SCHEDULE TRAINING HUB

WHATS CRITICAL?

PLANNING & SCHEDULING FUNDAMENTALS

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INTRODUCTION

Summary

This eBook is designed to provide people with fundamental knowledge and skills for planning and scheduling large projects. This eBook covers key methodologies and tools such as the Critical Path Method (CPM), Planning considerations & Planning a schedule.

Readers will learn to create, analyse, and manage project schedules to assist with timely and successful project completion.

Objective

The primary objective of this eBook is to equip participants with the necessary tools and techniques to effectively plan, schedule, and manage large-scale projects. By the end of this eBook, you should have a better understanding of :

1. Developing detailed project schedules using the Critical Path Method.
2. Create and manage detailed project schedules using CPM.
3. Plan a schedule and communicate to team members
4. Understand the different types of schedules, determining the critical path and near critical paths
5. Undertake schedule quality reviews and prepare quality metrics

Learning Prerequisites

Participants should have the following prerequisites to benefit fully from this course:

1. Basic understanding of project management principles.
2. Basic knowledge of scheduling techniques and terminologies.
3. Access to the internet and basic computer skills
4. Basic mathematical skills

Planning & Scheduling Fundamentals - Overview

Program Vs Plan Vs Schedule?

Project Plan - is an extensive document that outlines various aspects of a project. It serves as a roadmap for the entire project lifecycle.

Project Schedule - is a graphic representation of project activities and their details.

Program - consists of multiple related projects managed together to achieve strategic goals.

Note - your own organisation may have its own definitions of the above naming, which takes precedence.

Planning a project

- including the team & importance of team involvement
- 'Plan the Plan'
- Scope & Methodology
- Define the Work Breakdown Structure (WBS)
- Estimating Activity Durations
- Defining logic between activities
- Review resources
- Define project calendars
- Add contingency
- Reschedule & Review
- Baseline the schedule
- Update the schedule
- Communicate the schedule status
- Communicating the schedule

Critical Path Explained

- The Critical Path Method (CPM)
- CPM Technical terms
- Confirming the critical path
- Critical Path or Longest path
- CPM software
- Who owns the float?

Schedule Reviews, Diagnostics & Quality

- Schedule reviews
- Schedule metrics

Step 0 - Include the Team

Good planning requires input and buy-in from the project team; it is not an isolated process. Getting the project team closely engaged so that they can provide accurate information and buy-in to the schedule is the most important step.

The Planner does not own the schedule, the schedule belongs to the project team and the team should be involved in updating and reporting the schedule's status. The Planner's role is to facilitate, coordinate, understand, interpret, and advise.

The importance of the schedule as an essential delivery tool needs to be emphasised and supported by senior management. If senior management has not bought into the need for a robust schedule that is actively used to make key project decisions, then it is unlikely the rest of the project team will.

The schedule should be reviewed by the relevant members of the project team and anyone who is involved in delivering the work as it is being developed and as it is being delivered.

Regular reviews for changes should be carried out throughout the project's life. This will help to ensure the schedule has ongoing buy-in from the people responsible for delivering the project.

The Planner needs to build trust with the team and show them how the schedule can be used to help them deliver successfully.

Some methods that help with this include:

- Be curious, keep asking questions, and try to elicit information beyond what is being told.
- Regular communication and collaboration with the project team members responsible for delivery.
- Keep checking if the schedule matches their understanding of how each schedule aspect will be delivered. If any mismatches and gaps exist, these need to be re-aligned so that everyone delivers the same plan.
- Include the names or initials of project team members in a column next to the activities in the schedule they are responsible for delivering.
- Make it easy for the team to review the schedule by providing them with filtered views of the schedule showing the activities they are responsible for delivering.
- Ask team members what information they need from the schedule to help them deliver and assure them that the schedule is there to assist them, not audit them.
- Regular face-to-face meetings with individual project team members to review and update their activities in the schedule, followed by face-to-face meetings with the project team to report and discuss schedule updates, changes, issues, and risks.


PLANNING STEPS
SCHEDULETRAININGHUB.COM
1 Include the Team!
2 Plan the Plan
3 Scope & Methodology
4 Activity Listing
5 Activity Durations
6 Activity Logic
7 Review Resources
8 Define Work Calendars
9 Add Contingency
10 Re-schedule & Review
11 Baseline the Schedule
12 Update the Schedule
13 Communicate the Status
14 Schedule Metrics
15 Schedule Reviews

Step 1 Plan the Plan

Considerations when planning

- Will the schedule be a Client (Owner) schedule
- Will the schedule be a Contractors schedule
- who the audience is for distribution and reporting
- level of detail required
- will resources be added to the schedule now, or in the future
- will costs be added now or in the future
  - WBS (Work Breakdown Structure) and CBS (Cost Breakdown Structure) - do they align?
- will Earned Value Management be used?
  - WBS and CBS alignment required?
- will the planning software used need to communicate with other software systems e.g.. cost, EVM
- will Primavera P6 be the platform for using EVM or another software/platform?
- what reports will need to be setup for communicating the schedule and progress updates? Is additional activity coding required for;
  - Excel
  - Visio
  - Power BI
  - Time Chainage Diagrams
  - 4D modeling

    - GIS mapping
- what activity codes and/or User Defined Fields will be required
- Is the schedule part of a suite of schedules?
- Does the schedule need to be logic linked to other schedules?
- How will different schedules be logic linked to each other?

General

- The term ‘construction planning’ implies a primary responsibility to construction. This is generally accurate for traditional competitive tender system. Under a Project Management system, construction is only part of the co-ordinated team effort. Other members of the team will benefit from the information derived from the construction planning

Design/Documentation

- When design and construction is overlapped (fast tracked), much of the design will be critical - good planning can prioritise relevant design scope
- consider temporary works design & approvals required prior to installation/construction of the proposed temporary works. The temp design could become critical
- Value Engineering - once design is sufficiently progressed
- Risk Workshops - involve all relevant stakeholders

Resources

- specialist resources - in short supply and high demand, such as :
  - testing
  - commissioning
  - installation
  - client resources (design review/approval/inspections)
  - Industrial Relations issues
  - remote locations Vs - resources, equipment, productivity
  - installation by specialist contractors
  - Testing & Commissioning by specialist contractors/consultants
- before trying to plan the best utilisation of resources - determine what resources are available
- check the availability and experience of local resources/contractors, particularly for controlling resources
- are local resources already over-committed
- is there sufficient local supervision staff available
- do resources/supervision need to be imported to a remote location
- local availability of equipment, including servicing & maintenance
- controlling resources/labor - eg structure crews (form workers, reinforcement fixers) can be considered as controlling resources

Site Conditions

- review site conditions/access/restrictions
- review ground conditions & bearing pressures for equipment
- laydown areas for materials, equipment
- site amenities, office, parking etc
- power, water, drainage, sewer for site establishment
- noise restrictions
- allow for incomplete components of work that are caused by
    - temporary works
    - access requirements
    - materials handling requirements - hoists/cranes attached to structures
    - staged construction and handover
    - location of site offices/amenities/laydown/access roads
- hazardous materials removal
    - transportation routes
    - specialist dump sites
    - preparation prior to removal/transporting
    - encapsulation of materials prior to transporting
- site access and traffic movements during different construction phases/stages
- minimise existing services/utilities relocations
- adjoining properties - require structural underpinning?
- materials handling - double/triple handling
- mobile crane Vs fixed crane
- is temporary dewatering required
- worker access to the site/s

Location Impacts

- Site establishment & Amenities considerations:
  - relocation to be minimised
  - must not impede material flow or storage
  - should allow easy access to/from work face
  - fire risk to be minimised
  - security issues
  - temporary buildings to be relocatable
  - suitably design access paths/roads
  - walkways protected from weather
  - emergency vehicle access
  - what services/utilities are required/available
  - rubbish sorting/recycling & removal. Minimise rubbish
  - communications systems, early warning etc
  - boosting required (water, fire)
  - minimise double handling
- environmental concerns - heat, cyclones, noise, heritage
- onsite or local stockpiling Vs transportation & over dimensional loads
- understand geology of the site
- traffic conditions & restrictions
- Industrial Relations - location specific
- protection of heritage/indigenous assets
- protection of adjoining properties (gantries, scaffold, hoarding)
- protection of environmental assets
- inspect the site - adjoining properties, traffic conditions, physical obstructions, local authority requirements, local weather conditions
- develop installation methods to suit local conditions/environment

Long Lead Time & Procurement

- consideration of long lead-time procurement of specialist items, equipment, labor etc
- authority approvals
- approval of management plans
- is expedited delivery required (air freight or sea/road/rail freight)
- Long led-time materials (structural steel, precast items) can be regarded as controlling elements
- long lead-time items
  - Mechanical equipment (Air Handling Units)
  - Lifts/elevators & LMR equipment
  - Escalators/travelators
  - Fire pumps/boosters
  - specialist cabling pipes
  - Electrical switchboards/transformers
  - Vertical transportation
  - Supply & connection of essential utilities (temporary & permanent) to the site
  - Motorway tolling equipment
  - Rail equipment
  - Railway rolling stock
  - Railway signaling equipment

Time-line

- 'Required on Site' dates
    - people
    - supervision
    - materials
    - equipment
    - design documents/specifications
    - client/owner supplied items/materials/inspections
    - weather impact on installation - eg asphalt Vs very cold weather
- maximising off site fabrication
- multi activity charts - for installation cycle confirmation
- prepare a rough schedule - roughly estimate broad allocations of time for the main elements - eg site establishment > excavation > structure > Services > finishes > façade > T&C. Top down planning using agreed productivity rates and benchmarking against similar projects
- identify controlling activities/trades/resources/equipment
- consider installation methods that reduce the number of steps involved
- complex projects - the best delivery methodology will not be known until the schedule is reasonably developed taking into consideration available resources and apparent best sequence and has been reviewed and reconciled by the team.
- decisions based on cost - a faster installation method may not reduce costs, but may reduce schedule risks
- multi-building complexes - if the project is predominantly horizontally spread - divide it into individual groups or vertically arranged elements
- multi activity chart preparation & crane hook analysis

