MODULE 4

Process—
Primary Constraints

CHAPTER 3

Schedule

Predictive: Project Schedule Management

KNOWLEDGE AREAS	PROCESS GROUPS				
	Initiating	Planning	Executing	Monitoring and Controlling	Closing
Project Schedule Management		• Plan Schedule Management • Define Activities • Sequence Activities • Estimate Activity Durations • Develop Schedule		• Control Schedule	

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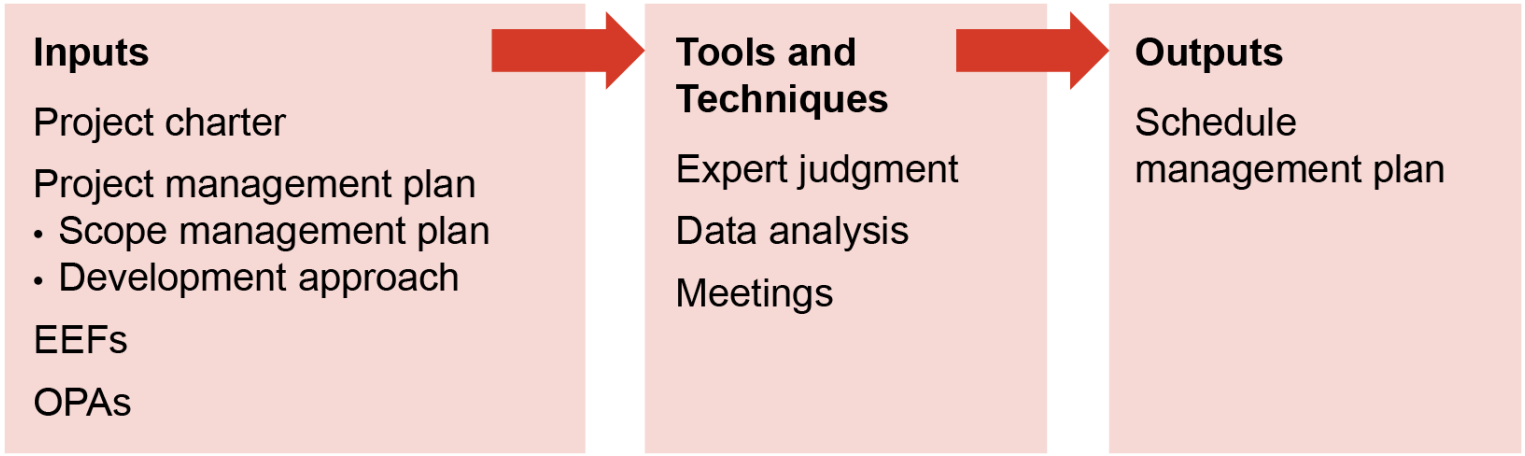
- Critically important, since project schedule often drives project budget

Agile/Hybrid Schedule Planning

If schedule-driven	• Budget also constrained: as much scope as possible. • Budget less constrained: as many resources as feasible.
Roadmap (milestone schedule) with MVP	• Add new milestones just-in-time to enable flexibility.
Schedule inputs	• Current size of backlog (can vary) vs. team velocity. • Mandatory or discretionary dependencies (blockers).
Velocity (capacity per iteration)	• Team and individual team member overall experience. • Team experience with current iteration's subject matter.

Predictive: Plan Schedule Management



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- **Inputs:** Scope baseline from project management plan and high-level milestones from project charter

Project Scheduling

Scheduling methodology + **Scheduling tool** + **Schedule model** + **Project data** = **Project schedule**

- **Methodology**—approach to determining activity relationships
- **Tool**—spreadsheets, scheduling tools (e.g., Microsoft® Project or cloud-based system)
- **Model**—framework showing all activities, durations, and relationships
- **Project data**—calendars, milestones

Schedule Management Plan

Units of measure

- Units of time, measurement system used

Model maintenance

- Ownership for model creation and maintenance

Control thresholds

- Action alert (e.g., percentage variance from baseline)

Measurement rules

- Control accounts to be measured, definitions, EVA techniques

Reporting

- What data, at what level, sent to whom, and how often

Defining Tasks for Agile/Hybrid Projects

Decomposing epics

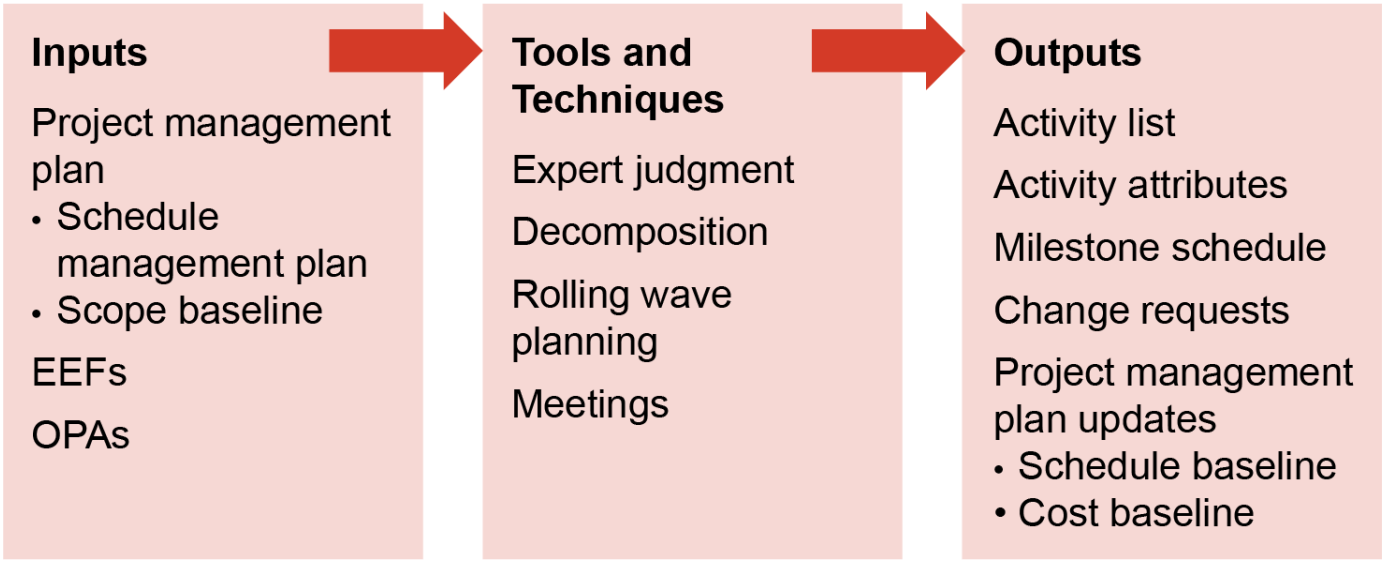
- Focus on "what," not "how" (same as work packages in WBS).
- "How" during iteration.
- Create:
  - User stories.
  - Defects (define error + how to replicate).
  - Spikes (timeboxed research or prototype).

User stories

- Brief description.
- Deliverable value.
- Specific user (persona).
- Promise for conversation.
- Clarify details (when WIP).

"As a [persona], I want [features/requirements] so that [specific benefit] is received."

Predictive: Define Activities



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- The activities that comprise each work package
- The level at which estimating, scheduling, executing, monitoring, and controlling occur

Activity Attributes

- Codes
- Resource requirements
- Owners
- Imposed dates
- Governing specifications
- Constraints
- Assumptions
- Types
  - Level of effort
  - Discrete effort
  - Apportioned effort
- Logical relationships
  - Predecessors and successors
  - Leads and lags

The activity list must provide enough information to guide team members.

Discussion Question

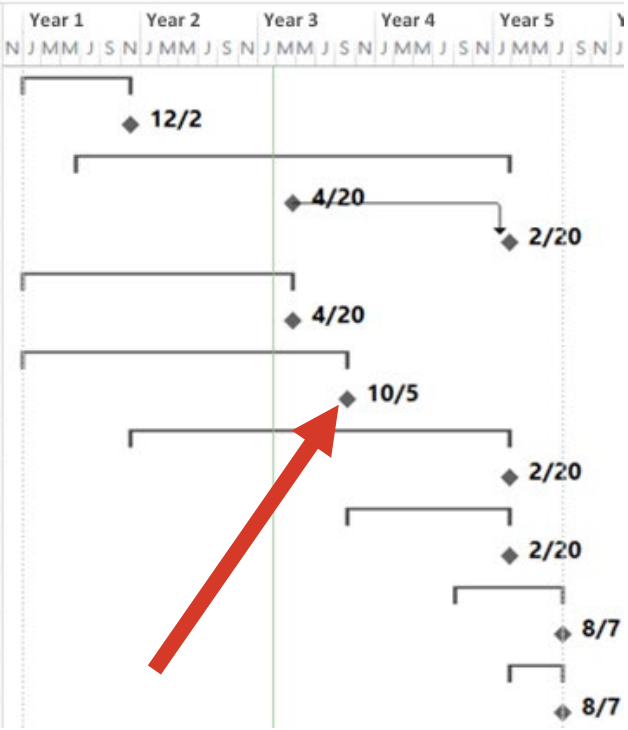
Which activity would be considered a level of effort (LOE) activity?

