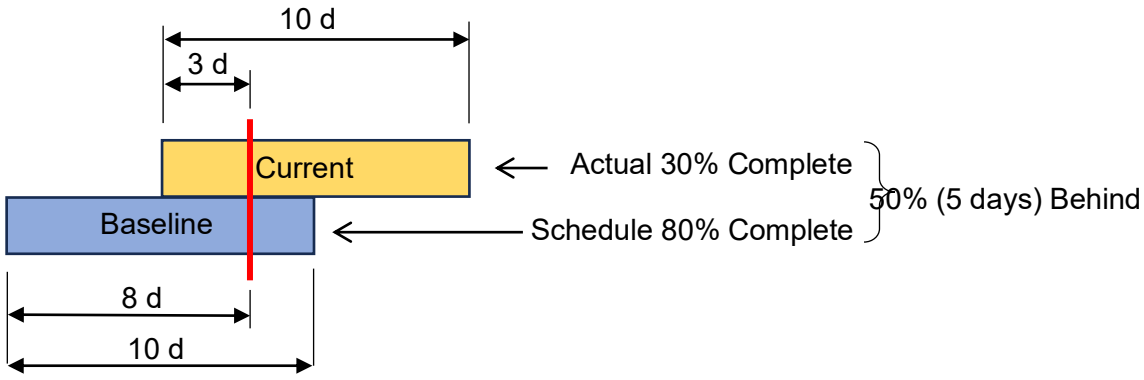


Figure 10: Percent completes for an activity that is behind schedule.
Source: Author

Example Problem 4

Continuing with Example Problem 3, four weeks have passed since the NTP. Silas wants to make a progress schedule and identify which activities are behind and ahead of schedule. The following is the status of activities that have been started:

- Survey contract Complete
- Perform survey Complete
- CAD setup Complete
- Incorporate survey data 50% complete – CAD scaling issue
- Existing conditions plan 50% complete – CAD scaling issue
- Driveway layout 67% complete
- Check turn radius 50% complete

Solution

Silas copies the baseline schedule and creates a new tab in Excel called “progress” schedule. Silas adds a vertical red line for the current date (October 30). He enters the percent complete for the above listed activities (all others remain at 0% complete). Figure 11 for the result. He adds text “Behind” next to incomplete activities to the left of the red line and adds text “Ahead” next to activities started that are to the right of the red line. Here are the ahead and behind activities:

- Incorporate survey data Behind
- Driveway layout Ahead
- Check turn radius Ahead

Circular Driveway Design
Project No. 04-4832
PM: Dee B.

Progress Schedule - Oct 30
Project Start: Mon, 10/2/2023
Display Week: 1

TASK 1 - Prelim. Design	RESOURCE	CRITICAL PATH	PROGRESS	WORK DAYS	START	END
30% Drawings						
Survey contract	PM	X	100%	5	10/2/23	10/6/23
Perform survey	Sub	X	100%	10	10/9/23	10/20/23
CAD setup	CAD	X	100%	2	10/23/23	10/24/23
Incorporate survey data	CAD	X	50%	2	10/25/23	10/26/23
Existing conditions plan	CAD	X	50%	2	10/27/23	10/30/23
Driveway layout	Civil	X	67%	3	10/31/23	11/2/23
Check turn radius	CAD	X	50%	2	11/3/23	11/6/23
Define slopes	Civil	X		2	11/7/23	11/8/23
Add Stormwater feature:	Civil	X		2	11/9/23	11/10/23
Site plan	Civil & CAD	X		4	11/13/23	11/16/23
Quality review	Quality	X		5	11/17/23	11/24/23
Submit to client	PM	X		1	11/27/23	11/27/23
Specifications List						
Create specifications list	PM			1	11/15/23	11/15/23
Quality review	Quality			5	11/16/23	11/24/23
Submit to client	PM			1	11/27/23	11/27/23
30% Cost Estimate						
After "driveway layout"	PM		80%	24	10/4/23	11/6/23
Obtain pricing	Estimator			6	11/7/23	11/14/23
Estimate direct costs	Estimator			3	11/15/23	11/17/23
Estimate indirect costs	Estimator			1	11/20/23	11/20/23
Quality review	Quality			3	11/21/23	11/24/23
Submit to client	PM			1	11/27/23	11/27/23
Key Dates						
NTP	PM		100%	1	**10/2/23**	10/2/23
Due Date (10 weeks)	PM			1	12/11/23	**12/11/23**
Float	PM			9	11/28/23	12/8/23