Productivity

- consider schedule 'black out' zones:
  - For example - Winter months Vs lower or poor earthmoving production
  - Utility relocations/terminations/shutdowns
  - Resource unavailability times
  - Rail possessions/occupations
  - Winter/Summer conditions for particular installations
- utilising precast structural elements
- safety - removing the risk, minimising 'plant Vs equipment' interactions
- safety - no go zones
- rate of production/delivery
- are temporary works required?
- equipment location will influence assembly methods
- faster progress may require additional materials handling equipment
- additional equipment may require additional laydown areas. Additional materials will need to be able to be supplied at a faster rate
- allow for unusual works - inaccessible work areas, mixture of materials/systems, multiple specialist resources/equipment, confined space, restricted space, working at heights
- allow for difficult or time consuming features or installation of components
- inclement weather impact on 'Just in Time' deliveries
- consider 'waiting times' for materials handling - both vertical and horizontal movements
- do local resources have the same productivity as metropolitan resources?
- consider how workers access and move around the site, for safe work and efficiency
- crane hook analysis - what materials and when. 'Just in Time' deliveries consideration for confined space sites
- local (remote location) for the manufacture of prefabricated items
- agree on whether the schedule will be pessimistic or optimistic - this my change the contingency or risk allowance to be added to the schedule

Methodology

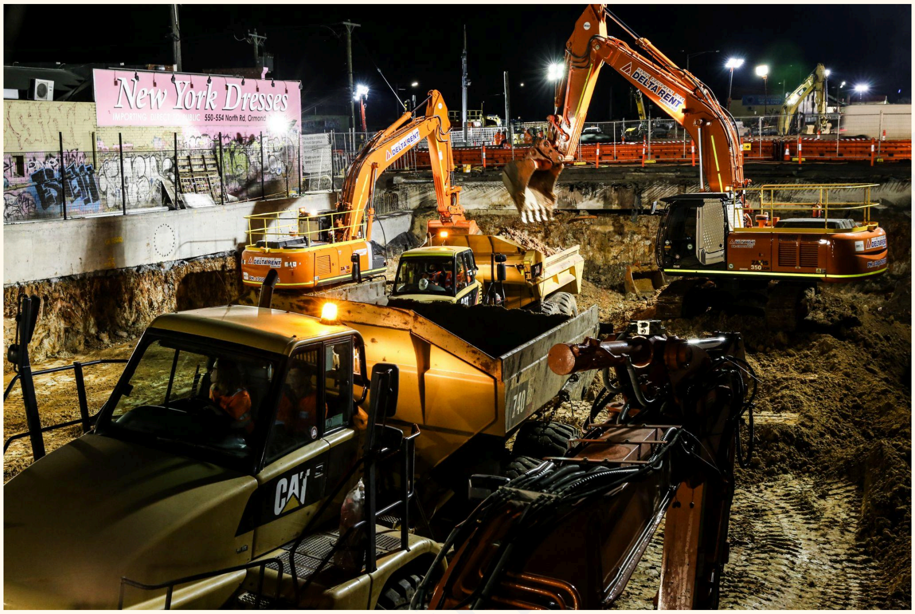
- before jumping into the detail - gather all the information available & develop a first impression about the broad approach
- the extent of construction work tends to increase as the design develops
- construction planning is the only reliable source of information relating to materials handling, site access, site facilities and construction duration
- consider installation methods that reduce labor congestion - spreading activities over levels or areas. Consider Prefabrication offsite. Look for ways of achieving smooth work flows and minimal down time. Ideally minimise 'tap on & tap off' (start/stop)
- depending on the type of project & organisation, planning should start before any firm design decisions have been made
- basic planning is not complete until there is a balanced framework of decisions and methodology by the Project Team
- basic planning establishes the broad framework of decisions about who, what, where and when
- almost everything can be delivered/installed/constructed in more than one way - basic planning looks at each operation in turn and develops likely method alternatives to establish the best overall framework of action
- staged construction - is there a requirement for early handover of parts of the project? Has the site establishment taken this into consideration? do temporary offices/amenities/access roads etc need to be relocated?
- the choice of installation/assembly method is influenced by:
    - resources available
    - equipment available
    - supervision available
    - specialised equipment
    - handling equipment
- installation methods to consider:
    - safety
    - access/egress
    - temporary works
    - evacuation
    - materials handling
    - storage areas

- confined space
- specialist resources
- removal of temporary works
- Design schedule
- Procurement (long lead-time) items

- bulk excavation methods
  - over excavation
  - sheet piling required?
  - de-watering
  - access/egress method
  - spoil removal
  - environmental controls required?
  - truck movements
  - restricted hours (noise)
- Concrete pours
  - suitably sized to minimise exposure to weather risk
  - suitably sized to allow for final finishing and protection (within daylight hours)
  - maximise gravity!
  - driving activity - supply of concrete, concrete pump capacity, crane and concrete skip/bucket/hopper
  - extent manual effort required
  - concrete mix design - slurry Vs low slump
  - traffic management of delivery trucks
  - concrete discharge rate form agitator to pump or skip
  - standard of concrete finish (class of finish, off-form?)
  - Site mixing of concrete (site based plant)
- Excavation
  - excavations and site retention can form a considerable portion of the overall schedule - careful planning of this stage can often result in greater construction time savings for less planning effort
  - poor control and supervision of 'in-ground' works results in more lost time in the ground than can ever be made up during successor phases of work
- Structural Steel
  - sometimes erratic delivery

  - overseas lead time
  - standard rolled size?
- Essential Services/Utilities
  - High Voltage electricity - substation required on site or adjacent site?
  - multiple substations required?
  - Are utility relocations relocated
  - Is traffic to be relocated?

Step 2 Scope & Methodology



The project's scope of work can be determined by:

- Reviewing relevant documents (drawings and plans, technical requirements, functional specifications etc.)
- Discussing the extent of work with the project team
- Comparing the project to other similar projects and benchmark data
- Project stages/phases for infrastructure projects typically include:
  - Project management and Client's activities
  - Interfaces, agreements, and approvals with external parties
  - Design development, reviews, and approvals
  - Procurement of subcontractors, long lead time materials and equipment
  - Off-site fabrication, storage, and delivery
  - Construction and installation
  - Testing, commissioning, systems integration, operational readiness, and handover
- Check if there is anything unusual or unique about the project that could affect the schedule including:
  - Unique design

    - Restricted operating environment (e.g. maintaining existing operations in and around new construction)
    - Restriction on working hours (e.g. night shifts, shutdowns)
    - Restricted access to work site (e.g. rail corridor, motorways)
    - Interfaces with external parties (e.g. utility providers)
    - High degree of complexity
    - Contract defined constraints (e.g. separable portions and sequential hand overs)
- Type of Delivery contract
    - Supply only
    - Design & Construct
    - PPP (Public Private Partnership)
    - Alliance or Incentivised Target

Step 3 Define the Work Breakdown Structure

The WBS should be established before adding activities and logic to the schedule, this will help to ensure a clear definition of scope.

This is a visual project breakdown that organises deliverables into different levels based on dependencies. It is essentially a project plan in a visual form, with the project objective at the top and sub-dependencies below.

Project managers use the WBS to break down complex scopes, visualise dependencies, and provide team members with a project overview. There are two types of WBS:

Deliverable based (which supports the project scope) and Phase based (which organises work based on phases & the overall time-line).

The WBS should accurately capture all the time phased deliverables and components of a project and the following points need to be considered carefully when setting up a project's WBS.

- Project reporting requirements
- Project phases and stages
- Project areas and zones
- Contracts, subcontracts, and packages of work
- Disciplines of work (e.g. civil works)

Cost control and earned value management (if required)

Structured to provide flexibility to accommodate new and additional scope or requirements.

If there is a project requirement to align the schedule with financial and cost tracking tools (e.g. earned value, cash flow etc.) then there needs to be enough flexibility in the schedule's WBS or Activity Codes so that they can be aligned with coding systems used elsewhere such as the Cost Breakdown Structure (CBS).

This often requires workshops and meetings with various departments (e.g. Planning Team, Cost Team, and Design Team) to ensure the differing needs and requirements of each department are met.

WBS and CBS alignment is often only practical and achievable at the higher levels of the WBS and needs to be done in the initial stages of the project, before the schedule, cost estimate and scope of works have been developed in detail.

Recasting or revising a WBS for a project part way through delivery can be very difficult and is often not feasible.

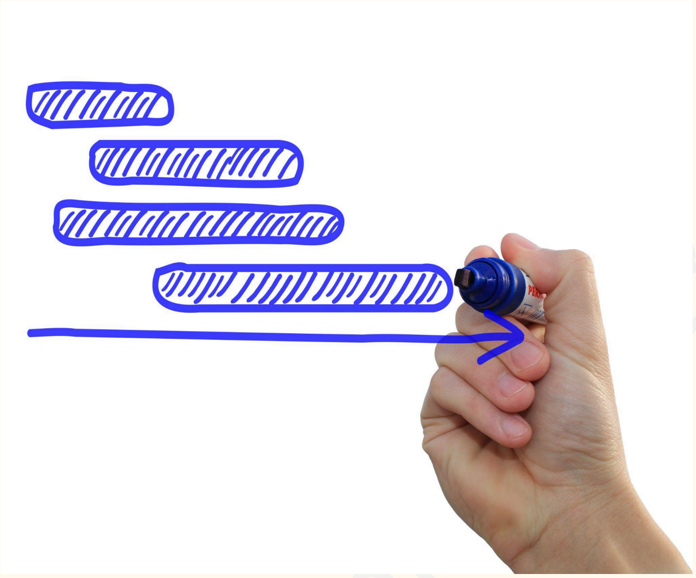
Lower levels of alignment between the WBS and CBS are best achieved using CPM software Activity Codes to map the discrete systems and deliverables within the CBS to the schedule.

Examples of WBS:

- **Deliverable based WBS for a simple house construction**
    - **Foundation**
        - Excavation
        - Footings
        - Concrete slab
    - **Structure**
        - Framing
        - Roofing
        - Windows and doors
    - **Interior**
        - Plumbing
        - Electrical
        - Drywall
        - Flooring
    - **Exterior**
        - Siding
        - Landscaping
        - Driveway

- **Phase based WBS for a construction project**
    - **Planning Phase**
        - Define project scope
        - Conduct feasibility study
        - Develop project charter
    - **Design Phase**
        - Architectural design
        - Structural engineering
        - Electrical and plumbing design
    - **Procurement Phase**
        - Material sourcing
        - Vendor selection
        - Contract negotiation
    - **Construction Phase**
        - Site preparation
        - Foundation work
        - Framing and roofing
    - **Control Phase**
        - Quality assurance
        - Progress monitoring
        - Issue resolution
    - **Closeout Phase**
        - Final inspections
        - Handover to client
        - Completion Documentation

Step 4 Activity Listing



Consider the type of schedule that is being developed. Is it a high level summary schedule or a detailed hour by hour maintenance schedule. Consider the unit of measurement. i.e. hours, days, weeks, months or quarters.