A. Scheduled auditing of project billings
B. Review of current technology during design phase
C. Project managers' regular correspondence with stakeholders
D. Hiring a consultant

Milestone Schedules

All significant points or events in a project

	Task Name	Duration	Start	Finish	Predecessors
1	**Preclinical Investigation and Testing**	**12 mons**	**Tue 1/1/Y1**	**Mon 12/2/Y1**	
5	Submit License Application	0 mons	Mon 12/2/Y1	Mon 12/2/Y1	4,3
6	**Submission**	**48 mons**	**Tue 6/18/Y1**	**Mon 2/20/Y5**	
8	Complete Profile Review	0 mons	Mon 4/20/Y3	Mon 4/20/Y3	7
9	Obtain License	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	8FS+24 mons
10	**Creation of Product Profile**	**30 mons**	**Tue 1/1/Y1**	**Mon 4/20/Y3**	
13	Complete Profile	0 mons	Mon 4/20/Y3	Mon 4/20/Y3	12
14	**Formulation and Packaging**	**36 mons**	**Tue 1/1/Y1**	**Mon 10/5/Y3**	
17	Complete Formulation and Packaging	0 mons	Mon 10/5/Y3	Mon 10/5/Y3	16
18	**Clinical Investigation**	**42 mons**	**Tue 12/3/Y1**	**Mon 2/20/Y5**	
20	Complete Investigations	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	19
21	**Construction of Manufacturing Facility**	**18 mons**	**Tue 10/6/Y3**	**Mon 2/20/Y5**	
25	Complete Construction	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	24
26	**Preparing for Launch**	**12 mons**	**Tue 9/6/Y4**	**Mon 8/7/Y5**	
33	Complete Launch Preparations	0 mons	Mon 8/7/Y5	Mon 8/7/Y5	28,31
34	**Launch**	**6 mons**	**Tue 2/21/Y5**	**Mon 8/7/Y5**	
39	Close Project	0 mons	Mon 8/7/Y5	Mon 8/7/Y5	38,37,36,35



Prioritizing and Sequencing in Agile/Hybrid Projects

Backlog grooming

- Highest to lowest in priority. (Can redo at each iteration.)
- Add, delete, or modify based on feedback.

WSJF/CD3

- CD3 = Cost of Delay/ Duration
- WSJF = Cost of Delay/ Job Size

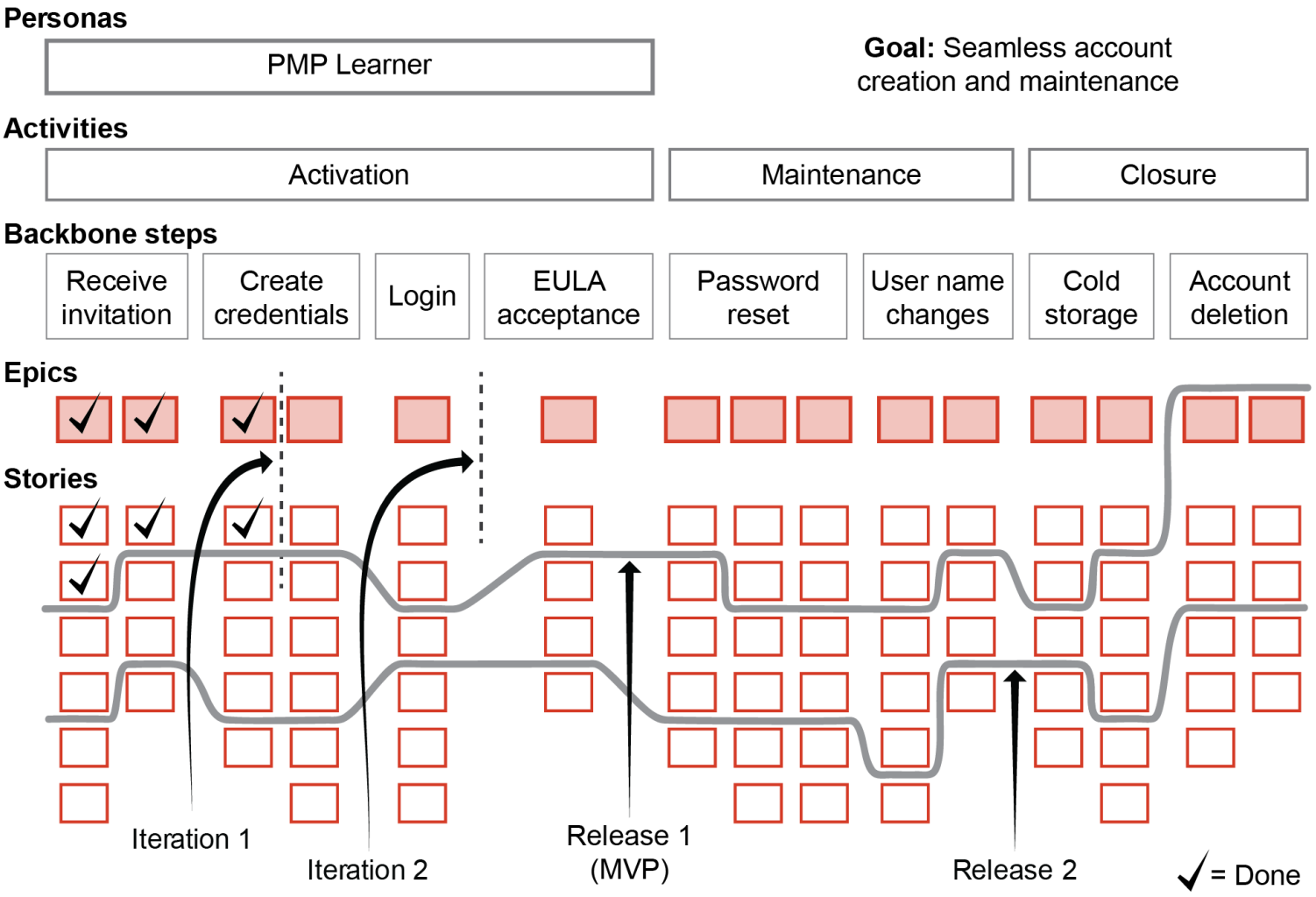
User Story Mapping

- To avoid "analysis paralysis" in large backlog.
- Can do when making roadmap or to refocus backlog.

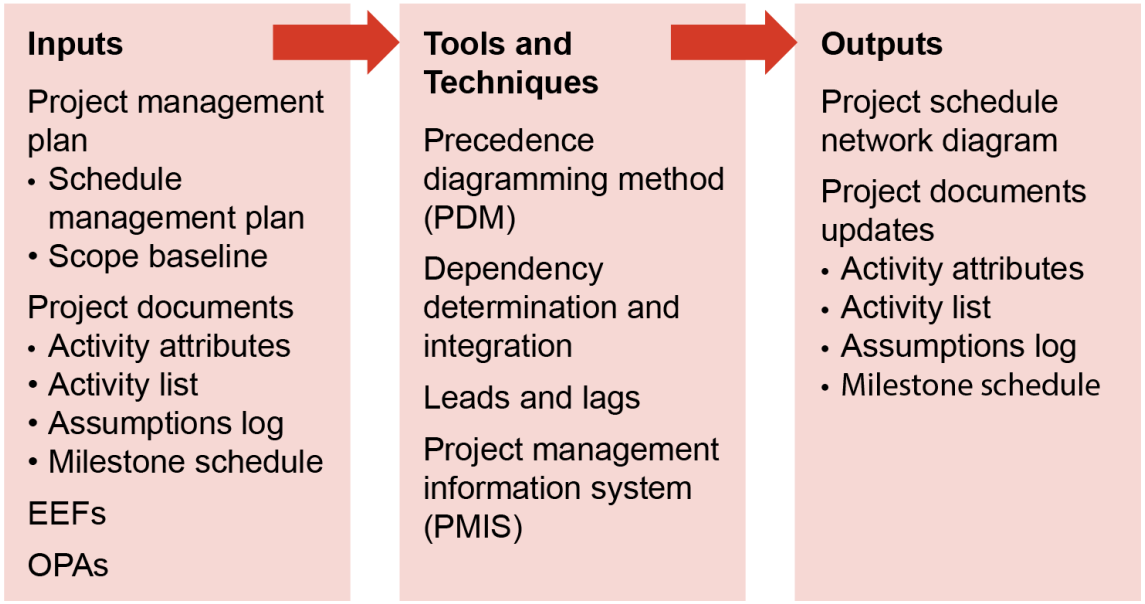
User Story Mapping Steps

1. Clarify mapping goal and scope.
2. Create personas.
3. Create story backbone (user journey in major tasks/steps).
4. Create activities (themes) and put above backbone.
5. Create epics.
6. Search for gaps.
7. Prioritize activities and stories and validate scope.
8. Slice map into major releases/features and iterations.

User Story Mapping



Predictive: Sequence Activities



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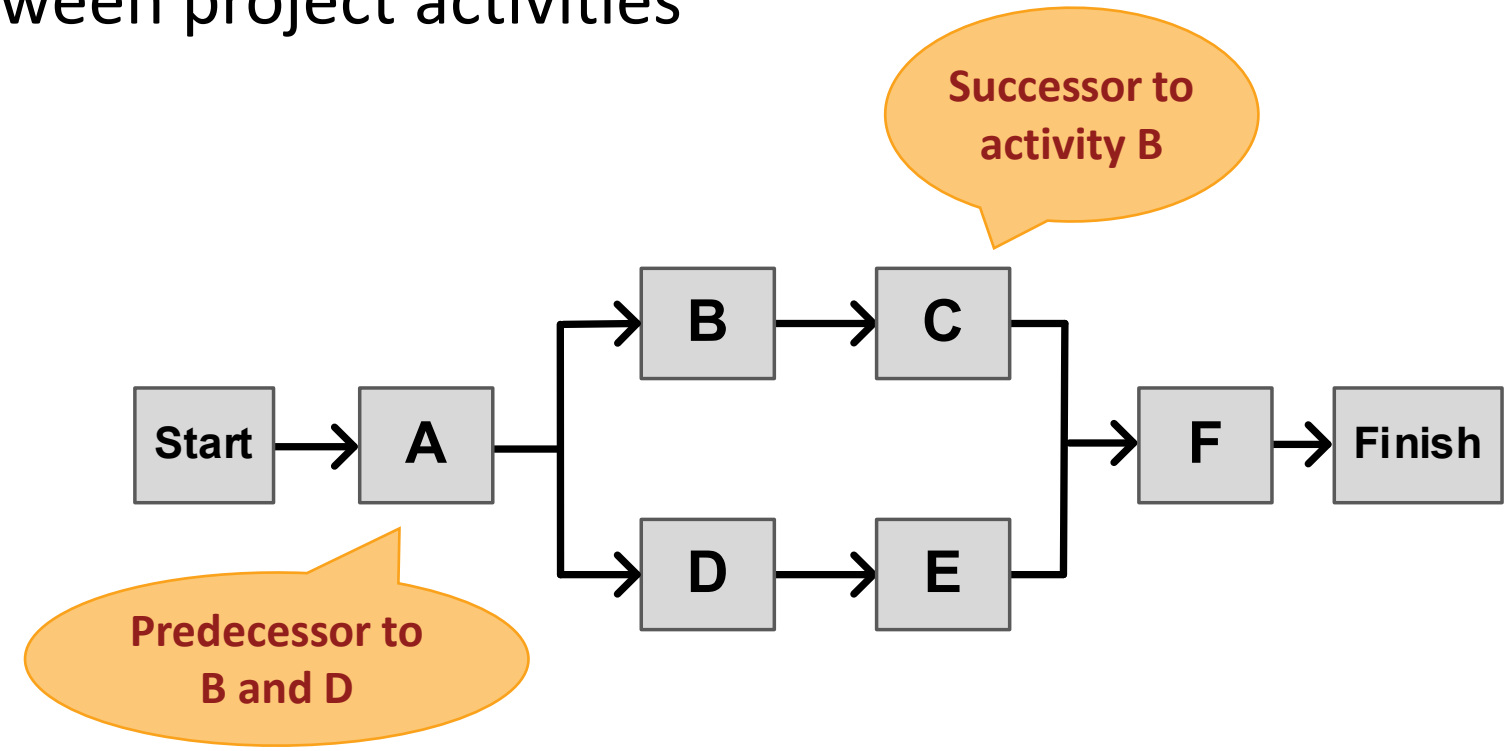
- Sequencing helps project managers identify opportunities to improve the **efficient use of time and resources**—given the relationships and constraints described in the activity list.