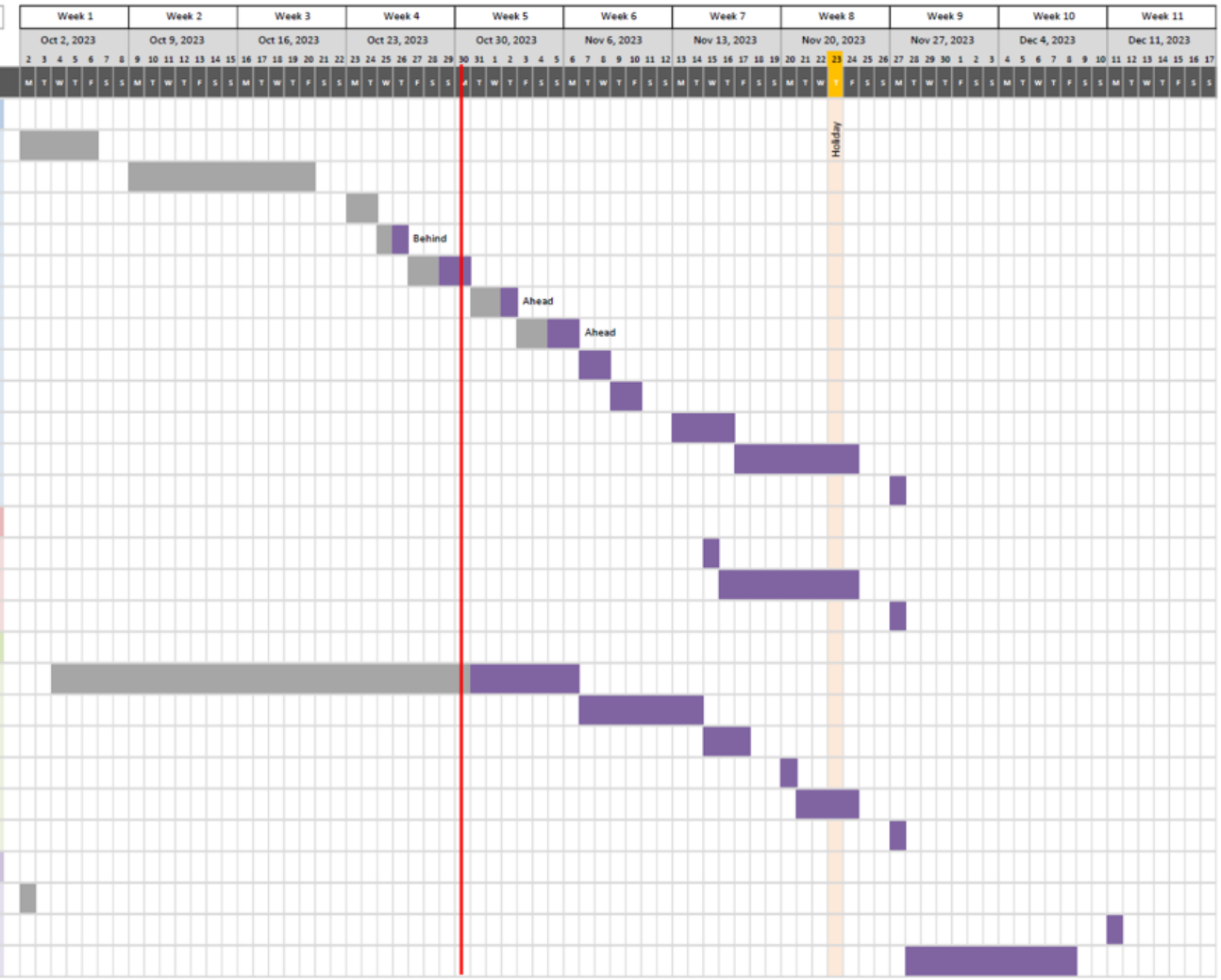


Figure 11: Progress schedule for Example Problem 4 with current date October 30.
Source: Author

Staying within Budget

The PM is ultimately responsible for keeping a project within the agreed budget. Design tasks often make up the majority of the budget on an engineering project, so oversight of design progress and activities is important.

Budget management involves these main tasks:

1. Estimate design costs,
2. Set budgets by task, activity, discipline, and/or staff,
3. Gain budget commitments from team members and subconsultants,
4. Regularly assess the budget status, and
5. Recover from cost overruns.

Estimating Design Costs

Typically, design costs are estimated during the proposal or project initiation stage. The following are common approaches for estimating design costs, in order of the most common first:

1. Estimate Activity Costs
    a. Example:

i.	Survey	Quote	$3,000
ii.	Geotech	Quote	$5,000
iii.	CAD setup	4 hrs * $100/hr	$400
iv.	Site Plan	40 hrs * $100/hr	$4,000
	…		

    b. Usually the most accurate estimate
2. Percent of Construction Cost
    a. Example: Construction cost estimated at $2M. Design at 10% is $200,000.
3. Reference Project
    a. Example: Similar project 5 years ago had a design cost of $100,000. In today's dollars with 5% inflation per year, that is $127,600.
4. Unit Cost
    a. Example: For a building size of 5,000 sq ft and typical design costs of $100 per sq ft, design cost would be $500,000.
5. Cost per Drawing
    a. Example: Preliminary drawing list has 50 drawings. At a design cost of $10,000 per drawing, design cost is estimated at $500,000.
6. Cost from Design Duration
    a. Example: Design period is 50 weeks with 10 full time staff at average $150/hr each, so design cost is estimated at $75,000.

When using approach 1 or 6, it is helpful to identify the direct and indirect costs. Although labor is often the majority of the design cost, other indirect costs can be significant. Table 2 provides examples of direct versus indirect costs.