Consider the overall duration of the proposed project and the duration units.

Does the contract or specification nominate maximum task durations for activities in the schedule?

All the activities required to achieve the project scope must be defined.

There should be an adequate number of activities to accurately plan and model the project's full scope of works.

The level of detail within a schedule should be consistent with the level of discussion to understand and deliver the works.

Schedules with too few activities will not be detailed enough to plan and forecast the project's deliverables accurately and will make it difficult to define critical paths, to track progress and to identify delays and their causes. In most cases schedules should contain a consistent level of detail for each phase of work.

Schedules with too many activities can become difficult to manage and may be ignored by those who need to understand it.

Excessive activities will not add value to the schedule's logic, critical path, float values and forecast accuracy. They can clutter the schedule and place additional demand on planning resources in maintaining and updating the schedule.

Activity descriptions should contain verbs, nouns, and area descriptions so that the activity can be easily identified. For example, 'Install structural steel level 2 to 3' is easier to understand than 'SS L2/3'.

Consider intelligent activity naming. For a multilevel building project - ***slab formwork*** could be a repetitive task, but in isolation the task description does not clearly describe the location of the task. Whereas, ***South Tower - Level 2 (North) Slab formwork identifies the following :***

- building identification (South Tower)
- level (level 2)
- location (North)

Avoid including dissimilar or unconnected works in one single activity. For example, 'Pour Concrete Level 2 Slab' complies; however, 'Pour Concrete Level 2 Slab and Lay Pavers Ground Floor' does not because it contains two unconnected works in the one activity.

Consider the continuity of work described under a single activity. If the scope of work defined by an activity may be executed during separate time intervals, then consider splitting the activity into multiple activities.

Summary/Hammock/Level-of-effort (LOE) activities should only be used as summary activities and should not be used to represent work associated with a physical product or deliverable.

Step 5 Estimate activity durations

Activity durations should be realistic, achievable, and most likely with no padding for margin or risk.

Activity durations should be as short as possible to assist with the measurement of accomplished work, and durations in the short and medium term generally should not exceed the schedule updating period (i.e. 4 weeks).

Long duration activities should be broken into shorter activities where practical. Exceptions include procurement of long lead time items and equipment.

schedules with a large ratio of activities with very short durations (i.e. 1 day or less) may be too detailed and will make it difficult to update and manage the schedule.

Methods for estimating activity durations include:

- First principles using measured quantities and reliable productivity rates
- Benchmarking and historical data for similar types of projects
- Experience
- Suppliers' quotes
- Plug estimates

A first principles approach using measured quantities, productivity rates, resource and plant availability and a knowledge of construction methodologies is recommended when estimating activity durations when sufficient design information about the project is known.

Project team experts and activity owners within the project team should be consulted when estimating durations as they often have the best knowledge of how long certain activities will take in practice (e.g. the Design Manager will be able to give accurate estimates for how long each stage of design development and approvals are likely to take).

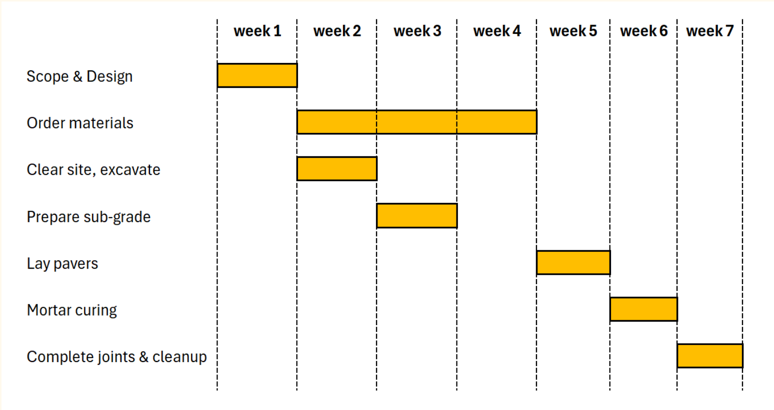
Assumptions related to duration estimates such as productivity rates, benchmark data and expert advice should be documented in the Basis of Schedule.

The number of resources available (labor and non-labour) can affect estimates of work and activity durations

Where possible significant resources should be assigned to the schedule to determine whether all required resources will be available when needed, to identify peak resource demands and to ensure resources can be managed effectively.

Any resources assigned to the schedule should be cross checked against resources allocated in the project budget.

Step 6 Define logic between activities



Clearly defined logic is one of the key criteria in establishing a credible and manageable schedule.

The schedule logic & sequence of work should be realistic and credible for the type of project being planned.

For a schedule to be accurate and robust all activities and milestones must have predecessors and successors except for the first and last activity or milestone in the schedule.

CPM Scheduling software relies on the activities being linked to calculate activity start and finish dates. If an activity's predecessor is missing, then the start of the activity will default to the current data date unless it is held to a date by a constraint.

If a successor is missing, then the late finish date of the activity will default to the latest date of the project and the activity will exhibit a large amount of float which could be inaccurate and misleading.

The only activity without predecessors should be the first activity or milestone, and the only activity without successors should be the last activity or milestone (no open ends).

Types of logic

Most relationship types should be Finish to Start.

Finish to Finish and Start to Start relationships between task dependent activities should be used sparingly.

Start to Finish relationships should not be used.

For planning purposes logic is grouped into two categories:

Physical logic

Physical Logic defines the relationship between activities that must happen in a particular order because of actual real-life physical constraints. A greater proportion of physical logic produces a more manageable schedule.

Sequence logic or Resource logic

Sequence Logic (or Resource logic) defines a preferred sequence of activities. The work described by such activities and logic does not have to occur in the defined sequence and, therefore, is subject to change.

Lags

Lags should be used sparingly as they introduce complexity and 'hidden' logic to the schedule that can be easily overlooked. They can also lead to scheduling errors when multiple calendars are used.

Lags should be replaced by breaking activities into smaller tasks with realistic predecessors and successors.

Any lags used should be documented in the *Basis of Schedule* with justifications explained. This encourages the Planner to think about the use of lags and it makes them visible to other members of the project team who do not have access to a soft copy of the schedule.

Constraints

Constraints should be used sparingly and kept to a minimum. Excessive constraints can introduce complexity and may result in unexpected scheduling results (such as negative float), an incorrect critical path or a critical path that is difficult to understand and interrogate.

Hard constraints (such as Mandatory Constraints) should not be used in most cases. These will hold constrained activities in place, regardless of any logic, and this can result in incorrect float and date calculations.

Situations where use of constraints may be required include:

- Contract completion dates and separable portions
- To represent important milestones, such as works area possession / handover dates, or deliverables provided by the Client
- Establishing a start to a sequence of work in an area defined by logic localized to that area
- As an alternative to using relationships with long lags where they do not truly represent competent logic

Any constraints should be documented in the *Basis of Schedule* with justifications explained. This encourages the Planner to think about the use of constraints and it makes them visible to other members of the project team who do not have access to a soft copy of the schedule.

Horizontal and vertical traceability

Logic in a schedule should have both vertical and horizontal traceability.

Vertical traceability ensures that dates, scope, and progress are consistent between the different sections or levels in a schedule. For example, the summary schedule is consistent with the detailed schedule.

Horizontal traceability ensures that interdependencies between activities have been planned in a logical sequence. For example, design activities link to procurement activities which link to construction activities and so on.

Path convergence and merge points

When an activity has many parallel activities as predecessors this is known as path convergence, and it creates a ‘merge point’ or ‘logic hotspot’ which can cause problems in managing a schedule.

Path convergence can affect the achievability of the schedule because the risk of achieving each of the predecessors becomes multiplicative, significantly reducing the probability of achieving the successor activity on time.

As a rule of thumb, the ratio of the number of relationships should be approximately 1.5 to 2 times the number of activities. When this ratio is greater than 2 it may indicate the presence of unnecessary logic and the schedule should be reviewed for ‘merge points’ with any unnecessary logic removed.

Step 7 - Determine the Critical Path

The critical path in project management refers to the sequence or order of schedule activities that determine the entire duration of a project.

It represents the longest path through the project, consisting of every activity that must be completed from start to finish. Identifying the critical path is crucial because it helps prioritise and delegate tasks, ultimately shaping the overall project timeline

Refer to the next Step 'Critical Path Explained' for detailed explanation, calculating the Critical Path, examples and Quiz.

Step 8 Review Resources

As previously highlighted in previous considerations, resources considerations to be understood:

- Resource unavailability times (restricted days or hours of work)
- consideration of long lead-time procurement of specialist resources or consultants
- Are overseas resources required? will these resources be working remotely and will there be sufficient supervision/management?
- specialist resources - are they in short supply and high demand, for;
    - testing
    - commissioning
    - installation
- what are key client resources that may impact essential documentation reviews and onsite inspections (design review/approval/inspections)
- what are the controlling resources/labor - eg structure crews (formworkers, reinforcement fixers) can be considered as controlling resources

- before trying to plan the best utilisation of resources - determine what resources are available
- check the availability and experience of local resources/contractors, particularly for controlling resources
- are local resources already over committed
- do local (regional/remote location) resources have the same productivity as metropolitan resources
- is there sufficient local supervision staff available
- do resources/supervision need to be imported to a remote location
- is the choice of installation/assembly method influenced by:
    - resources available
    - supervision available
- consider installation methods that reduce labor congestion
- Testing & Commissioning by specialist contractors/consultants
- will resources be on a work/time off roster eg. Fly in Fly out. Additional resources will be required to maintain work crew sizes and production rates
- Consider whether schedule logic will be resource driven
- consider local Industrial Relations requirements

Step 9 Define Project calendars

Multiple calendars with different work hours can introduce complexity as they are often not handled well by scheduling software and can produce unexpected scheduling results (such as negative float).

The number of calendars should be kept to a minimum, and when multiple calendars are required the working hours within each calendar must be the same (i.e., 8 hours per day).

Calendars define the available working time for activities in the schedule.

Calendars must include all non-working time (e.g., public holidays, RDO's, weekends etc.)