Precedence Diagramming Method

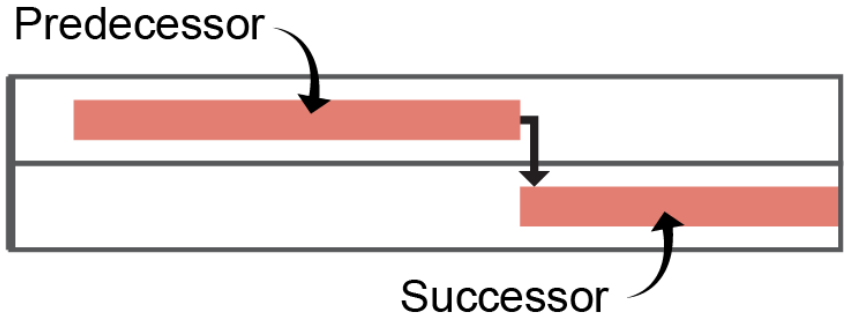
Activity-on-Node (AON)

Determining the sequence and logical relationships between project activities

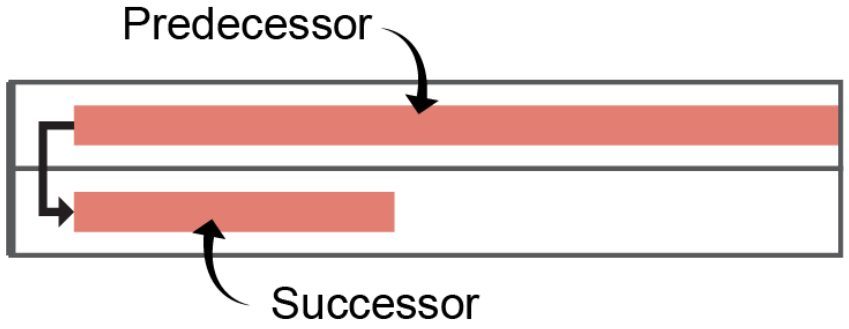


Types of PDM Relationships

- **Finish-to-start (FS)** *(most common)* Predecessor must be finished before successor can begin.

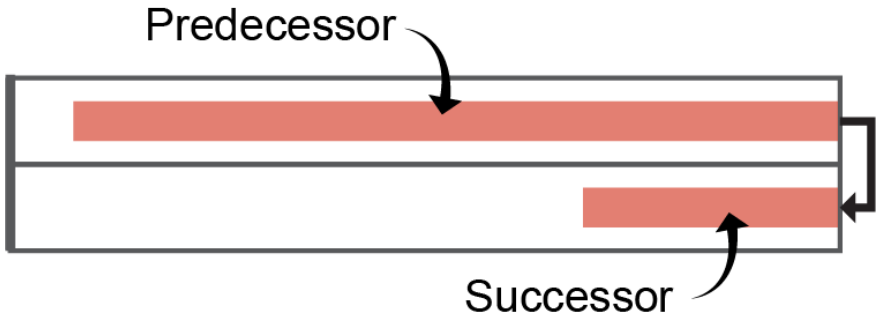


- **Start-to-start (SS)** Successor can begin once the predecessor has begun.

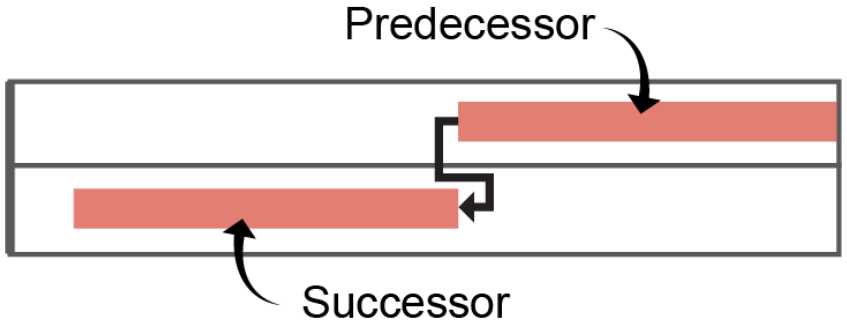


Types of PDM Relationships

- **Finish-to-finish (FF)**
  Successor can begin while predecessor is ongoing, **but** predecessor must finish first.



- **Start-to-finish (SF)**
  (most uncommon)
  Successor must start before predecessor can finish.



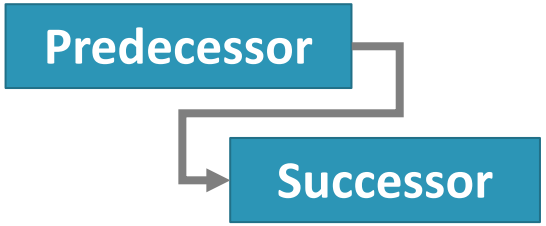
Discussion Question

To construct a new maintenance vehicle building, the project manager determines that installation of the electrical system (task 6) cannot begin until the roof has been installed (task 4). What is the PDM relationship between tasks 6 and 4?

Types of Dependencies

Mandatory vs. Discretionary	Internal vs. External
Mandatory • Legally or contractually required • Inherently required (hard logic) **Discretionary** • Preferred approach based on best practices (soft logic)	**Internal** • An internal activity depends on another internal activity. **External** • Project activity depends on performance of an entity outside the project team.

Leads and Lags

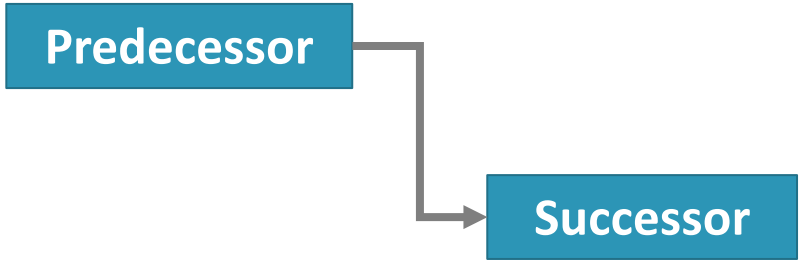


Lead

Amount of time a successor activity can be advanced in relationship to a predecessor

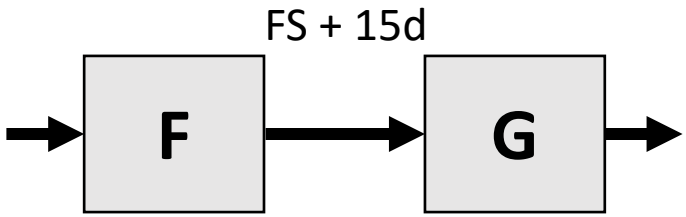
Lag

Amount of time a successor activity will be delayed in relationship to a predecessor



Discussion Question

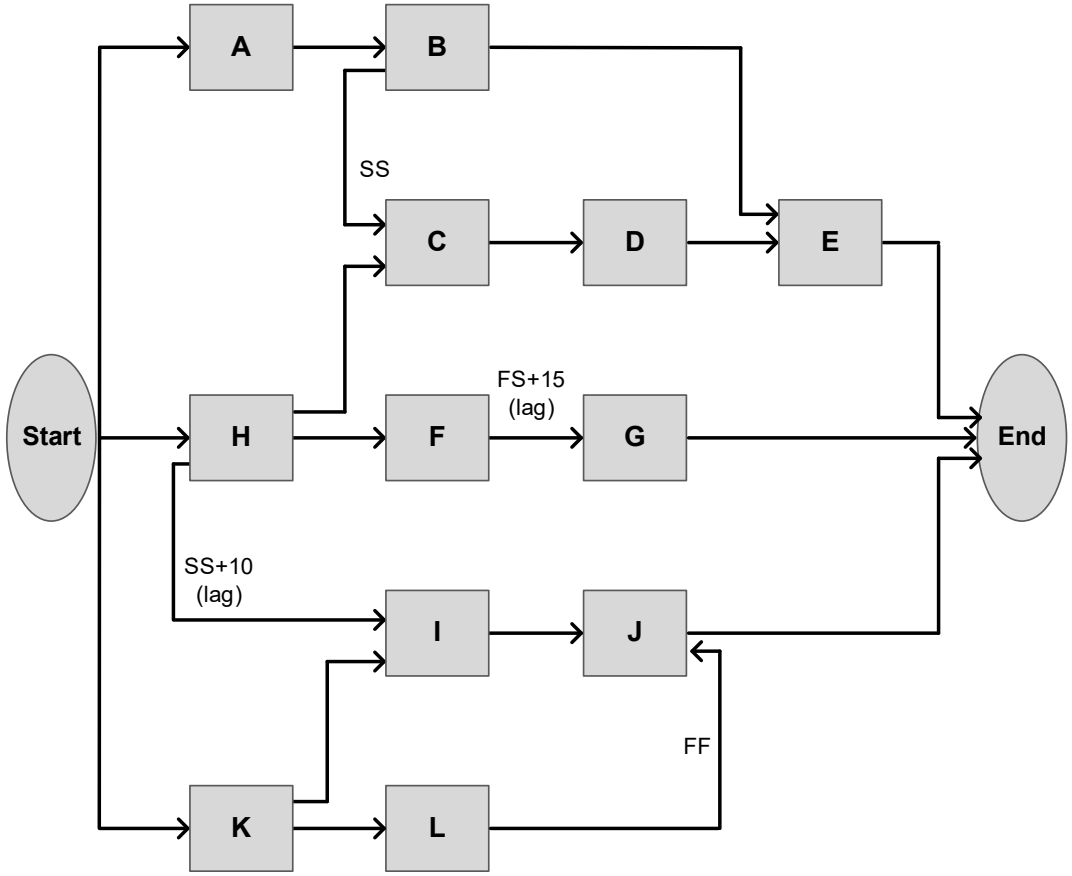
What does the following relationship in a network diagram indicate?