Table 2: Direct and Indirect Costs		
Cost Type	Items	Sources & Typical Values
Direct	Labor	Raw hourly pay times overhead factor (2 to 3)
	Subconsultant or Subcontractor	From quotes or rate sheets
	Travel Expenses	Airfare, rental car, hotel, meals, mileage, parking
	Misc. Expenses	Printing, certifications, supplies, safety gear
	Permit Fees	Regulatory agency fees
Indirect	Markup	0 to 10% on subs & expenses
	Overhead	0 to 30%
	Profit	0 to 10%
	Contingency	0 to 30%
	Insurance	0 to 2%
	Taxes	0 to 5%

Assessing Budget Status

The current budget status can be determined by the “earned value” approach. Earned value is the initial budget value of the work completed to date. If spending (actual cost) is greater than the earned value, the project is overbudget. If spending is less than the earned value, the project is underbudget. The earned value assessment can be applied to the overall project and to individual activities by using a spending breakdown and percent complete for each activity.

Example Problem 5

Continuing with Example Problem 4, Silas wants to assess the budget status on Oct 30.

Solution:

Silas creates the excel sheet shown in Figure 12. He inputs data in the green "% Complete" column, which when multiplied by the budget gives the "Earned to Date" values. He then inputs the green "Spent to Date" fields. The difference between the two is the amount over or (under) budget.

The sums at the bottom represent the overall project "Earned to Date" of $10,260, "Spent to Date" of $10,100, for a difference of $160. Since spent is less than earned, the project is $160 underbudget.

Example Problem 6

Continuing with Example Problem 5, help Silas identify which discipline is overbudget.

Solution:

Looking at Figure 12, the two disciplines with overbudget activities are CAD and Civil:

- CAD has one task overbudget, three tasks underbudget (1 completed), and a net amount underbudget
- Civil only has the one activity started, "Driveway Layout," which is $490 overbudget

Therefore, the Civil discipline is overbudget.

Circular Driveway Design			Budget Status					
Project No. 04-4832					Assessment Date:		10/30/2023	
PM: Dee B.					Overall Budget Status:		UNDER	-$160

TASK 1 - Prelim. Design	RESOURCE	INITIAL BUDGET	% COMPLETE	EARNED TO DATE	SPENT TO DATE	% SPENT	BUDGET STATUS	AMOUNT OVER (UNDER)
30% Drawings			INPUT		INPUT			
Survey contract	PM	$ 500	100%	$ 500	$ 400	80%	UNDER	$ (100)
Perform survey	Sub	$ 3,000	100%	$ 3,000	$ 3,000	100%	ON BUDGET	$ -
CAD setup	CAD	$ 2,000	100%	$ 2,000	$ 1,800	90%	UNDER	$ (200)
Incorporate survey data	CAD	$ 2,000	50%	$ 1,000	$ 1,200	60%	OVER	$ 200
Existing conditions plan	CAD	$ 3,000	50%	$ 1,500	$ 1,000	33%	UNDER	$ (500)
Driveway layout	Civil	$ 3,000	67%	$ 2,010	$ 2,500	83%	OVER	$ 490
Check turn radius	CAD	$ 500	50%	$ 250	$ 200	40%	UNDER	$ (50)
Define slopes	Civil	$ 500		$ -	$ -	0%	N/A	$ -
.								
.								
.								
Contingency	Other	$ 3,000		$ -	$ -	0%	N/A	$ -
TOTALS								$ -
Total to Date		$ 40,000	40%	$ 10,260	$ 10,100	25%	UNDER	$ (160)

Figure 12: Budget Assessment Table for Example Problem 6.
Some tasks with 0% complete are not shown.
Source: Author

S-Curve

The total “Earned to Date” and “Spent to Date” values can be recorded on a regular basis, typically once a month, and then plotted along with the original budget values to form what is called an “S-Curve”. Time is the X-axis and the budget/spent is the Y-axis (in dollars or percent). See Figure 13 for an example.