Typical calendars for different types of activities are as follows:

- Office based work / Design and procurement:
- 5-day week / 8-hour day with public holidays and 2-week Christmas break
- Construction and installation:
- 5-day or 6-day week / 8-hour day with public holidays, rostered days off and a 2-week Christmas break
- Occupations & closures / Curing:
- 7-day week / 8-hour day with no non-working time

Detailed Railway occupation schedules (hour by hour) should always be in separate schedules outside of the master schedule

Consider relevant local Industrial Relations for different trades with respect to working calendars.

Step 10 Add Contingency

A schedule with no contingency allowance has a greater risk of running late.

Contingency should always be included in a schedule for inherent risks and for any potential unplanned events (contingent risks) that might cause delays.

Project complexity and location, industry experience, historical information, and common sense need to be considered when estimating schedule contingency. For example, heavy civil projects will be subject to wet weather delays whereas building fit outs may not be.

For relatively simple project schedules, inclement weather allowance could be added as a single activity. More complex projects may require more analysis. Eg Civil projects with complex earthworks may need to consider applying the allowance as a non-work day within working calendars.

Calendars can also be used to represent dry and wet seasons. The calendar option may be a better 'model' for indicating cyclic productivity throughout the year.

Utilising the calendar non working days for 'contingency' essentially ***hides*** the contingency, which is not preferable. This method is also not ideal for showing the drawdown, to date from total contingency and the remaining contingency available.

Similarly, for projects such as road or rail, where tie-in connections to existing infrastructure may require these works to only occur on certain (hours/days/weeks). A good example is a Rail track possession/occupation - construction works leading up to the track possession could be delayed by 3 days (eg. due to insufficient productivity) resulting in the track possession being canceled. The next available track possession could be 3 months away. In this situation, a Project calendar for 'Track Possessions' would be better at modeling the impact of delays.

As a guide, high-level contingency allowances can be as follows:

*10% to 15% of net schedule duration for wet weather allowance for external works

*10% to 15% of net schedule duration for all other works (e.g., design, procurement, internal works)

*Note - The geographical location of the project and local weather conditions need to be analysed and considered to confirm whether the above percentage values are relevant.

A more considered approach to estimating schedule contingency involves performing a quantitative schedule risk analysis (QSRA) to estimate a range of likely schedule durations and completion dates.

Schedule risks and the behavior of mega projects fall into a class of their own. What is the definition of a mega project?

If we use cost - $2B, $5B, $20B? How would Super-Mega Projects be classified? $50B... $100B?

What if we use complexity? Is a $500M highly specialised and complex project (Eg. Communications Satellite) with hundreds of complex design and construction interfaces deemed a mega project, due to its extreme complexity and specialisation?

A feature of mega projects is that they are typically not a single project, but a series of projects or sub-projects. A mega project could be a schedule consisting of numerous projects.

Quite often when we consider risks as a 'negative'. An opportunity can be considered as the positive impact of uncertainty. A risk adds uncertainty, whether the outcome is negative (a threat) or positive (an opportunity).

The base case of the schedule needs careful consideration – how aggressive is the base schedule and can it be reasonably achieved? The contingency period allocated to the schedule needs to reflect the base case.

The Basis of Schedule document should clearly outline the target schedule strategy, whether conservative or aggressive.

Are the productivity rates and the contingency allowance based on historical data? Ie an assumed average of past performance.

Consider the era of the historical data being reviewed. The recent Pandemic has resulted in 'before' and 'after' Pandemic production rates and supply chain issues.

Previous experience on numerous large/mega projects in various countries has highlighted that lack of schedule integration contributes to considerable cost & schedule overruns. Google will return hours of interesting reading on this topic.

Long-duration 'Mega' Projects also run the risk of 'scope creep', client changes, changes in technologies and installation methodologies.

Commissioning and Integration were the main culprits of the lack of schedule integration.

Even using the PERT method to estimate activity durations will result in a conservative schedule.

Schedule quality is imperative for a reasonable SRA output. Schedule tasks with open ends (nil predecessors or successors) will considerably devalue the SRA output. Likewise, activities with too many ‘hard’ constraints will make the schedule no more than a ‘picture’.

This is done by including the inherent and contingent risks from the project's risk register in the analysis.

The inherent risks are included as a range of durations for key activities in the schedule (e.g., no. of piles per day per rig).

The contingent risk events are included as discrete activities with a likelihood of occurring and time impact when they do occur (eg. equipment failure).

Once these have been entered into a suitable schedule risk modeling tool (e.g Safran Risk, Acumen Risk, OPRA or similar) the risk model is run, and the schedule contingency can be selected based on the required probabilistic confidence level (e.g. P90). This approach also provides closer alignment between the schedule, the cost estimate, and the risk register.

How to include contingency in a schedule

Schedule contingency should be included as one or more discrete activities as predecessors to each contract completion milestone, key interface milestones, and the completion of project stages or Separable Portions.

Separate contingency activities could also be considered for different project phases ie. Design, Procurement, Construction, Commissioning.

Similarly, separate contingency activities could be added for different phases of construction - bulk excavation, structural elements, internal works etc.

This ensures that early target dates are planned for, it communicates clearly to all project stakeholders how much contingency has been included and it allows contingency to be managed and drawn down as and when it is required.

Contingency built into activity durations and schedule calendars is more challenging to manage, as it hides contingency and makes it difficult to 'draw down' and communicate how much contingency is included and how much contingency has already been 'consumed' as the project progresses.

Step 11 Re-schedule the schedule and review

When the schedule has been developed it can be rescheduled and the outcomes should be reviewed with the Project Team.

Information to be reviewed by the project team includes:

- Project duration and end date(s)
- Activity durations, start and finish dates
- Is all the scope included?
- Does the schedule reflect agreed delivery strategies and is it aligned with the top-down summary schedule?
- Critical path and total float (see below)

Critical path

There should be a clear, identifiable, continuous, and realistic critical path from the status date to the project completion date(s).

The critical path is be defined by ISO 21500 Guide to Project Management as: 'The sequence of activities that determine the earliest possible completion date for the project or a phase of the project'

The critical path should be well understood, and it should make sense. By understanding the activities on the critical path, the project team can better manage the activities, risks and opportunities that are more likely to impact the project's end date.

Parallel critical paths and near critical paths with the potential to become critical also need to be considered and understood.

The critical path (CP) should not include LOE activities, lags, unusually long duration activities, or constraints that force unimportant activities onto the CP.

The percentage of activities on the critical path (and near the critical path) should also be assessed. A higher number of critical and near critical activities in the schedule places greater risk on achieving the project's end date(s).

Total Float

Projects are very dynamic and activities that have float at the beginning of a project can become critical later. Always review for time saving opportunities across the whole schedule, not just on the critical path.

Time savings are not achieved through ambitious production rates but rather by applying new logic and sequencing which may include additional resources, parallel activities, earlier access and alternate design or delivery methodologies.

Negative float in a schedule increases the risk of achieving the project's completion date(s). In schedules with negative float the critical path can be difficult to determine, especially if the negative float is a result of scheduling errors in the software.

Any negative float in the schedule due to scheduling errors (i.e., when it is unintended) needs to be corrected and removed.

Activities with unreasonably high float indicates that there may be logic missing from the

Step 12 Baseline the schedule

A baseline creates a reference point against which changes, and progress can be measured and managed. Once the project team has agreed to the schedule it should be baselined.

The baseline schedule must be realistic and achievable.

Establishing a baseline schedule is essential to effective management. A baseline schedule represents the original configuration of the schedule plan and signifies the consensus of all stakeholders regarding the required sequence of events, resource assignments, and acceptable dates for key deliverables.

It is consistent with both the schedule plan and the schedule budget plan and defines clearly the responsibilities of schedule performers.

The baseline schedule includes not only original forecasts for activity start and finish dates but also the original estimates for work, resource assignments, critical paths, and total float.

The baseline schedule is not the same as the current schedule. The current schedule is updated from actual performance data. Therefore, it is the latest depiction of performance and accomplishments, along with the latest forecast of remaining dates and network logic.

The **baseline schedul**e represents the schedule's commitments to all stakeholders, while the current schedule represents the actual plan to date.

The **current schedul**e is compared to the baseline schedule to track variances from the plan. Deviations from the baseline inform management that the current plan is not following the original plan all stakeholders have agreed to.

Deviations imply that the current approach to executing the schedule needs to be altered to align the schedule to the original plan or that the plan from this point forward should be altered.

Step 13 Update the schedule

schedule updates are about the forecast, not the history.

The schedule is a dynamic model and needs to accurately reflect the project's progress and changing status. This is done by updating the status of the activities in the schedule at regular intervals. Frequency of updates will depend on the type of project and the project's phase.

A clear process for updating and reporting schedule progress and status against the agreed baseline should be established early on.

Updating a schedule against an agreed baseline and reporting this information back to the project team provides a comprehensive means of monitoring the progress of the works and helps to:

- Identify and mitigate variances and delays early
- Re-plan and provide new forecasts for the remaining works
- Provide a record of the impact of variations and scope changes
- Substantiates the adequacy of the resources for the execution the works

Progress updates should include gathering information on the following items:

- Physical progress of works (e.g., 4 out of 10 footings complete, physical completion = 40%)
- Time related progress (actual start date, actual finish date, remaining duration or expected finish date).
- Physical progress might not directly dictate the remaining duration or expected finish date. This is because many activities do not involve linear production or expenditure of man hours, and this is the reason why physical % complete and remaining duration should be de-linked in the schedule.
- Variances to key milestones and specific reasons for variances along with proposed mitigation actions
- Ongoing productivity and progress trends and the impacts of these trends on future durations
- Validation of and changes to previous assumptions

- Key issues, risks, and time saving opportunities related to the schedule

schedule inputs and status updates should always be done in face-to-face meetings with those who are closest to the information.

Check schedule progress and status updates against physical deliverables whenever possible.

Regular site walks are the best way of verifying actual progress of construction activities. This helps with identifying, understanding, and reporting the current issues, slippages, mitigation measures, assumptions, opportunities, and risks associated with the schedule.

schedule revisions

Minor revisions

- A minor revision is a revision that does not have a significant impact on the overall schedule.
- Typical reasons for minor revisions include:
    - More detailed information becoming available after the initial setup of the Project.
    - Letting of subcontracts resulting in alternative sequences of work within a works package.
    - Minor variations to the works.
    - Proposed alterations to work sequences to mitigate incurred delays (Contractor's normal mitigation with no cost and resources impact).

Such changes should typically not require resetting of the Baseline schedule except when the change in work sequence significantly alters the critical / near-critical path and the baseline project end-date(s).