Project Schedule Network Diagram

Graphical representation of the sequence and logical relationships among project activities

- Activity-on-node (AON) format
- PDM relationships
- Leads and lags



Estimating Story Points in Agile/Hybrid

Difficulty is relative.

- Task size/complexity
- How hard to clarify "how"
- Experience of person(s)
- Familiarity of task
- Degree can be automated
- Risks

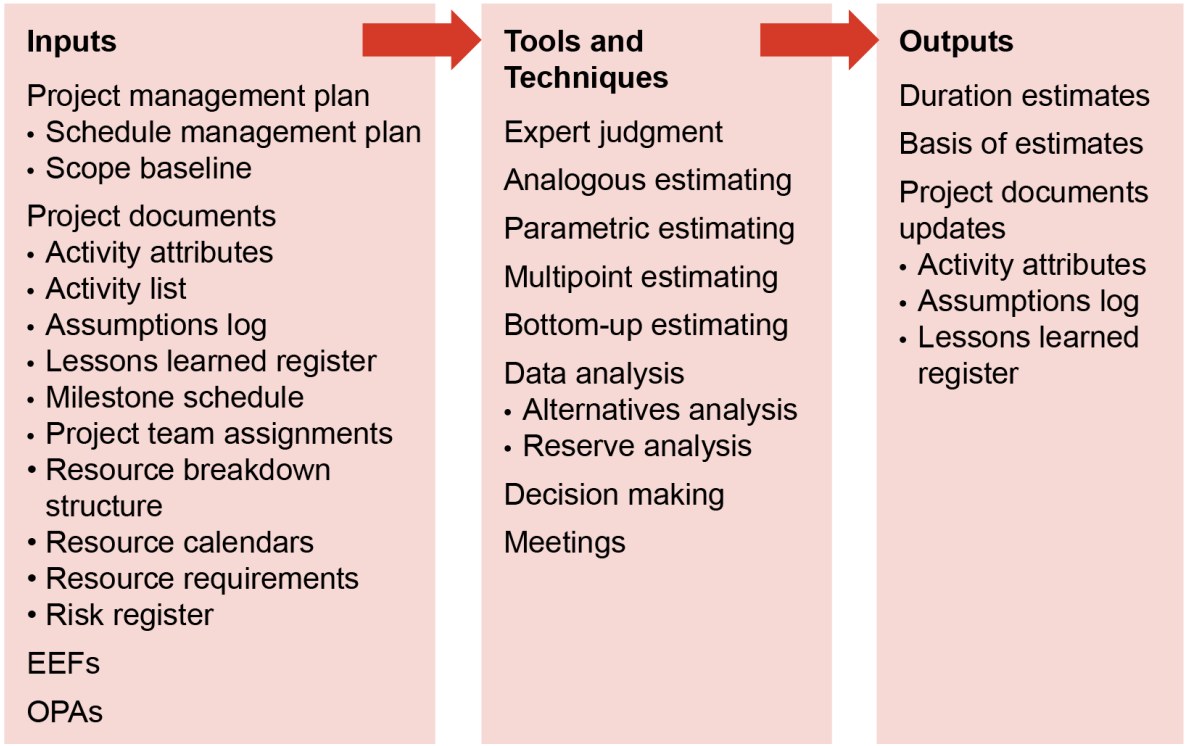
Enablers

- Small enough stories
- Estimate as team discussion

Estimating Story Points in Agile/Hybrid

- Actual duration estimates may be seen as definitive.
- Simple linear scale hard to differentiate (e.g., 6 or 7?).
- Tee-shirt sizing. (Assign ranges of points to XS, S, M, L, XL.)
- Fibonacci (e.g., spirals in nature) reinforces comparison.
  - Each cumulatively larger: Add most recent to prior value.
    - 0, 1 → 0 + 1 = 1, so 0, 1, 1.
    - 0, 1, 1 → 1 + 1 = 2, so 0, 1, 1, 2, and so on.
    - Often shown as 0, 0.5, 1, 2, 3, 5, 8, 13, 21, 34, 55…
    - Or on planning poker cards as ?, 0, 0.5, 1, 2, 3, 5, 8, 13, 20, 30, 50, ∞.
  - For each story in backlog, all pick a point value privately and reveal at same time (to avoid bias); then discuss.

Predictive: Estimate Activity Durations



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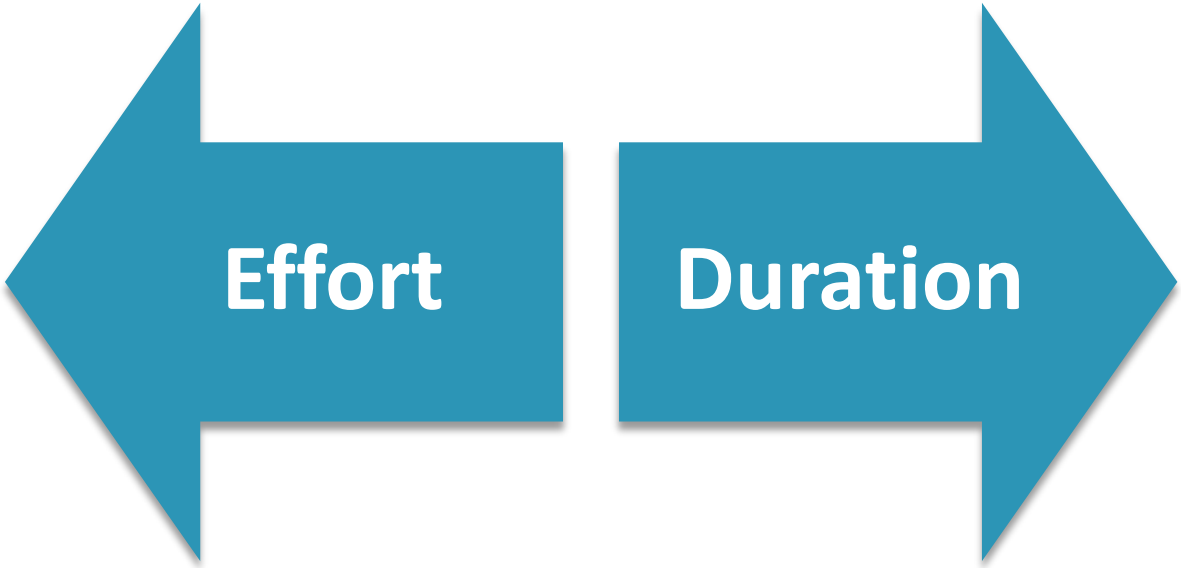
- Document data sources, methods, and assumptions used in estimating.

Effort versus Duration



Budgeted labor units

Number of labor units (hours, days, weeks) required to complete an activity

Calendar time

Total number of work periods required to complete an activity

Analogous Estimating

- Uses historical data from similar activity or project and adjusts for differences
- Can be improved by using higher-quality expert judgment
- Quick and relatively inexpensive…a good reality check
- Relative estimating: similar method, but more detailed

Parametric Estimating

- Algorithm or rule of thumb.
- How much time is needed per unit produced—page, square foot of floor, kilometer of roadway.
- May be an OPA based on historical internal data.
- May be an external resource (e.g., industry guidelines).
- Accuracy depends on quality of parametric rates.

Multipoint Estimating

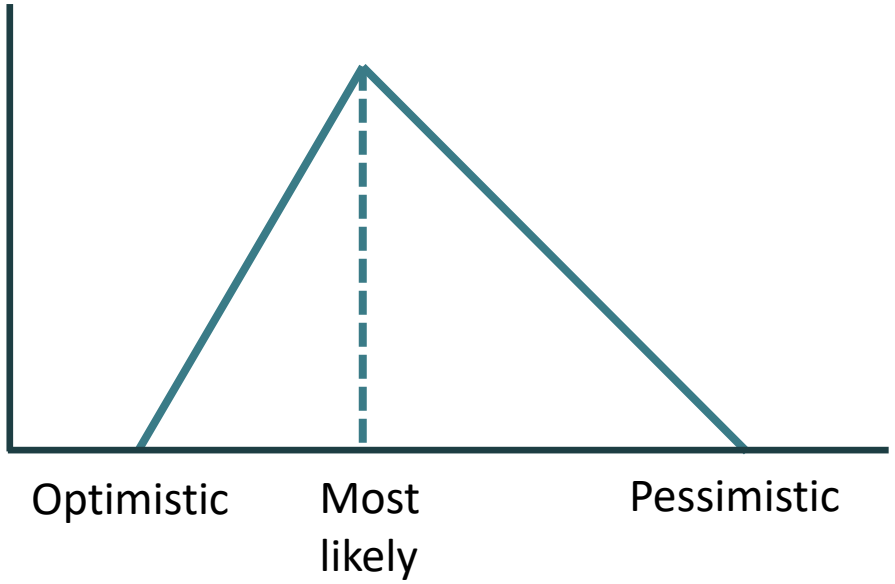
Based on an averaging of multiple estimates rather than a single estimate

Used to estimate time and cost

- **tE:** expected time estimate
- **tM:** most likely time estimate
- **tO:** optimistic time estimate
- **tP:** pessimistic time estimate