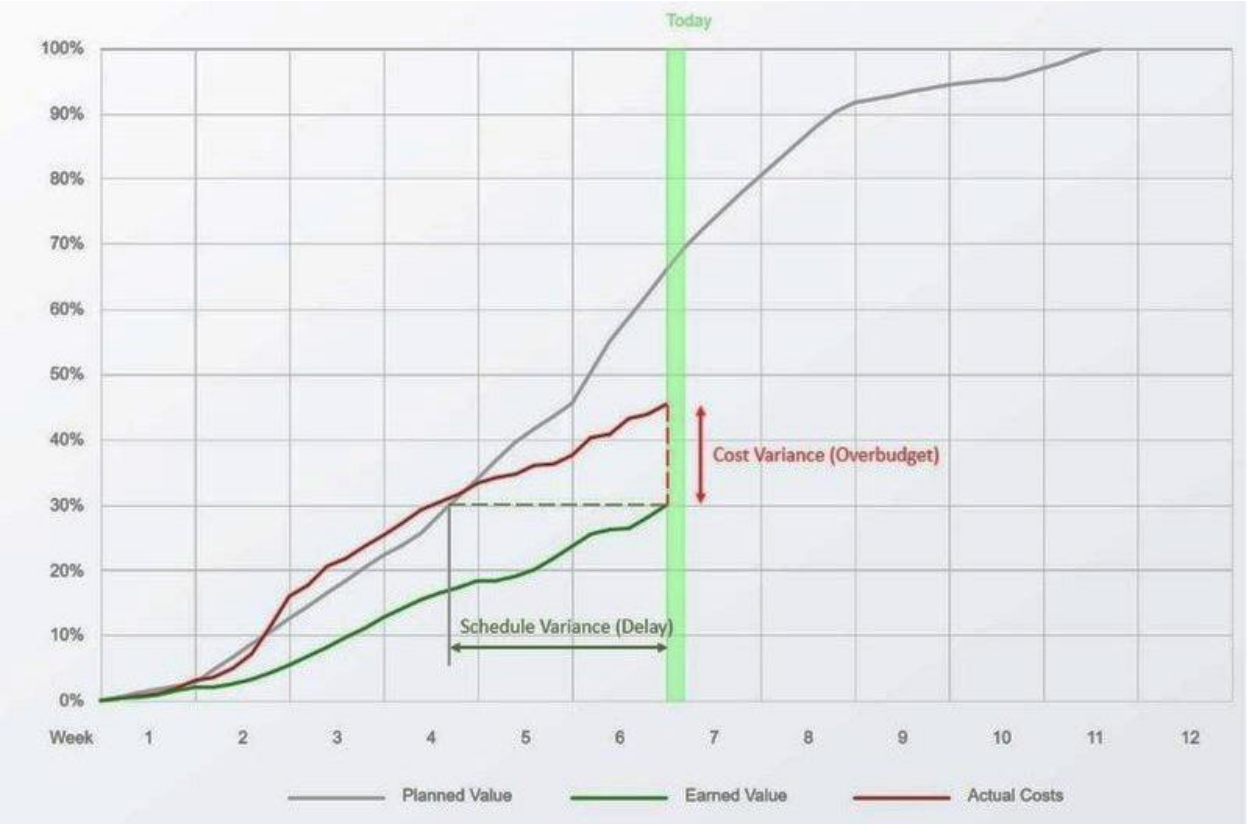


Figure 13: Earned value “S-Curve” for a project that is overbudget and delayed based on total spent (actual cost) and earned value at the end of week 6 of 12. The gray “Planned Value” line represents spending according to the baseline schedule.

Source: commons.wikimedia.org/wiki/File:EarnedValueChartNormalized.jpg, Kokcharov, CC-BY-SA-4.0

It is called an S-Curve because spending is usually greatest in the middle period of the project which makes the curve steeper in the middle and ends up shaped like a stretched out letter “S”.

Earned Value Parameters

Earned value data can be used to calculate other parameters to assess the state of the project and help direct actions to keep the project within schedule and budget. Common parameter formulas are in Table 3.

Table 3: Earned Value Parameters

Parameter	Abbr.	Formula
Total Budget	TB	from Contract
Activity Budget	AB	from budget breakdown
Planned Value (Baseline Budget to Date)	PV	∑ AB (to Date)
Actual Cost (Spent to Date)	AC	from accounting
Earned Value (Earned to Date)	EV	∑ AB x % Complete
Cost Variance	CV	CV = EV – AC
Schedule Variance	SV	SV = EV – PV
Cost Performance Index	CPI	CPI = EV/AC
Schedule Performance Index	SPI	SPI = EV/PV
Estimated Cost at Completion	EAC	EAC = TB + CV

Example Problem 7

Continuing with Example Problem 6, after week 7 is complete, help Silas identify the schedule variance, cost variance, and contingency remaining based on Figure 14.