Major revisions

A major revision is a revision that has a definite impact on the overall schedule and / or significantly changes the schedule methodology, resulting in inaccurate progress reporting.

Major revisions would typically be caused by:

- Significant changes or additions to the scope of work.
- Major variations.
- Changes to contract completion dates.
- Major delays to the works.
- Instructed acceleration to the works.
- Such revisions require re-establishment of a revised Baseline schedule.

The Critical Path Method Explained

Before explaining how to calculate a Critical Path, some common technical terms need explaining :

Activity

A distinct item of work completion of which is necessary to finish the project.

Duration

A realistic, best estimate of the amount of time necessary for accomplishing the work involved in an activity. Measured in time units. eg days.

Early Start (ES)

The earliest point in time when an activity can start, assuming all prerequisite activities take place as scheduled.

Early Finish (EF)

The earliest date that an activity can finish, assuming that it began on its early start date.

Late Start (LS)

The point in time by which an activity must start if there is to be no delay in subsequent activities.

Late Finish (LF)

The date by which all work involved in an activity must be completed in order to avoid delaying subsequent activities.

Critical Path

The sequence of activities from project start to finish that has the least amount of float, i.e., requires the longest total amount of time to complete.

Longest Path

The longest path refers to the sequence of activities with the **highest total duration**. It may or may not be the critical path.

Total Float

The amount of extra time available to an activity or activities on a path when all activities start as early as possible.

Free float

Uniquely available to an activity. It also indicates the duration that the activity can be delayed without delaying successor tasks

Slack

Another term used for Float

Task

Another term for an activity

Zero float

Denotes activities that have no flexibility but must start and finish on or before their scheduled dates for the project to be completed on time.

Negative float

Denotes activities scheduled to occur after their late dates. The project is delayed.

The Critical Path Method (CPM)

Scheduling Methods

Time Chainage Diagram

A time–distance diagram, also known as a time chainage diagram, is a powerful tool used in longitudinal projects like pipelines, bridges, tunnels, roads, tunneling and transmission lines.

The time–distance diagram visually presents a project's time schedule alongside its linear position (distance).

The chart has two axes:

Time Axis: Usually vertical, representing the project's timeline (days, weeks, months or years).

Location Axis: Horizontal, indicating the linear position (linear distance, or vertical height/levels.

The direction of the chainage (distance) can increase or decrease based on project geography.

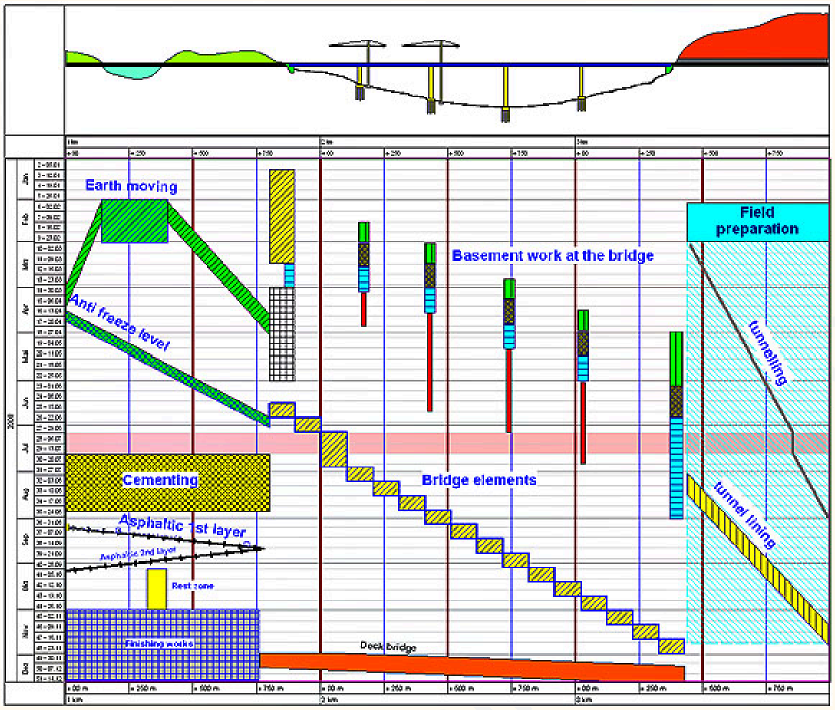
Schematics of the construction project may enhance the location axis.

Color-coded shapes represent different activities, showing their occupation of the work site over time.

Benefits:

- Visualization -Easily see all visible activities along the construction site in a single diagram.
- Conflict Detection - Identify conflicting access points visually.
- Progress Direction - Show the direction of activity progress.
- Resource Coordination - Optimise resource allocation.

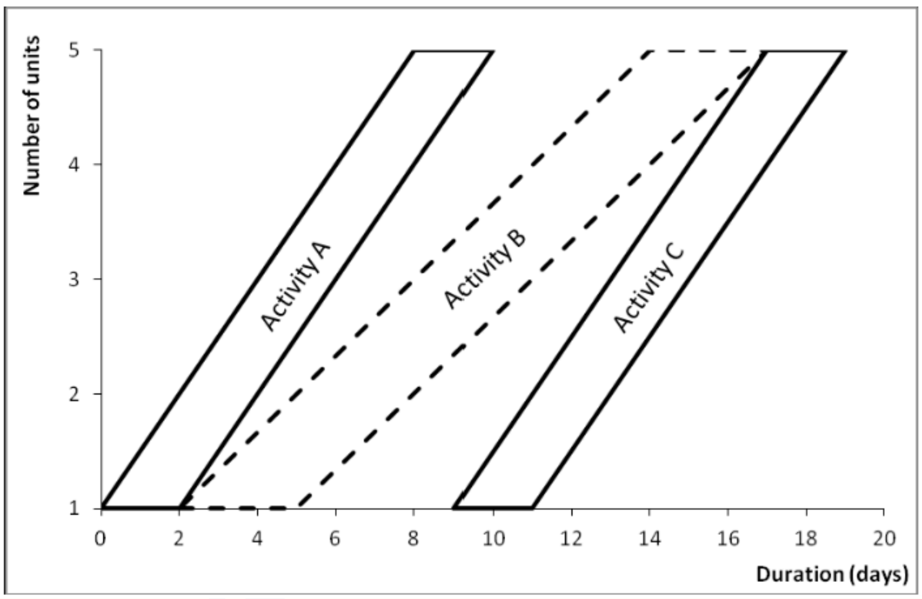
Remember, a time chainage diagram enhances coordination and decision-making, making it a valuable tool for managing complex projects.


Earth moving
Field preparation
Basement work at the bridge
Anti freeze level
tunnelling
Cementing
Bridge elements
tunnel lining
Asphaltic 1st layer
Asphaltic 2nd layer
Rest zone
Finishing works
Deck bridge

Line Of Balance

Is a project management technique that visually represents the repetitive and sequential nature of work within a project. It helps managers quickly assess whether activities in a repetitive process operation are "in balance."

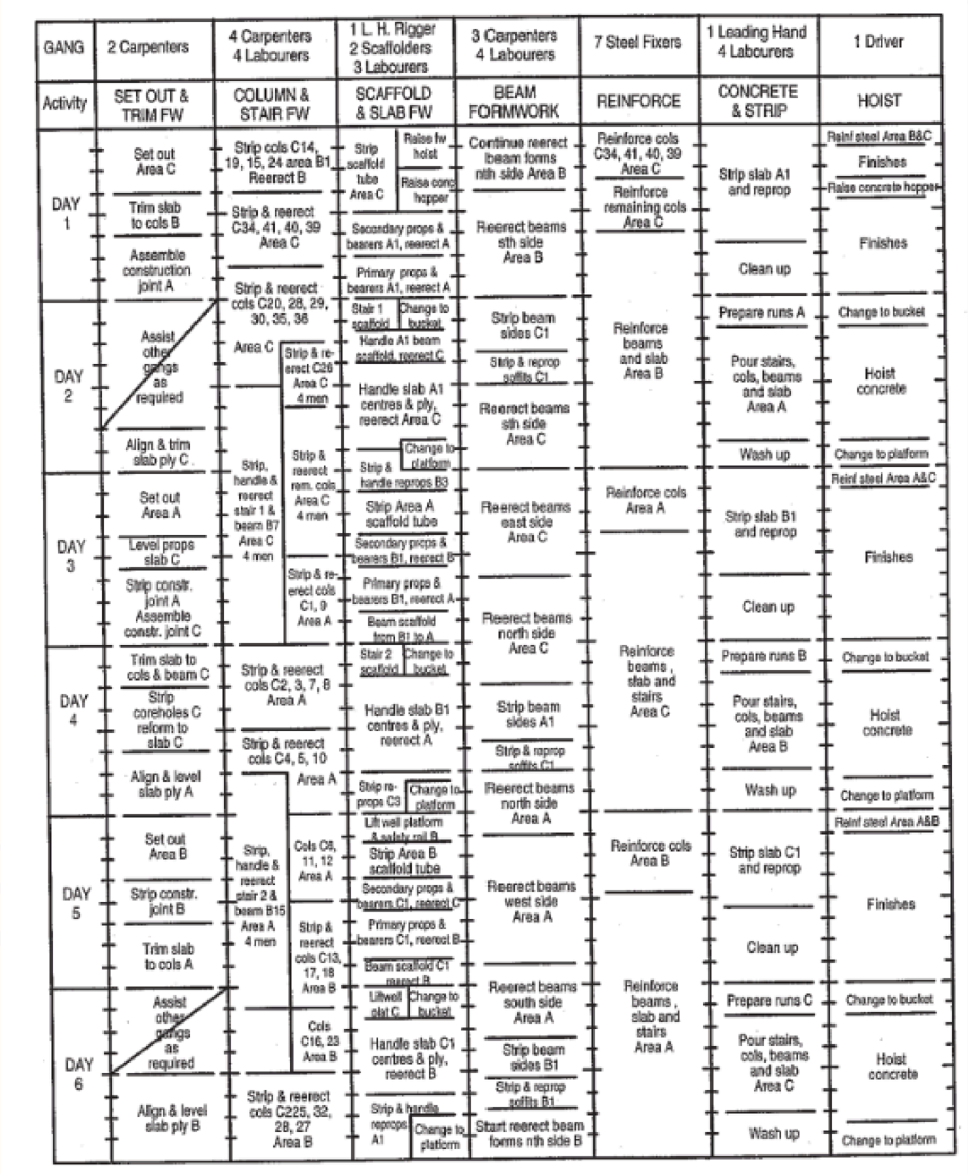
It shows whether completed activities 'align' with the planned schedule and whether future activities are on track.