Triangular Distribution for Multipoint Estimate

Simple average of optimistic, most likely, and pessimistic estimates



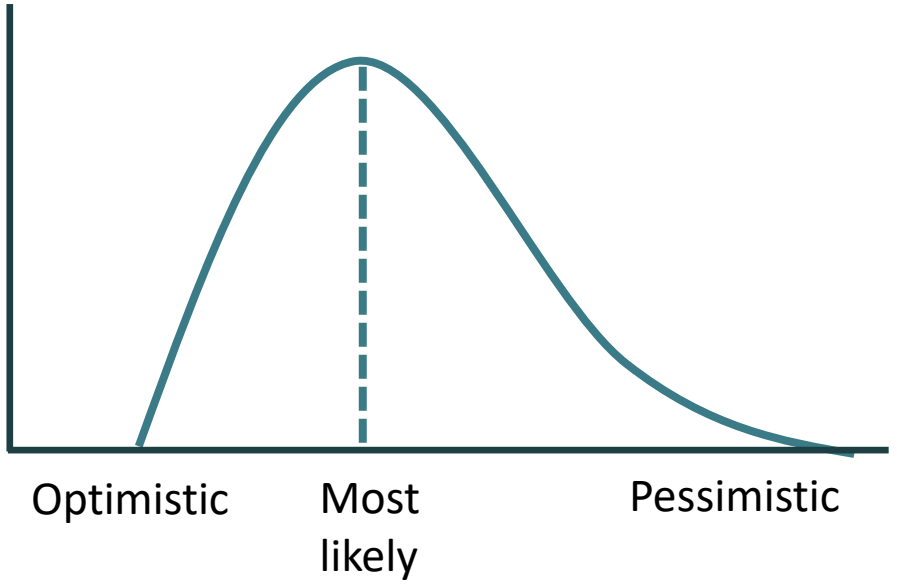
$$tE = \frac{tO + tM + tP}{3}$$

Beta (PERT) Distribution for Multipoint Estimate

More weighting on most likely to minimize outlier impact, e.g., unrealistic optimism.

Weighted average.

Divide by total of weightings (1 + 4 + 1).



$$tE = \frac{tO + 4tM + tP}{6}$$

Discussion Question

Historically, a type of activity has taken 16 weeks. But this team has never done the activity before, and you fear it could take half again as long. Your assistant thinks it will take less time—12 weeks—because of improved tools. What is the PERT estimate for this activity?

A. 14.67 weeks
B. 16.67 weeks
C. 17.33 weeks
D. 25 weeks

Discussion Question

What purpose does a reserve analysis serve in a project schedule?

A. It increases individual activity times to protect the project team.
B. It applies expert judgment to duration estimates.
C. It creates a time buffer of unallocated time to be used as needed.
D. It provides an early warning when the schedule is likely to be exceeded.

Basis of Estimates

- How estimates were developed
- What assumptions were used
- What constraints were considered
- What precision range is defined
- How confident the estimates are

Preparing Schedules for Agile/Hybrid Projects

Determine in detail what team commits to for next iteration, pulling from backlog into WIP.

Estimate total project duration and calendar schedule.

- Given constraints such as milestones/deadlines

Methods

- Iterative scheduling with a backlog (for iteration-based)
- On-demand scheduling (for flow-based)
- Agile release planning

Iterative Scheduling with Backlog

- Iteration-based: Iteration duration fixed (timeboxed).
- Calculate load (remaining backlog) vs. capacity (team velocity).
- Both load and capacity can vary (new stories, vacations).
- Limit complexity by fixing team size (relatively stable capacity).
- Translate story points into time estimates using historical data for specific team. (Available only after first iteration.)
- Velocity: Actual story points per iteration for stories/features actually completed. (After several iterations, find average.)

$$\text{Estimated Number of Iterations} = \frac{\text{Load}}{\text{Capacity}} = \frac{\text{500 Story Points}}{\text{25 Points/Iteration}} = \text{~20 Iterations}$$

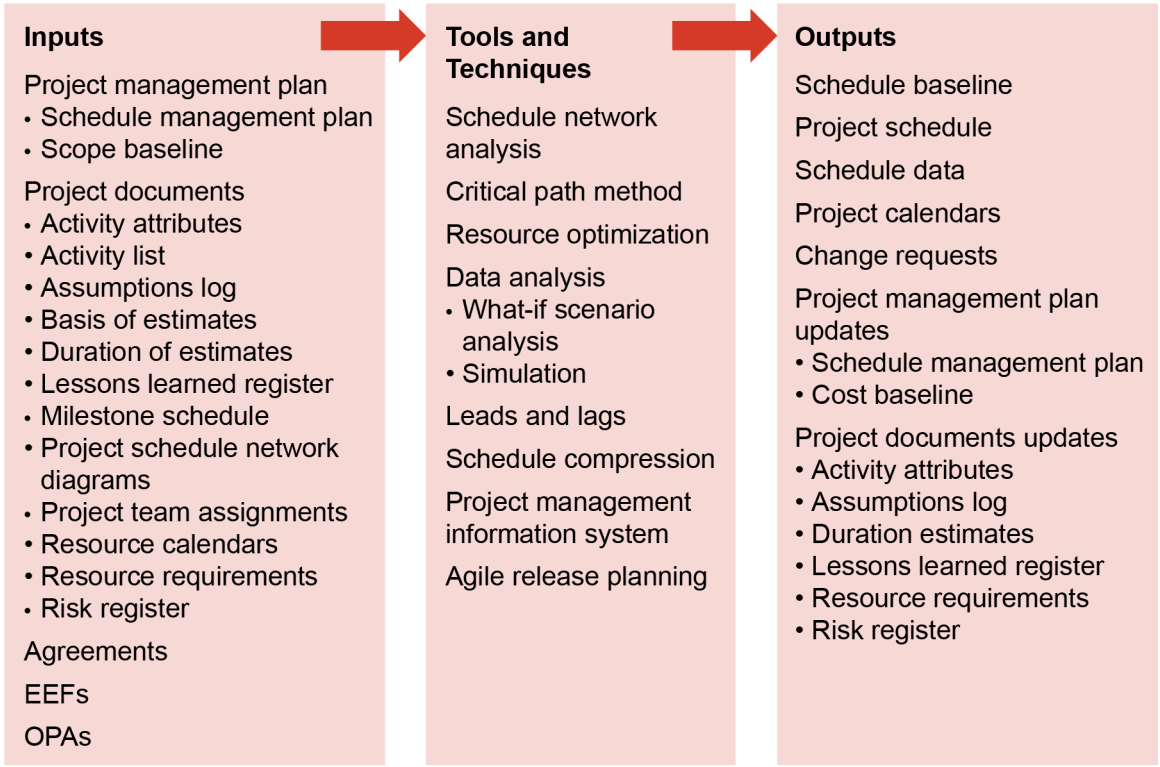
On-Demand Scheduling

- Flow-based: Iteration duration varies by how long to complete value to customer (release).
- Continuous flow: Features added to WIP on demand when resources available. (No waiting for iteration cycle.)
- Priority: Finish WIP first to add value (strict WIP limits).
- Estimate number of weeks needed for iteration.
  - Load for iteration: Story points for meaningful increment.
  - Capacity (velocity) per week since iteration can vary.
- Useful for incremental projects (e.g., prototyping):
  Each iteration similar in duration due to repeated tasks.

Agile Release Planning

- High-level summary timeline of releases
- How many iterations will be needed for each release of deliverables
- Features tied to each iteration

Predictive: Develop Schedule



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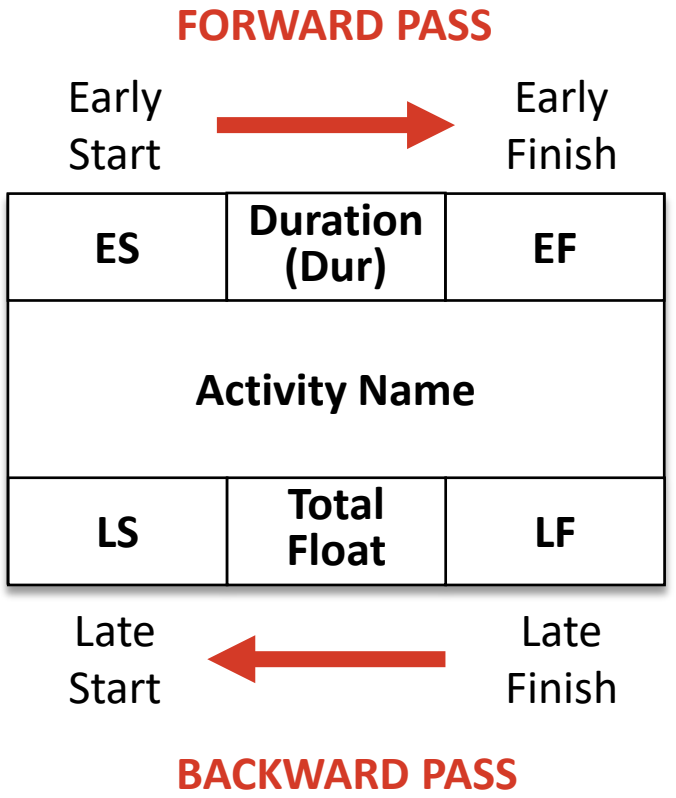
- Uses information from all prior processes in this Knowledge Area and cross-checks with inputs from Project Risk Management and Project Resource Management Knowledge Areas

Critical Path Methodology (CPM)

Finds the shortest possible project duration and points of flexibility in the network logical paths



Critical path

The sequence of activities that represents the longest path through a project, which determines the shortest possible duration.