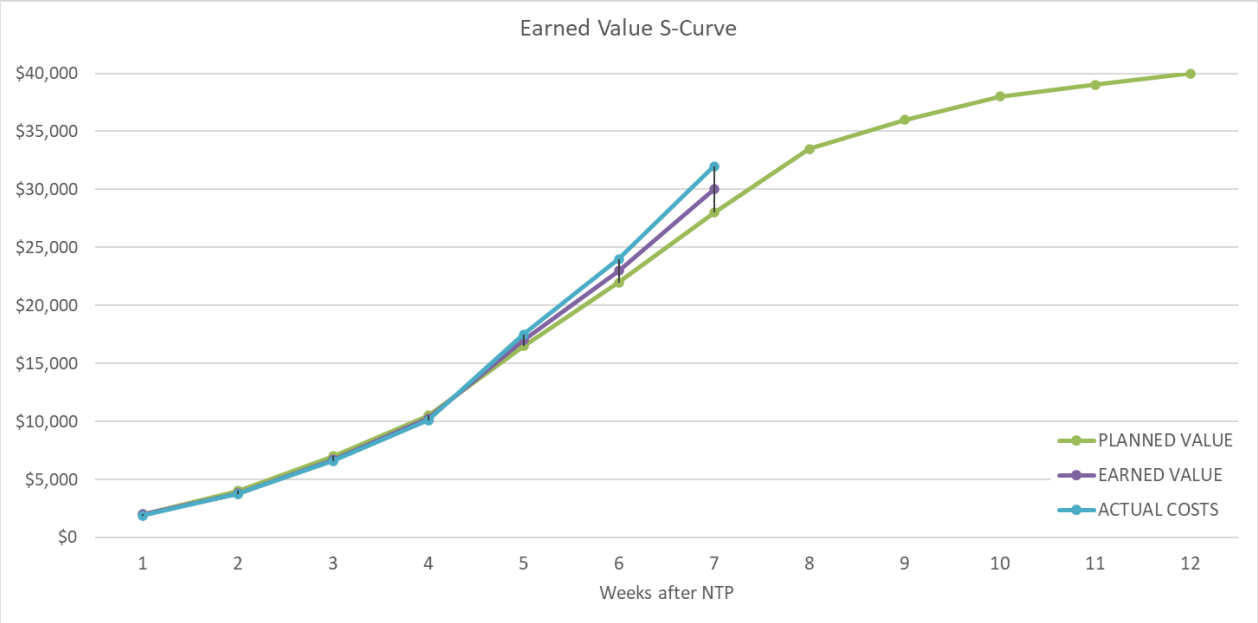


Figure 14: S-Curve for Example Problem 7.

Source: Author

Solution:

Based on Table 3 and Figure 14:

- Schedule variance (SV) = EV – PV = $30,000 - $28,000 = $2,000
  SV is positive so project is ahead of schedule.
    - Cost variance (CV) = EV – AC = $30,000 - $32,000 = ($2,000)

  CV is negative so project is overbudget.
    - Contingency remaining = Cont. + CV = $3,000 + ($2000) = $1,000

  There is still contingency remaining, although it has been reduced.

Gain Commitments

A leader can accomplish very little without the help of a team. And odds are most team members will already be busy with other work. Thus, the success of the project depends on team members giving the project the time and attention required. Probably the most effective way to ensure this happens is by gaining commitments from each team member.

Examples of gaining commitments from team members:

- Email:
  - PM emails team members asking for number of hours (budget) and weeks (schedule) needed for each to complete their portion of the work.
  - Each team member responds with hours and weeks needed.
- Phone Calls:
  - PM calls each team member and asks for budget and schedule needs.
  - PM documents the responses and follows up with an email to each team member indicating the budget and schedule commitment.
- Individual Meetings:
  - PM meets with the lead engineer for each discipline and asks for budget and schedule needs.
  - PM documents the responses and follows up with an email to each lead engineer indicating the budget and schedule commitment.
- Group Meeting:
  - PM facilitates a group meeting and asks for budget and schedule needs from each member.
  - PM documents the responses and follows up with a group email indicating the budget and schedule commitments.

Gaining commitments is effective because staff:

- Want to keep their word
- Want a reputation as trustworthy
- Take ownership of their budget and schedule
- Are more likely to put in extra time as needed
- Are less likely to take on too much work from other projects
- Feel that their input is important
- Fear being blamed if the project goes overbudget or beyond schedule

To foster commitment, leaders can:

- Clearly define goals and expectations for both the overall project and individual staff or discipline teams
- Involve team members in project planning activities
- Ask what is needed from others for them to meet their goals
- Ask what may hold them back from meeting goals
- Check-in with team members on project status, including budget and schedule
- Reiterate the importance of staying within budget and schedule