Multi Activity Chart

A Multi Activity Chart is a tool used in method study to analyse more than one activity simultaneously within the same time frame.

It helps visualize the interrelationships between different subjects (such as workers, machines, or equipment) during a process.



There are several types of Multiple Activity Charts:

Man-Machine Chart: Describes the activity of a worker and the machine(s) they are attending to over time.

Man-Man Chart: Analyses two different activities (e.g., two workers) against the same time scale.

In summary, Multiple Activity Charts help optimise processes by understanding how different activities interact and identifying opportunities for improvement

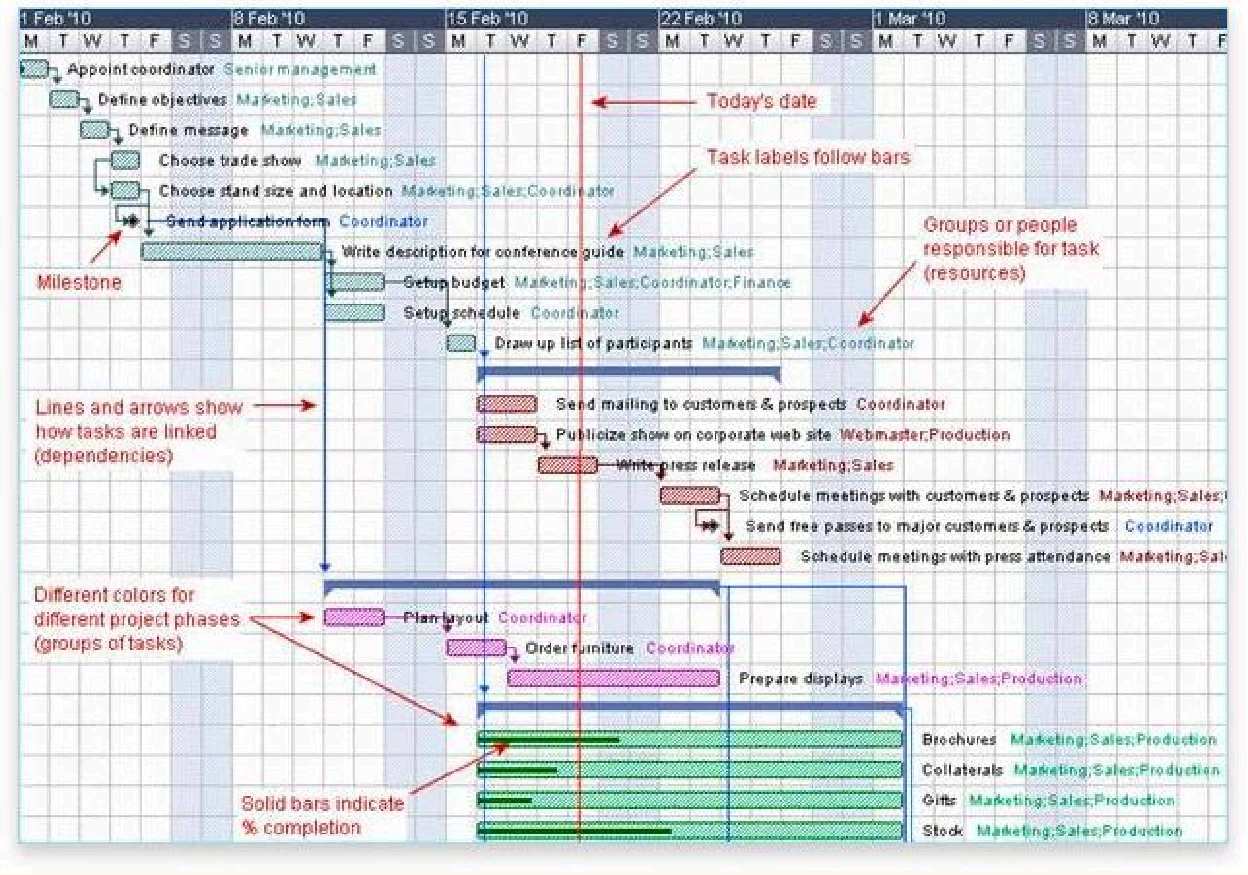
Bar Chart (Gantt Chart)

A Bar Chart represents the sequence and duration of activities in a project.

Each bar represents one activity, with the length of the bar indicating the activity's duration and the position of the bar indicating the time period when the activity is projected to take place.

The Bar Chart has two variables:

- 1) Time
- 2) Scope



The Critical Path Method (CPM)

The critical path method (CPM) refines the **Bar Chart** representation of a project by adding relationship ties between activities so that if anything changes, its effects on the rest of the schedule can immediately be seen.

The "critical path" is simply the chain of activities from the start to the finish of a project that has the least amount of float (takes the most time to complete), such that any delays in the critical path activities will negatively impact the finish date of the project. The usefulness of the CPM is that it allows you to run "what if" scenarios and spot potential problem areas early, while there is still time to proactively deal with them. It also provides an effective way of documenting the impact of delays on a project.

The CPM method has Three Variables:

- 1) Time
- 2) Scope
- 3) Logic

In an Activity Diagram, a network of tasks can be set up to show the dependent sequence of activities within a project. The Critical Path Method can be applied to such a network to answer the most common question asked of project managers: *How long will the overall project take?*

Critical Path can be determined by :

- manual calculation
- using a spreadsheet
- using CPM software such as Primavera P6, Microsoft Project, Asta Power Project or similar

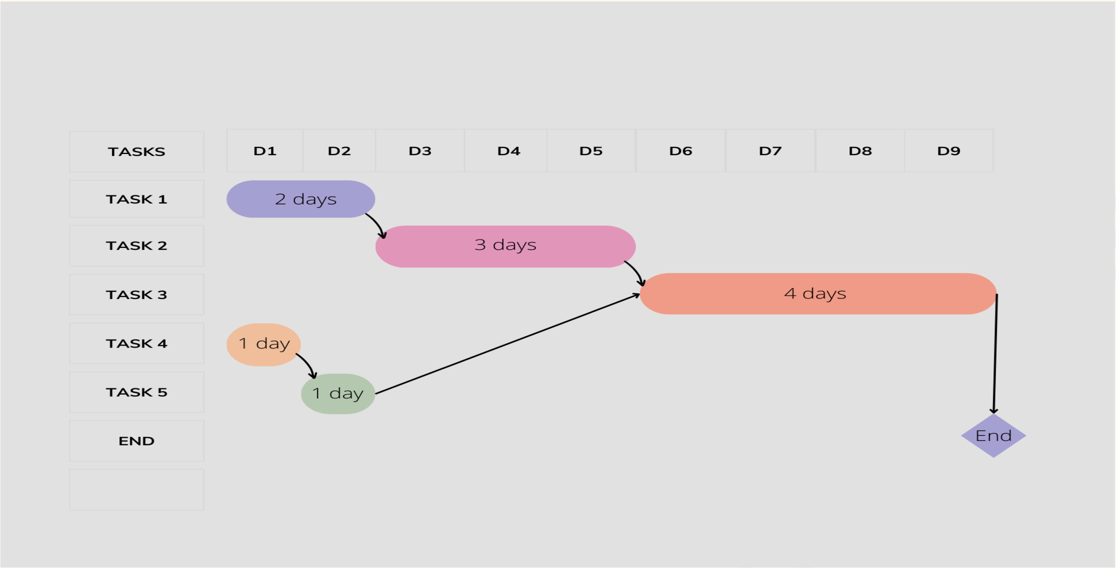
We will explain the manual method, using the instructions described below.

A very common next step is to add timings to show how long each task will take and then to identify the critical path, which is the route through the network that will take the longest amount of time.

Tasks that are not on the critical path have more leeway (float) and may be slipped (delayed) without affecting the end date of the project. This is called float (slack).

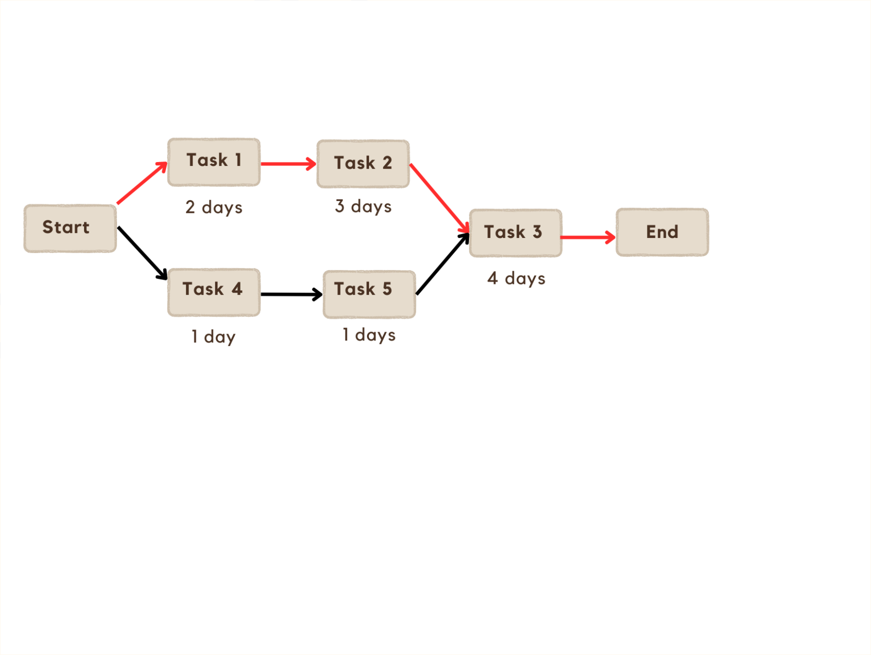
Tasks on the critical path have no float and this feature may be used to identify the critical path. It is also quite common to have more than one critical path, a near-critical path, or a parallel path.

A simple bar chart is shown here:

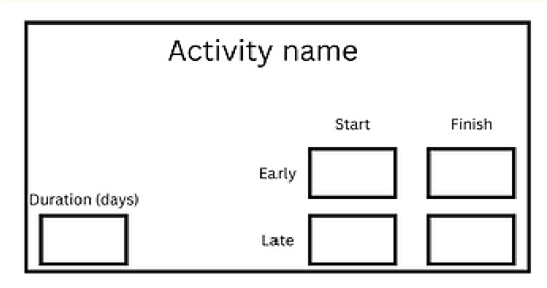


How do we calculate the Critical Path?