CPM Methods

Next Day

- Assumes project starts on **day one.**
- Subsequent activities start on finish of largest predecessor activity **plus one.**

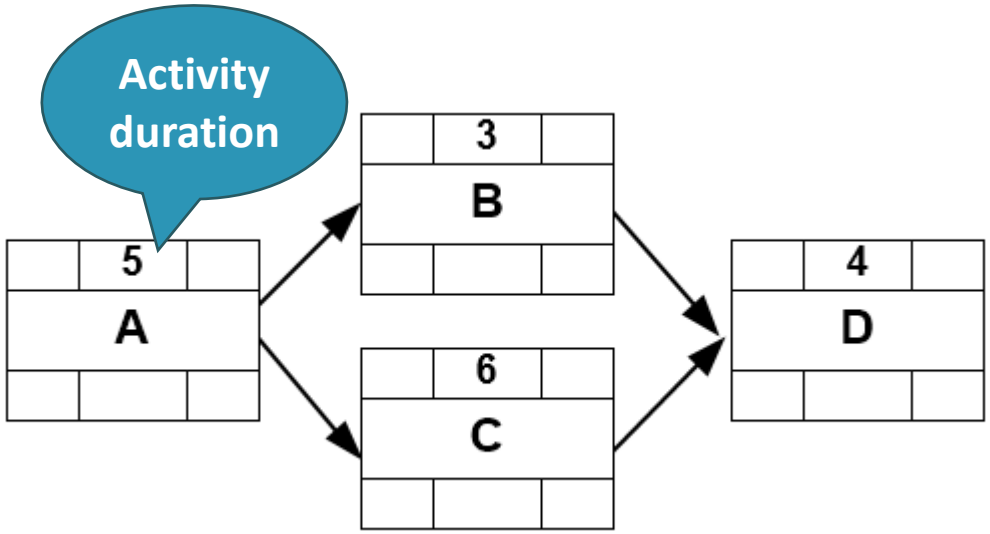
Same Day

- Assumes project starts on **day zero.**
- Subsequent activities start on **same day** as finish of largest predecessor activity.

Step 1 of CPM: Create Network Diagram and Calculate Path Durations.

1. Create network diagram.
2. Identify possible paths.
3. Sum durations of activities on each path.

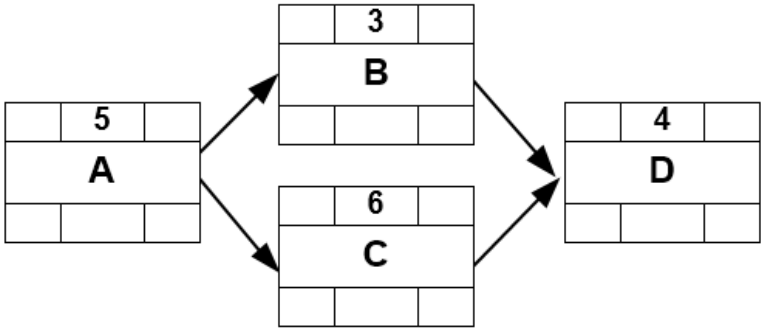
- Projects may have multiple "near-critical" paths.
- The critical path may change.



Possible paths:
A-B-D
A-C-D

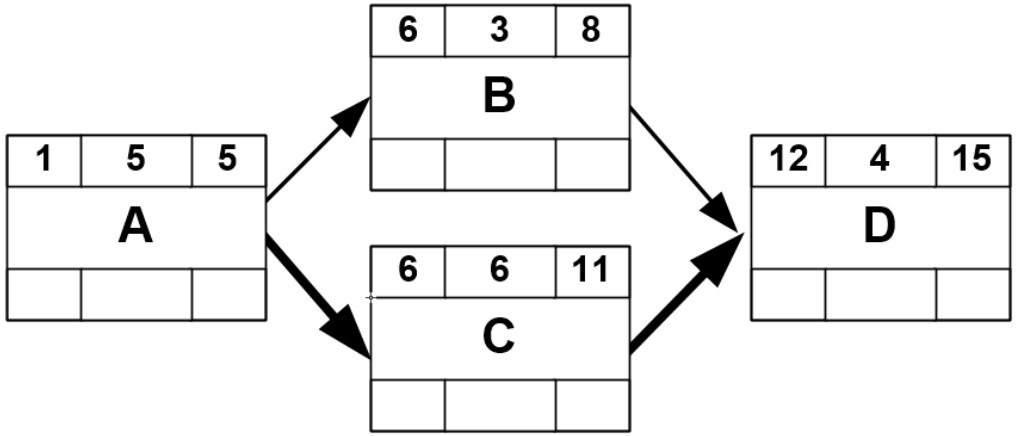
Discussion Question

What is the critical path in this network diagram?



Step 2 of CPM: Do Forward Pass.

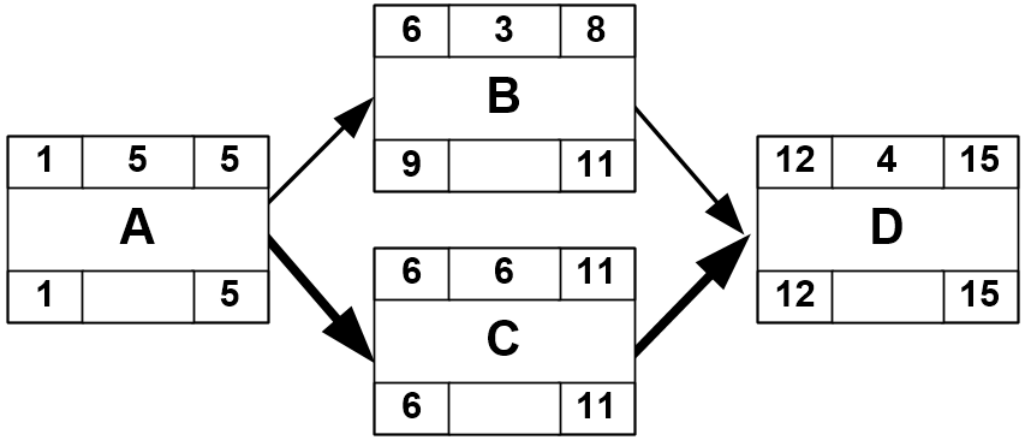
- Now to begin the process of finding our areas of schedule flexibility.
- What are the ES and EF for each activity?



Next-Day Forward Pass Rules
1. ES + (DUR – 1) = EF
2. EF of Largest (Latest) Predecessor + 1 = Successor ES

Step 3 of CPM: Do Backward Pass.

- Starting from the latest possible completion date, find the LF and LS for each activity.



Next-Day Backward Pass Rules

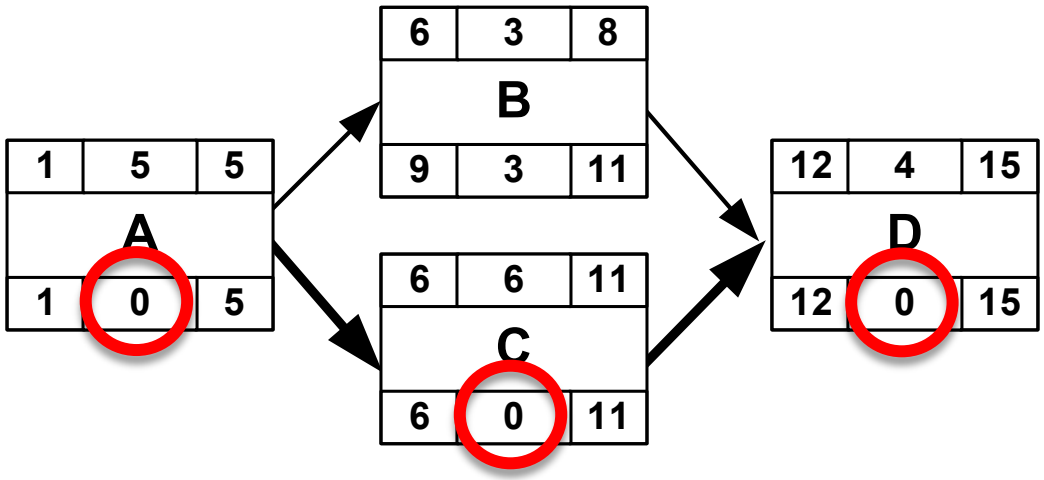
1. For final activity, ES = LS and EF = LF
2. LS of Smallest (Earliest) Successor – 1 = Predecessor LF
3. LS = LF – (DUR – 1)

Step 4 of CPM: Calculate Total Float.

Total float:

The amount of time an activity can be delayed or extended from its early start date without delaying the project finish date or violating constraints

The critical path has zero float.

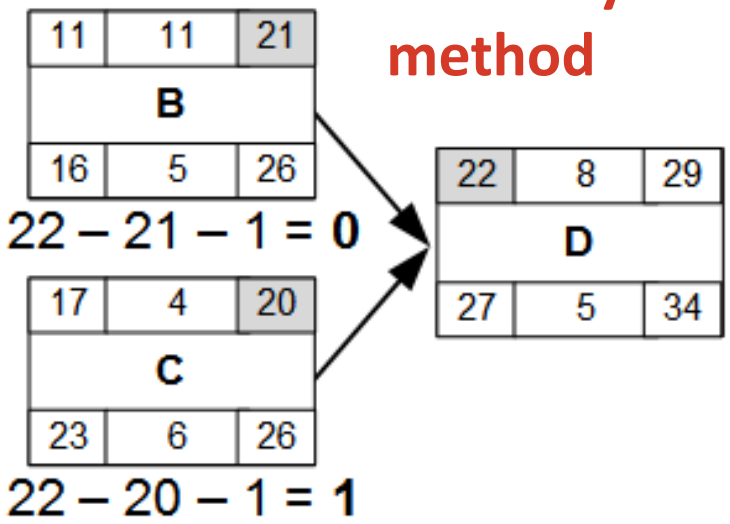


Activity B has a total float of 3. Its start could be delayed or its duration extended if necessary.