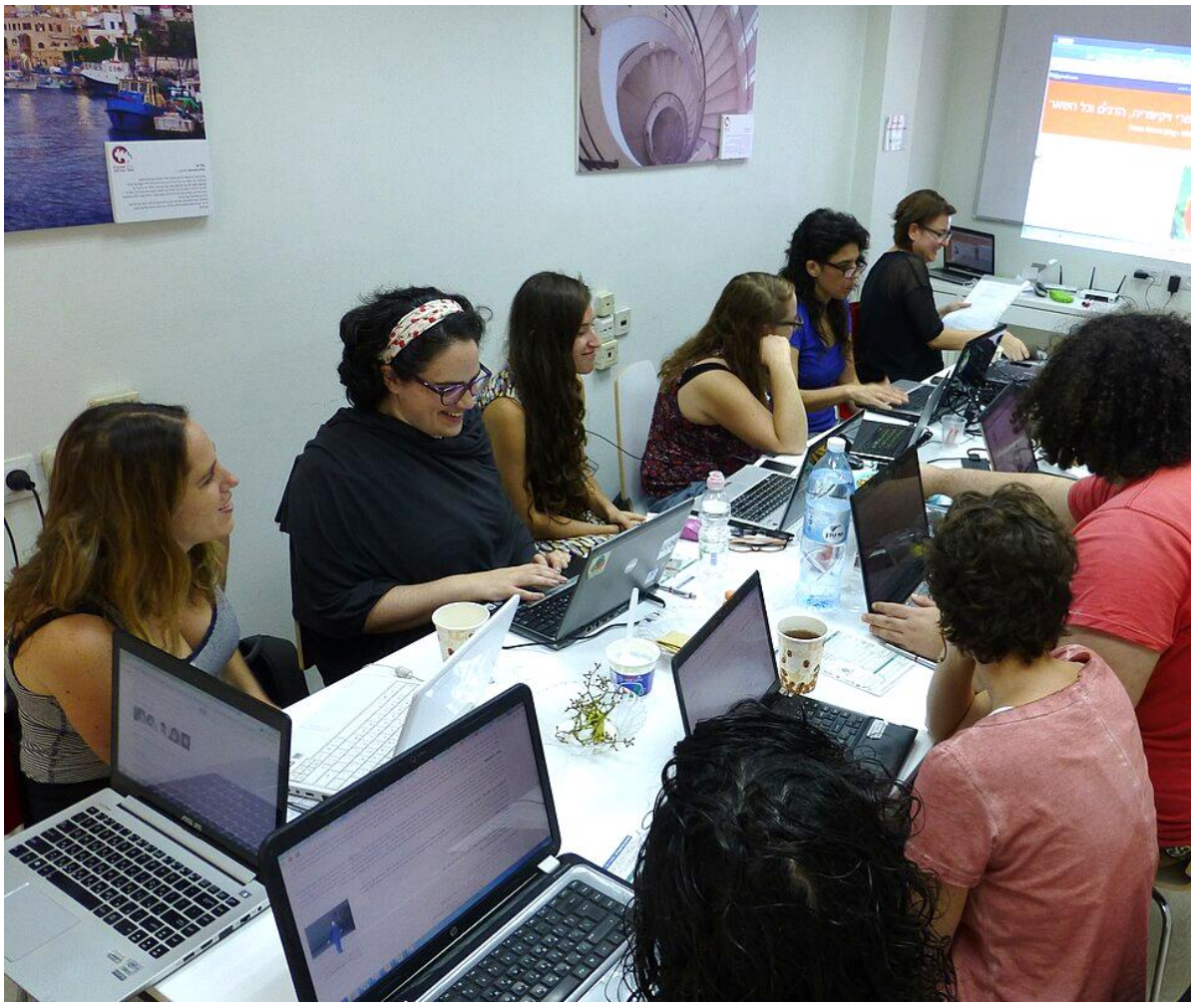


Figure 15: Internal project meetings are a good opportunity to review original commitments along with the status of the budget and schedule.

Source: commons.wikimedia.org/wiki/File:Wiki_Women_Editors_Project_-_Opening_Meeting_(9).JPG, Chenspec, CC-BY-SA-3.0

Change Management

A “change” is a need to include something not identified in the scope of work or agreement. Usually this is a change to the design, such as adding a feature. But it can also be a delay outside the control of the design team. Note that addressing a quality review comment to fix an error is not a “change” in this context.

Nearly every engineering project has scope changes. It helps to be prepared for these changes with a change management plan. And then once a potential change is identified, procedures should be followed to minimize the risk of rework or poor quality work. A typical change workflow is as follows:

1. Potential change is identified
2. Cost and budget impact quantified
3. Change details presented to stakeholders
4. Change approved (in writing or by signed contract)
5. Budget and/or schedule revised
6. Change implemented
7. Change quality reviewed
8. Revised design submitted

A Change Order Log keeps track of changes and includes all the changes to the budget and schedule. See Table 4 for an example.

Table 4: Example Change Order Log

Proposed Change No.	Change Order No.	Name	Cost	Schedule Change	Status
PC1	N/A	Building Expansion	$80,000	+10 wks	Denied
PC2	CO1	New Separate Building	$100,000	+12 wks	Approved
PC3	CO2	Add Cooling System Redundancy	$20,000	+ 2 wks	Approved
PC4	TBD	Add Access Control	$10,000	+ 0 wks	Pending

Risk Management

Risks are potential events that would have a negative impact on the project. Risk management involves these activities:

1. Identifying risks
2. Preparing for risks
3. Responding to risks

The goal of risk management is to minimize the impact of risks in order to keep the project on track for meeting project goals.

Risk Register

A risk register is a table with a list of identified risks. Normally, there are columns for risk description, probability (aka likelihood), cost & schedule impact (aka severity or consequence), priority (aka rank), mitigation strategy, response, and status. See Table 5 for an example.

Table 5: Example Project Risk Register

Risk No.	Component / Project	Risk Description	Likelihood	Cost Impact	Schedule Impact	Mitigation Strategy	Status
1	Project B	Add parking spaces due to building occupancy change	High	$100,000	12 weeks	Apply for zoning variance	Active
2	Entire Program	Operations staff change and new review comments provided	Medium	$50,000	4 weeks	Document and finalize review comments	Active
3	Projects A & B	Key electrical engineer no longer available	Medium	$20,000	4 weeks	Gain written commitment	Mitigated

Risk Ranking

One way to prioritize risks is to assess the severity (aka impact or consequence) and likelihood (aka probability) of each risk. See Figure 16 for a plot of severity versus likelihood with resulting risk scores from 1 to 12. This is called a risk matrix.