Build a simple Activity Diagram, including estimating the time required (or duration) for all tasks. Based on the simple bar chart above :



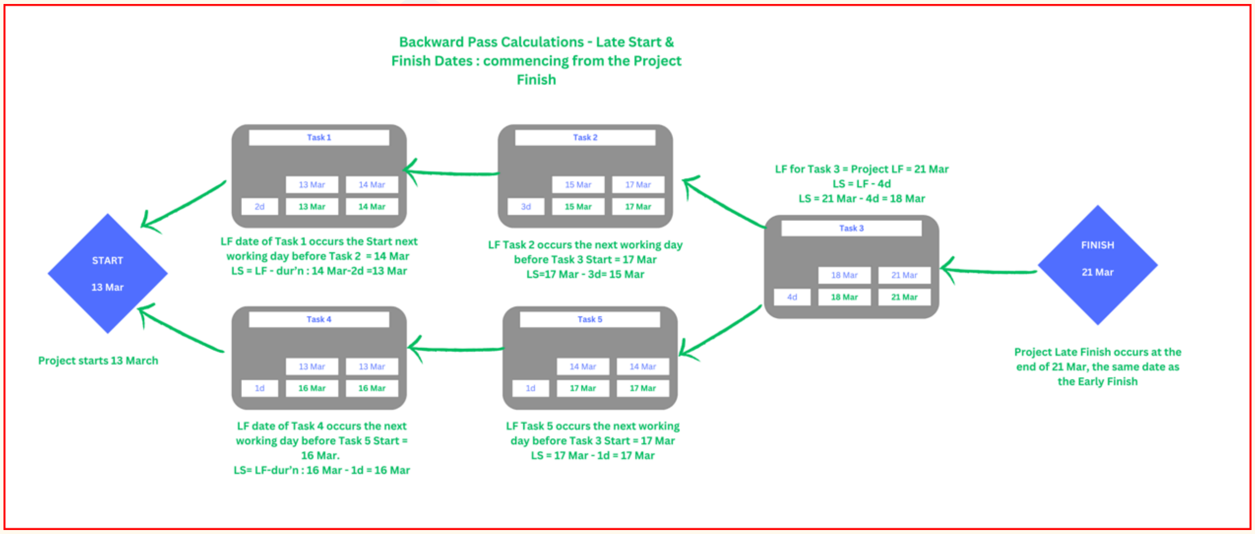
Next, we need to Include a space on each task 'card' for early and late start and finish dates or times (times, rather than dates, are required for tasks where hours or minutes are significant).



The early start and early finish are simply the earliest times that a task can start or finish. The late start and late finish are the latest times that a task can start or finish.

For this example, we will assume that each calendar day is available for work. Start date 13 MAR 2025 (13MAR). We also assume that the work day commences at 8am and finishes at 4pm.

Starting with the tasks at the beginning of the diagram, complete the early start and early finish for each task in turn, following the arrows to the next task, as in the figure below.



The early start of a task is the same as the early finish of the preceding task. If there is more than one predecessor task, then there are several possible early start figures. Select the latest of these.

The early finish for each task is equal to the early start plus the duration of the task. The final calculation is for the earliest completion time for the project. This is calculated in the same way as the early start date.

Starting with the tasks at the end of the diagram, calculate the late start and late finish for each task in turn, following the arrows in the reverse direction to the previous task, as in the diagram below.

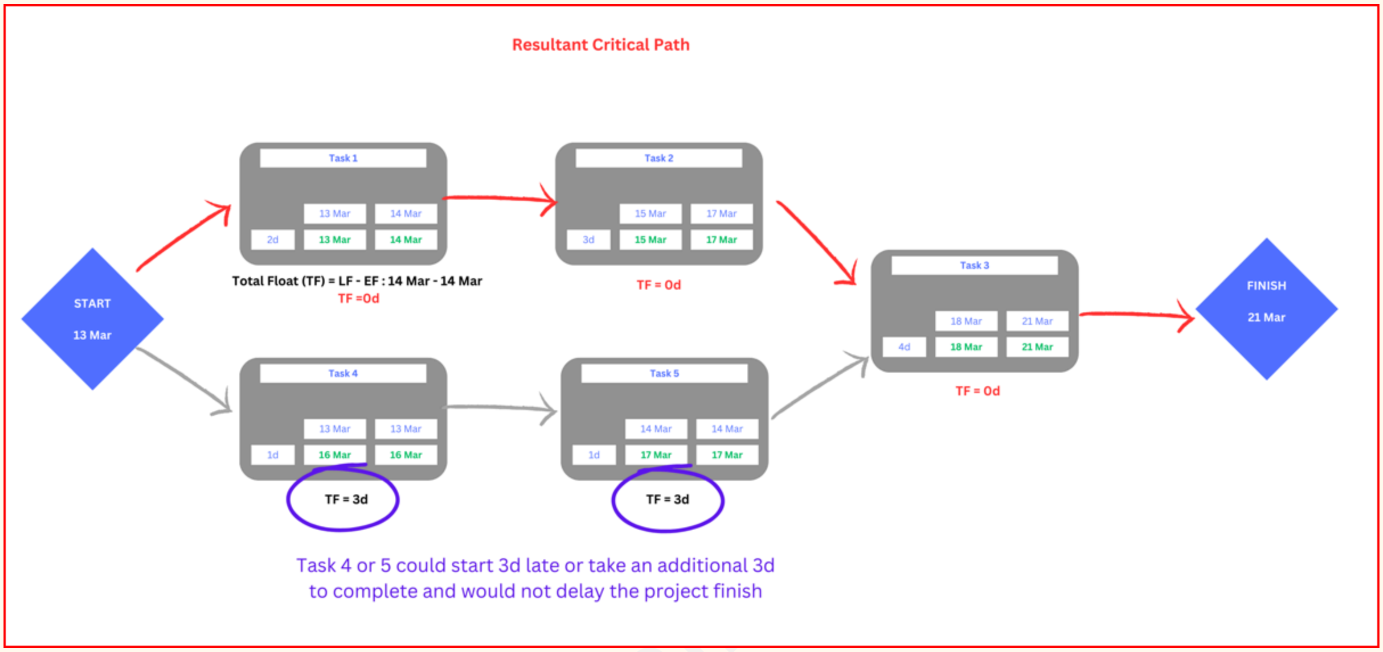
The late finish is the same as the late start of the succeeding task (for the final tasks in the project, this is equal to the earliest completion date). If there is more than one successor task, then there are several possible late figures. Select the earliest of these.

The late start for each task is the late finish minus the duration of the task.

You now have, for each task, the earliest and latest times that it can start and finish.

Now find the slack time (or 'float') for each task by subtracting the early start from the late start. The slack time is the amount of time the task can be slipped by without affecting the end date of the process.

The critical path can now be identified as all paths through the network where the slack time is zero.

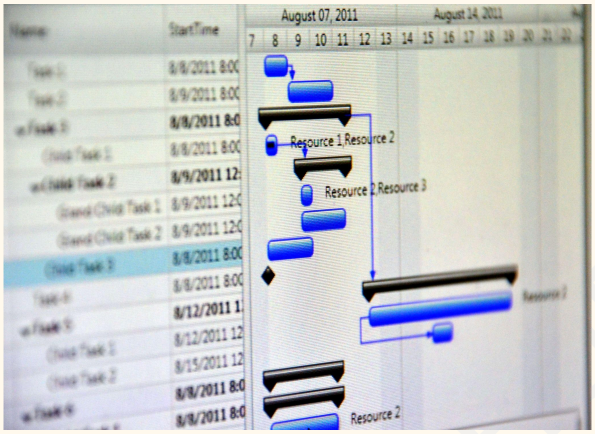


It may be possible to reduce the critical path of a project (and consequently pull in the completion date) by rearranging some tasks that have an optional sequence or by moving key people onto tasks in the critical path so you can reduce the time for these tasks.

The above 'Project' was a simple 5 Task schedule, with relatively simple logic (Finish - Start). Complex projects with numerous activities and complicated logic requires CPM software to undertake the above forward pass and backward pass calculations, quickly and accurately.

It is important, as a planner, to understand the fundamentals of CPM, before jumping into CPM software. Not all CPM software is the same.

Confirming the Critical Path



The critical path is generally defined as the longest continuous sequence of activities in a schedule. It defines the schedule's earliest completion date or minimum duration. Activities on this path are termed "critical path activities." Typically, the sequence of activities with the longest total duration is also the path through the network with the lowest total float.

Total float is the time an activity can slip before its delay affects the schedule end date. When the network is free of date constraints, critical activities have zero float, and therefore any delay in the critical activity causes the same day-for-day delay in the schedule forecast finish date.

For example, if an activity on the critical path is delayed by a week, the scheduled finish date will be delayed by a week unless the slip is mitigated.

Therefore, the critical path is most useful as a tool to help determine which activities deserve focus and, potentially, management help. The critical path assists schedule management in prioritizing resources to have the most positive effect on schedule performance.

Typically, total float is set to zero, and the scheduling software marks as critical all activities with zero or less-than-zero total float.

Activities with total float within a narrow range of the critical path total float are "near-critical" because they can quickly become critical if their float is used up in a delay.

Near-critical paths need only a small delay of time to become critical. Management must monitor critical and near-critical activities through sound schedule

management because any delay in them will delay the entire schedule. Near-critical paths are monitored according to a float threshold tailored to the schedule.

For example, a brief schedule might consider a 5-day slip to be a near-critical threshold. In schedules scheduled to take years, a 2- or 3-month's slip in near-critical paths might make the path critical. Because prolonging a schedule by 5 days on a short project is as easily possible as prolonging a multiyear project several months, schedule managers should manage all near-critical and critical paths.

The critical path is not constant. The sequence of activities that make up the critical path changes as activities are delayed, finished early, occur out of planned sequence, and so on.

Activities that were previously critical may become noncritical, and activities that were not critical may become critical.

It is crucial that schedule management understand that an important activity is not necessarily "critical." At any point in time, the critical path may or may not contain activities that management believes are particularly important.

A delay in an activity may be important for any number of reasons related to scope and cost without delaying the finish milestone date. In contrast, some mundane activities—training, for example—may be on the critical path and not particularly risky but can delay the scheduled finish date if they take longer to accomplish.

Similarly, an activity of long duration should not be referred to as a "critical path activity" simply because it will take a long time to accomplish. "Critical activity" in scheduling parlance has a specific definition that should be adhered to when reporting and evaluating schedule data.