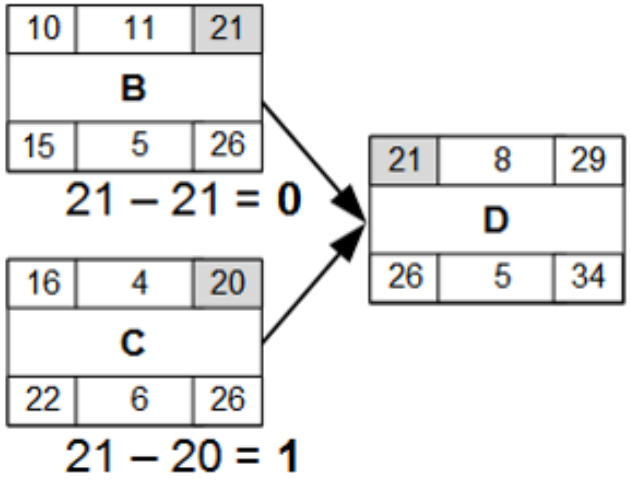
Free Float

The amount of time an activity can be delayed without delaying the early start of any successor or violating a constraint

Next-day method

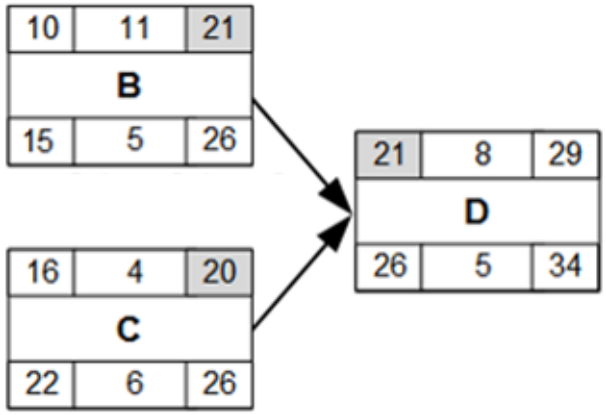


Same-day method



Discussion Question

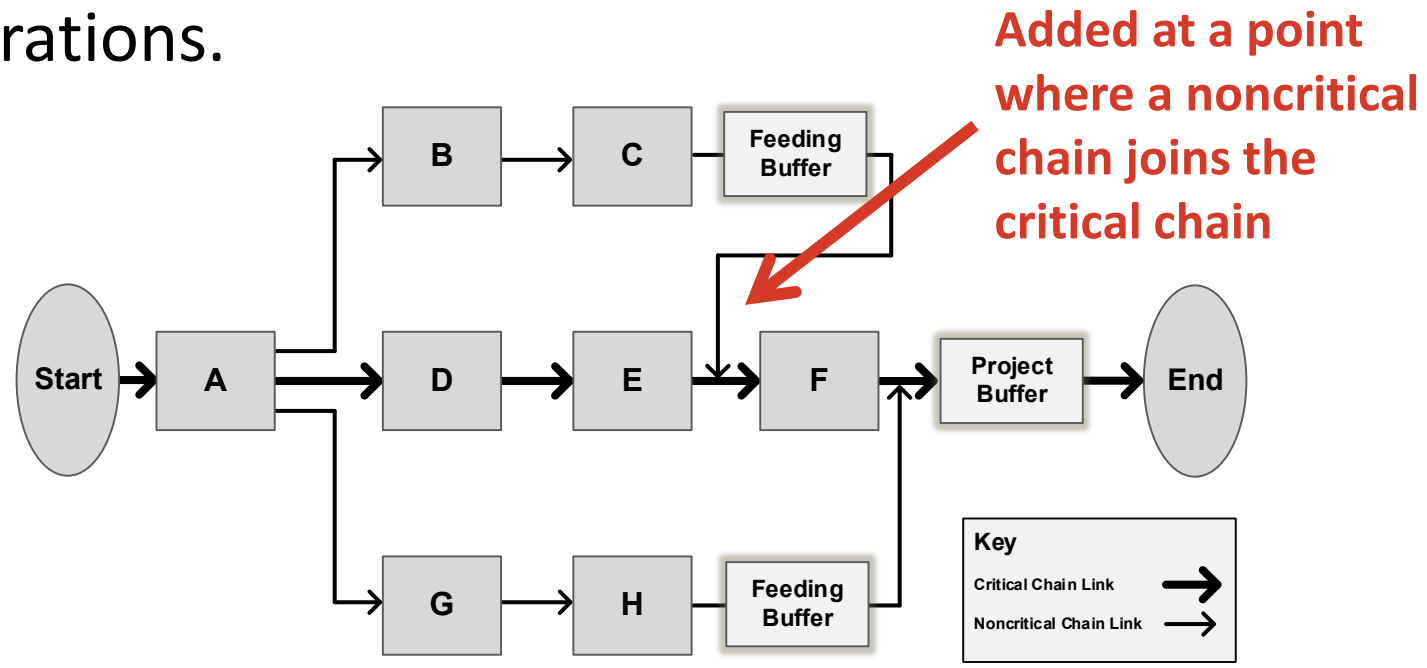
How much free float does activity C have? Assume that the schedule is using the same-day method.



Critical Chain Method

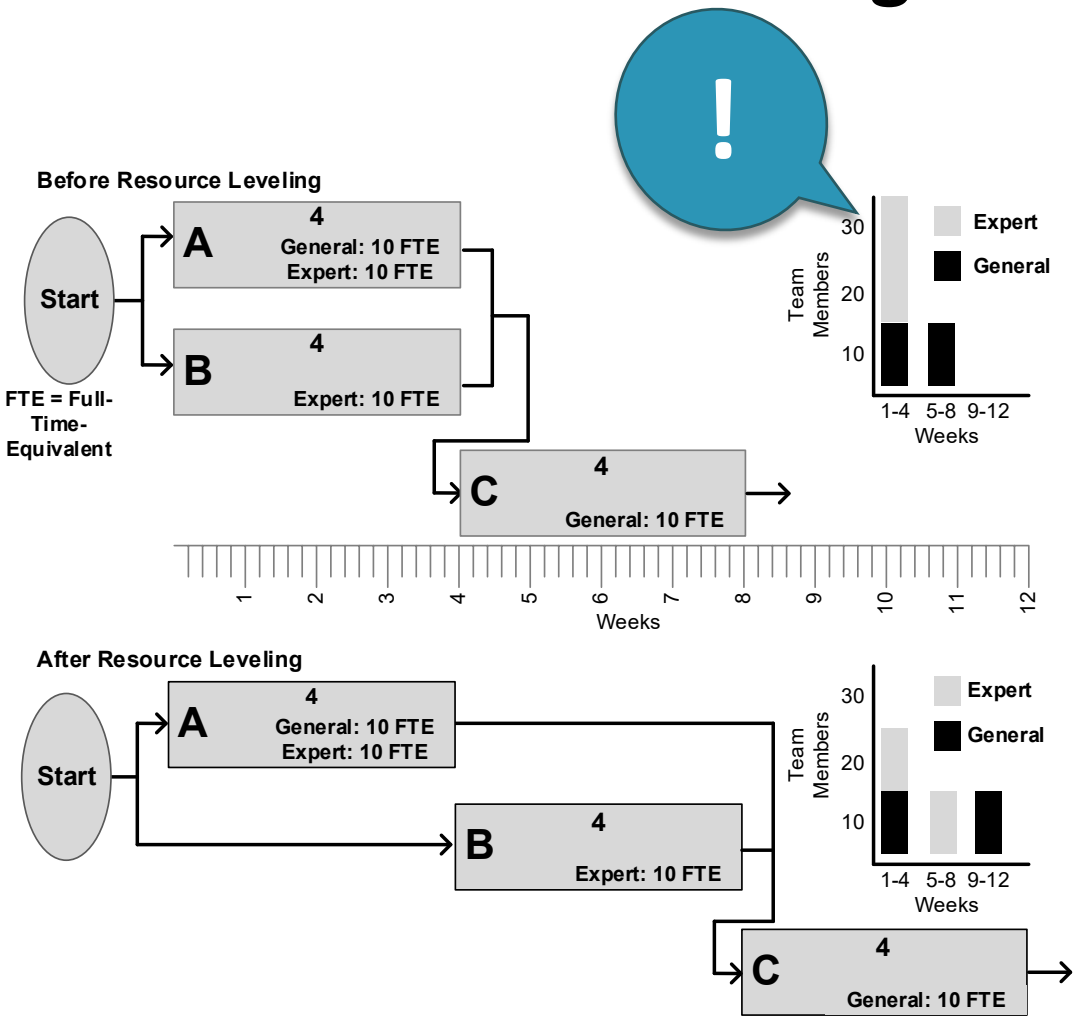
- The critical chain is the resource-constrained critical path.
- This method is used when there is uncertainty about activity durations.

Buffer: Common pool of scheduling time available for use by any activity on a given path.



Resource Optimization: Resource Leveling

- Start and finish dates are adjusted to balance demand for resources with a limited supply.
- After leveling, the start dates of tasks B and C have been adjusted, and the schedule for A-B-C now lasts 12 weeks rather than 8.



Resource Optimization: Resource Smoothing

- Schedule float is used to adjust activity start dates so that access to limited resources can be aligned with resource availability.
- Critical path is not changed; end date is not extended.
- Activities can be delayed only within their free and total float.

Schedule Compression

Crashing	Fast Tracking
▪ **Adding resources to shorten the schedule,** usually for activities on critical or near-critical paths ▪ Called **swarming** in agile	▪ **Performing activities in parallel** for all or part of their durations, thereby shortening the overall schedule
Key risk: **Insufficient benefit for added cost**	**Key risk:** **Rework**

Discussion Question

What risk is created by a schedule that runs multiple activities in parallel?