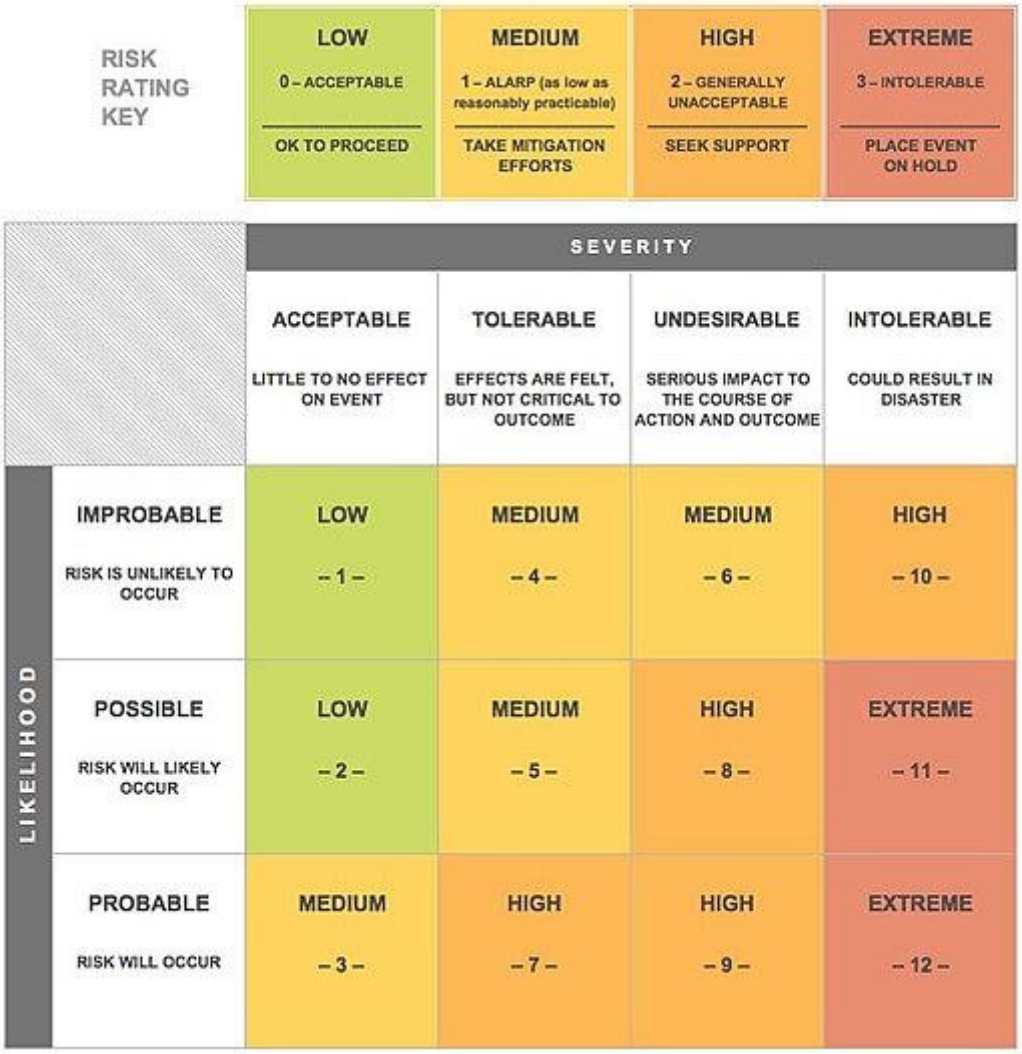


Figure 16: Risk assessment matrix with “severity” resulting in higher scoring.
Source: commons.wikimedia.org/wiki/File:IC-Risk-Assessment-Matrix-Template.jpg, U3115299, CC-BY-SA-4.0

Another approach for risk ranking is to sum the severity and likelihood values (each on the same scale), per this formula:

Total Risk = IF * Severity Score + Likelihood Score
where IF = Importance factor (often 1.5 to 2.5)

Quality Management

Quality management strives to improve the design documents by achieving the following:

- Eliminate errors and emissions
- Eliminate conflicts and clashes between disciplines
- Make the documents clear, readable, and consistent
- Reduce construction costs
- Reduce construction risks
- Fully achieve all design criteria

Design Reviews

Design reviews are also called peer reviews or quality reviews. They involve having one or more individuals review the design documents. The following are different types of reviews that can be done, with growing levels of effectiveness:

- Self-check
- Estimator review
- Project manager review
- Constructability review or construction team review
- Engineer-of-Record (EOR) review or PE review
- Single discipline review or intra-disciplinary review
- Multi-discipline review or inter-disciplinary review
- Independent review or third party review

Key elements of a design review:

- Review design at critical stages such as Basis of Design Report (BODR), 30%, 60%, 90%, Final.
- Review all submittals of design documents to client and permit agencies.
- Reviewer should be competent and experienced in the subject.
- Reviewer should be independent of the design effort, if possible.
- Review drawings, specifications, reports, calculations, supplier quotes, permits, etc.
- Save review comments and drawing markups.
- Consider using a standard template for recording review comments.

Inspiring the Team

The project manager should inspire the design team to accomplish the project goals. The following are specific tasks that can make a big difference in leading the team to success:

- Create a positive vision for project:
  - Identify inspirational aspects of the project. For example, new technologies, new software, sustainability, positive environment impact, social impact, popular products, interesting location, first of its kind improvements, major challenges to overcome, futuristic approach, etc.
  - How will the improvements make a difference in the lives of others?
  - Find impactful ways to share the inspirational aspects of the project
  - Envision success for the project, both internally and externally
  - Consider social media posts or stories on the project

- Foster team identity:
  - Create a team logo
  - Create a fun motto or saying
  - Social events
  - Team building exercises

- Early commitments:
  - During the proposal/development phase, inform key team members of the potential project including estimated budget and duration
  - Once project starts, request budget and schedule commitment from staff
  - If a verbal commitment is given, document it with an email

- Regular updates on project status:
  - Team members will be more engaged if they know the project status
  - Consider weekly or monthly status updates by meetings or emails
  - Updates should include budget status, schedule status, and any changes
  - Meet one-on-one for any individual performance problems

- Recognize outstanding work:
  - Find ways to recognize individuals who are performing well or have achieved something exciting
  - Options include words of gratitude, public recognition, bonus payment, award plaque or certificate, group celebration, and informing their supervisor

- Individual and Group Communication
  - Regular group meetings, either weekly or bi-weekly
  - Regular and unplanned individual meetings

- Listen to the needs of team members
- Help resolve conflicts and mitigate personality clashes

- Sharing Information

- Ensure team members have access to project documents
- Periodically review the network folder structure, file names, and contents
- Point out key document locations to team members
- Ask team members if they are missing information

- Motivate and Empower the Team

- Be engaging and encourage the team to achieve great things
- Put in the effort to ensure everyone is clear on upcoming tasks and have the information they need
- Overcommunicate when needed as a precaution
- Respect and empower the project manager as the leader of their project and project team; avoid micro-management
- Be a transformational leader, as shown in Figure 17



Figure 17: The Full Range Leadership Model. The goal is for a leader to put regular effort into motivating and empowering the team in order to maximum engagement.
Source: Public Domain

Summary

This course addressed the unique demands of being a leader for an engineering design project.

Key takeaways are as follows:

- A PM should spend the most time on planning activities
- Create a project specific organization chart
- Develop a clear scope of work with defined deliverables early in planning
- Create a detailed work plan at the beginning of the project
- Identify and track the critical path
- Use percent completes and earned value to check budget status
- Gain budget and schedule commitments from staff
- Keep a change order tracking log and get change approvals ASAP
- Keep a risk register log and prioritize risks for mitigation
- Ensure design reviews are completed
- Be a transformational leader and inspire the team

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Engineering Project Management - Quiz

Updated: 12/22/2025

1) **Which is NOT a "Performance Domain" in the PMBOK Guide?**
   a) Planning
   b) Resources
   c) Delivery
   d) Stakeholders

2) **Which is NOT a "Principle" in the PMBOK Guide?**
   a) Risk
   b) Team
   c) Agile
   d) Quality

3) **What can help define the roles of staff?**
   a) Permit matrix
   b) Periodic matrix
   c) Communication matrix
   d) Organization chart

4) **Which is often found in a contract?**
   a) Pictures
   b) Means of construction
   c) Milestones
   d) Business case

5) **Which is a typical component of a written scope of work?**
   a) Notary signature field
   b) Design criteria
   c) Meeting minutes
   d) Insurance limits

6) **What section of a contract could contain "lump sum"?**
   a) Dispute Resolution
   b) Terms of Payment
   c) Scope of Work
   d) Schedule

7) **What can be attached to a contract to add clarity to the scope of work?**
   a) Meeting agenda
   b) Company qualifications
   c) Org. chart
   d) Drawing list

8) **What is missing from a Scope of Work that already has sections for Design Criteria, Deliverables, and Assumptions?**
   a) Front end documents
   b) Tasks with work details
   c) Design requirements
   d) Theories

9) **What is another name for a project plan?**
   a) Work plan
   b) Work breakdown
   c) Baseline schedule
   d) Milestone list

10) **Which is NOT a good option for adding float to a schedule?**
   a) Add at the beginning
   b) Add at the end
   c) Add to high risk activities
   d) Add in multiple places

11) **What is the status of a 20-day activity which should be 50% complete per baseline schedule, and is 9 days complete on the latest progress schedule?**
   a) Behind schedule
   b) On schedule
   c) Ahead of schedule
   d) Unknown

12) **Which cost estimating technique is considered most accurate for a proposal?**
   a) Estimate activity costs
   b) Unit cost
   c) Cost per drawing
   d) Reference cost

13) **Which is NOT a direct cost?**
   a) Travel expenses
   b) Insurance
   c) Labor
   d) Hours

14) **What does it mean if spending is less than earned value?**
   a) Project underbudget
   b) Project on-budget
   c) Project overbudget
   d) Behind schedule

15) Which three lines are plotted to create an S-Curve?

a) Planned value, earned value, labor hours
b) Planned value, earned value, actual cost
c) Income, earned value, actual cost
d) Income, expenditures, actual cost

16) Why is gaining commitments effective?

a) Staff take ownership of their budget and schedule
b) Staff want to keep their word
c) Staff feel their input is important
d) All of the above?

17) Which is NOT a common way to gain a commitment?

a) Phone call
b) Email
c) Meeting
d) Letter

18) Which columns are normally on a risk register?

a) Risk Description, Severity, Response, Deadline
b) Risk Description, Probability, Evidence, Response
c) Risk Description, Cause, Evidence, Lesson learned
d) Risk Description, Probability, Severity, Response

19) What is the name of the initial project schedule?

a) Kick-off schedule
b) Baseline schedule
c) Progress schedule
d) Schedule of values

20) Which should a PM spend the most time on?

a) Documenting
b) Planning
c) Executing
d) Checking