A. Delay to project end date
B. Increased use of resources
C. Loss of control
D. Problems with quality

Data Analysis and Modeling

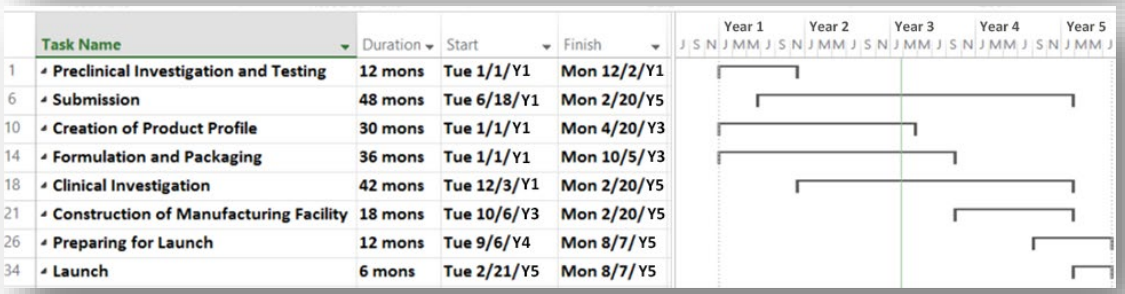
- Assessing schedule risk by examining the impact of changing variables
- Automated tools such as spreadsheets and scheduling software applications

What-if scenarios	Simulation (e.g., Monte Carlo)
One attribute is changed at a time while others are held constant.	**Multiple** variables are changed each time, based on probabilities
Outcome: Specific impact	Outcome: Overall probability distribution

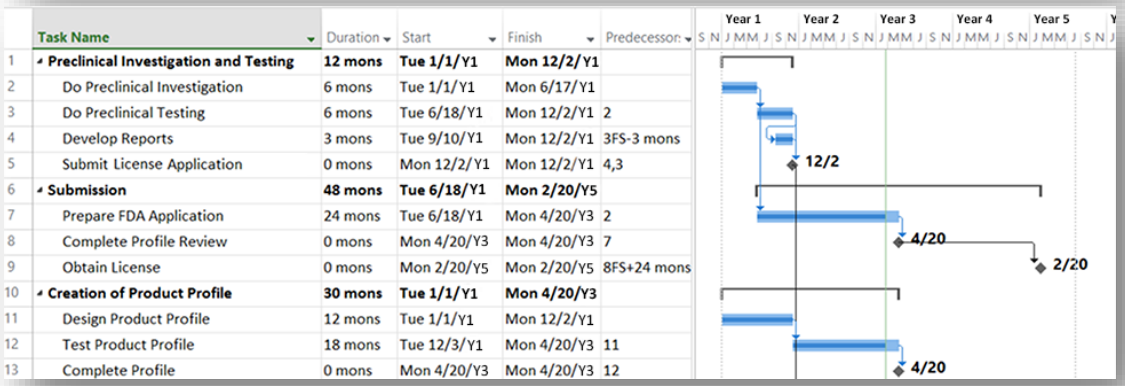
Project Schedule

- Gantt chart
- Customize view for audiences:
  - ✓ **Milestones** only for senior management and certain stakeholders
  - ✓ **Summary** for stakeholders
  - ✓ **Detailed** for project team

	Task Name	Duration	Start	Finish	Predecessor
5	Submit License Application	0 mons	Mon 12/2/Y1	Mon 12/2/Y1	4,3
8	Complete Profile Review	0 mons	Mon 4/20/Y3	Mon 4/20/Y3	7
9	Obtain License	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	8FS+24 mons
13	Complete Profile	0 mons	Mon 4/20/Y3	Mon 4/20/Y3	12
17	Complete Formulation and Packaging	0 mons	Mon 10/5/Y3	Mon 10/5/Y3	16
20	Complete Investigations	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	19
25	Complete Construction	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	24
33	Complete Launch Preparations	0 mons	Mon 8/7/Y5	Mon 8/7/Y5	28,31
39	Close Project	0 mons	Mon 8/7/Y5	Mon 8/7/Y5	38,37,36,35



	Task Name	Duration	Start	Finish
1	**Preclinical Investigation and Testing**	**12 mons**	**Tue 1/1/Y1**	**Mon 12/2/Y1**
6	**Submission**	**48 mons**	**Tue 6/18/Y1**	**Mon 2/20/Y5**
10	**Creation of Product Profile**	**30 mons**	**Tue 1/1/Y1**	**Mon 4/20/Y3**
14	**Formulation and Packaging**	**36 mons**	**Tue 1/1/Y1**	**Mon 10/5/Y3**
18	**Clinical Investigation**	**42 mons**	**Tue 12/3/Y1**	**Mon 2/20/Y5**
21	**Construction of Manufacturing Facility**	**18 mons**	**Tue 10/6/Y3**	**Mon 2/20/Y5**
26	**Preparing for Launch**	**12 mons**	**Tue 9/6/Y4**	**Mon 8/7/Y5**
34	**Launch**	**6 mons**	**Tue 2/21/Y5**	**Mon 8/7/Y5**



	Task Name	Duration	Start	Finish	Predecessor
1	**Preclinical Investigation and Testing**	**12 mons**	**Tue 1/1/Y1**	**Mon 12/2/Y1**	
2	Do Preclinical Investigation	6 mons	Tue 1/1/Y1	Mon 6/17/Y1	
3	Do Preclinical Testing	6 mons	Tue 6/18/Y1	Mon 12/2/Y1	2
4	Develop Reports	3 mons	Tue 9/10/Y1	Mon 12/2/Y1	3FS-3 mons
5	Submit License Application	0 mons	Mon 12/2/Y1	Mon 12/2/Y1	4,3
6	**Submission**	**48 mons**	**Tue 6/18/Y1**	**Mon 2/20/Y5**	
7	Prepare FDA Application	24 mons	Tue 6/18/Y1	Mon 4/20/Y3	2
8	Complete Profile Review	0 mons	Mon 4/20/Y3	Mon 4/20/Y3	7
9	Obtain License	0 mons	Mon 2/20/Y5	Mon 2/20/Y5	8FS+24 mons
10	**Creation of Product Profile**	**30 mons**	**Tue 1/1/Y1**	**Mon 4/20/Y3**	
11	Design Product Profile	12 mons	Tue 1/1/Y1	Mon 12/2/Y1	
12	Test Product Profile	18 mons	Tue 12/3/Y1	Mon 4/20/Y3	11
13	Complete Profile	0 mons	Mon 4/20/Y3	Mon 4/20/Y3	12

Other Scheduling Outputs

Schedule data

- Activity attributes
- Milestones
- Resource histograms
- Alternative schedules
- Contingency reserve schedules

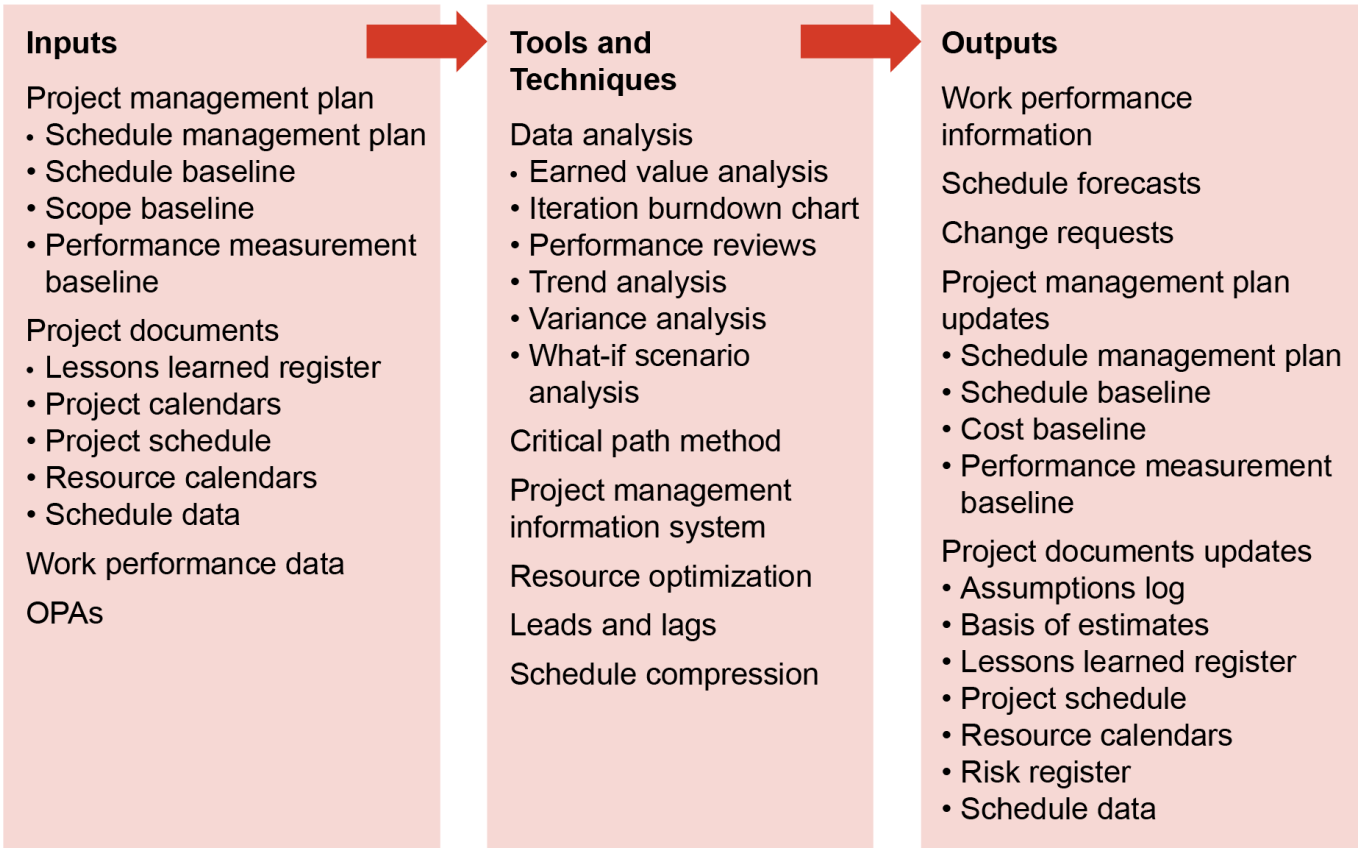
Project calendar

- Calendar showing available workdays and assigned work
- May be multiple calendars (e.g., vacation calendar, company calendar)

Measuring, Modifying, Controlling Agile Schedules

- Short iterations: control easier due to fast feedback.
- Monitor schedule for current iteration and overall.
- Prominent kanban board makes schedule issues obvious.
- Iteration planning ceremony sets commitments:
  - Iteration-based: Ensure that load is feasible or shorten scope.
  - Flow-based: Scope fixed; iteration period estimate is baseline.
- Daily standups: Scrum master gets data for variances.
- Retrospectives: Review variances in scope (iteration-based) or time (flow-based).
- Burnup/burndown charts.

Predictive: Control Schedule



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Project Manager's Role in Controlling Schedules

- Be proactive.
  - Identify root causes **before** they influence the schedule.
- Actively manage risks.
  - Monitor risks continually.
- Communicate and listen.
- Champion the value of a realistic schedule.