Total Float

Once the early and late dates have been derived, the schedule can be assessed for flexibility. The difference between the time an activity may start or finish and the time it must start or finish in order for the project to be completed on time is known as total float (TF). Total float is calculated as the difference between an activity's early and late dates:

TF = LS – ES

or

TF = LF – EF

Critical Path or Longest Path?

In the Critical Path Method (CPM) for project scheduling, the terms "longest path" and "critical path" are often used interchangeably, but they can have distinct meanings depending on the specific project management context and the software being used.

Critical Path

The critical path is the sequence of activities in a project schedule that determines the shortest possible duration of the project.

Zero Total Float: Activities on the critical path have zero total float. This means that any delay in these activities will directly impact the project completion date.

Longest Duration: The critical path is the longest duration path through the schedule network diagram from start to finish, taking into account the dependencies between tasks.

Determines Project Duration: The total duration of the critical path determines the overall project duration.

The critical path is crucial to stakeholders because it indicates the tasks that cannot be delayed without affecting the project's completion date.

Managing the critical path effectively is key to ensuring project success.

Longest Path

The longest path, while often synonymous with the critical path, can be differentiated in most modern CPM software. The longest path is:

The Path with the Greatest Duration: The sequence of activities from the start to the end of the project with the longest total duration, not necessarily with zero float.

This distinction becomes relevant in complex projects with multiple start and end points or in projects where activity constraints affect the task's free & total float. In certain cases, activities may have negative float as a result of constraints applied to activities.

Not Always Critical: In some cases, especially in projects with multiple stages/ phases or constrained schedules, the longest path may not always be critical in terms of impacting the project's final delivery date, due to the presence of different constraints or float values calculated based on these constraints.

Key Differences

Float and Impact on Project Duration: The critical path is defined by (less than or equal to) zero float, meaning no delay is possible without affecting the project's delivery date. The longest path, while it may have the greatest duration, might sometimes allow for delays (depending on the project management approach and the presence of constraints) without immediately impacting the project's end date.

Sensitivity to Project Constraints: The identification of the longest path can be more sensitive to various project constraints (like fixed start and end dates for certain tasks) than the critical path. This is particularly relevant in software or methodologies that differentiate between the two based on how floats are calculated and constraints are applied.

In most applications, especially in relatively simple projects, the critical path and the longest path may indeed refer to the same sequence of tasks. However, in more complex scheduling scenarios with multiple constraints, it's important to understand the potential differences between these concepts for accurate project planning and risk management.

Effective Schedule management requires close monitoring of both to ensure timely project completion and to identify potential risks and delays.

Complex mega projects that have numerous (hundreds) of schedule interfaces within the schedule or with other schedules can result in parallel critical paths.

Levels of criticality should be considered.

Absolute Critical: 0 days total float

Critical: < 20 days total float

Near Critical: 20>40 days total float

Another consideration is reviewing multiple float paths for understanding near critical path activities.

Retrospective longest path analysis

In the retrospective longest path analysis approach, the focus lies on determining the critical path as it actually occurred during the project, distinct from the contemporaneous or actual critical path identified through other methods. This methodology involves several steps to unveil insights into project performance.

Initially, the delay analyst establishes or verifies a detailed as-built schedule, capturing the project's actual timeline accurately. Subsequently, tracing back from the project's completion date, the delay analyst identifies the longest continuous path - the retrospective as-built critical path. This path showcases the sequence of activities that significantly influenced the project's duration.

Further investigation into project records (correspondence, diary entries, records of interview etc.) follows to understand the causes behind identified critical delays. By scrutinising events and circumstances throughout the project's lifecycle, the analyst gains insights into factors contributing to deviations from the planned timeline.

However, it's essential to acknowledge a limitation of this method: its relatively constrained ability to accommodate shifts in the critical path during project execution. While effective in pinpointing key delays and their causes, this approach may not fully capture instances where the critical path underwent changes during the project's progression.

Intro to CPM software

As of March 2024:

- Primavera P6
- Asta Power Project
- Microsoft Project
- others

P6 Vs MS Project Vs Asta

The three primary scheduling and control software packages used in the building, construction, and resources industries are Microsoft Project, Oracle Primavera P6, and Asta Powerproject (Elecosoft). Each of these software packages has distinct origins, architectures, and industry applications, offering various advantages and facing certain disadvantages within their operational contexts.

Origins

Microsoft Project was developed in the US in 1984, initially aimed at managing software development projects. Its functionality has evolved over time, with significant features like Cost Resources and Calendar Exceptions being added.

Oracle Primavera P6 originated as Eagle Ray in the 1990s, later acquired by Primavera Systems. It was designed for software and business development projects and has since become a staple in more extensive project management applications.

Asta Powerproject was developed in the early 1980s in the UK, with a strong focus on the building and construction industries. It incorporates features specifically tailored to these sectors.

Architecture

Microsoft Project offers three versions: Standard (desktop for standalone files), Professional (desktop for server or Microsoft Project Server files), and Web App (browser-based, for Microsoft Project Server files). The Standard version is most commonly used by building and construction companies.

Oracle Primavera P6 operates projects from a database rather than single project files, supporting Oracle and Microsoft SQL databases. It comes in Professional Project Management (PPM) and Enterprise Project Portfolio Management (EPPM) database types, with Windows and Web Client applications for interfacing.

Asta Powerproject provides flexibility in operation, allowing for single or multiple project files, user concurrency, and database integration. It is favored for its concurrent licenses and free reader option, making it cost-effective.

Industry Usage

Microsoft Project is widely used by residential builders, architects, quantity surveyors, and smaller civil construction companies. It's appreciated for its simplicity, cost-effectiveness, and familiarity among users, though it is often not updated with actual dates for revised end dates.

Oracle Primavera P6 is preferred for large commercial building projects, medium to large civil construction firms, and almost all resource companies in mining, oil, and gas industries. Its structured approach to schedule updates and extensive data handling capabilities make it suitable for large-scale projects.

Asta Powerproject has a smaller market penetration in Australia but is valued by large commercial construction companies and builder developers for its construction-specific functionality and flexible licensing.

Advantages

Microsoft Project is known for its ease of use, widespread familiarity, cost-effectiveness, and simple deployment within IT infrastructures.

Oracle Primavera P6 excels in handling large project data, enforcing proper schedule updates, and providing robust baseline and forecasting features.

Asta Powerproject offers extensive scheduling options, construction-specific functions, and cost advantages through concurrent licensing and a free reader.

Disadvantages

Microsoft Project can be challenging to manage in complex scenarios due to its template issues, limited relationship modeling, and difficulties in handling multiple resources and calendars.

Oracle Primavera P6 may present graphical limitations and requires careful management of planned dates and baseline data to avoid confusion.

Asta Powerproject faces challenges with market penetration and operator availability, alongside a steep learning curve due to its advanced features.

In summary, these three scheduling and control software packages offer a range of tools tailored to the diverse needs of various industries. Microsoft Project is suited for smaller projects and users seeking simplicity and affordability. Oracle Primavera P6 caters to large-scale projects requiring detailed schedule management and data handling. Asta Powerproject is recognized for its construction-specific functionalities and flexible licensing, appealing to companies not needing to exchange schedule files frequently.

Who Owns the Float?

The question of who "owns" the float (slack) in a Project schedule can be complex and often depends on the specific contract terms, project management practices, and jurisdictional legal standards. There are generally three perspectives on float ownership:

Project Ownership:

Some argue that since the float is a component of the project schedule, it inherently belongs to the project itself. This perspective suggests that the project owner or the party funding the project has the right to dictate how the float is used, as they have a vested interest in the project's timely completion.

Contractor Ownership:

Others argue that the contractor or the party responsible for creating the project schedule owns the float. This view is based on the idea that the contractor's expertise and effort in planning and managing the project schedule entitle them to control over the float. They may use it as a buffer to manage risks and uncertainties inherent in the construction process.

Shared Ownership:

A more collaborative approach suggests that float is a shared resource between the project owner and the contractor(s). This perspective recognises that both parties have a stake in the project's success and that effective use of the float requires cooperation and communication. Shared ownership of the float encourages collaborative problem-solving and flexibility in managing the schedule.

The ownership of float can have significant implications for project management, particularly in situations where delays occur. It can affect decisions about schedule adjustments, claims for time extensions, and financial liabilities for delays.

To avoid disputes, it is crucial for contracts to clearly specify how float is to be managed and who has the rights to use it. In practice, detailed contract provisions regarding float management and ownership can help clarify these issues and provide guidance for both project owners and contractors.

Be mindful that float can be manipulated by constraints, questionable logic, unnecessary logic with lead/lags, redundant logic, duplicated tasks or Milestones. Schedules can be front-end loaded or transfer risk unnecessarily between stakeholders.

Schedule Reviews

Schedule reviews undertaken internally for Governance/Organisation approval are an essential part of the schedule acceptance process. A Basis of Schedule (BoS) document provides an overview of the project and the planning and schedule methodologies used.

Schedule Documentation

Basis of Schedule document (BoS)

The basis of scheduled document should include the following items:

- Project description & Scope
- Documents that were relied on (design documents, specifications, reports, surveys, contracts, technical requirements)
- Project owners 'Schedule Management Plan'
- Schedule strategy
- Construction Methodology
- Key Productivity information & Resources
- Working Calendars
- Activity duration calculations for key activities
- Schedule Risk Analysis report
- Explanation of Critical Path

- Constraints used in the schedule
- Resource Histograms
- Schedule Quality Checks
- Key Milestones, Completion dates, Separable Portions etc
- Staging or Phase drawings
- Time Chainage Diagram if relevant
- Summary Schedule output
- Detailed Schedule output
- Critical Path
- Near Critical Paths

Schedule Management Plan

- The schedule management plan is a collection of processes, approaches, templates and tools that comprise the project's execution strategy and objectives as reflected in the project's schedule.
- The Schedule Management Plan should be unique to each project and defines how the schedule will be developed, updated, progressed and how it should be communicated to various levels of Management
- The Schedule Management Plan can refer to Guidelines for additional information. Eg. a guideline for Time Chainage Diagram Preparation which provides details on the preparation, formatting etc of the TCD. Reference would be made to the chosen or specified CPM & TCD software.

Reviewing schedules by others

Schedule reviews require detailed analysis, careful investigation, and close interaction with the project team.

The reviewer's role is not that of policing or auditing – rather it is uncovering and communicating hidden stories about the status and achievability of the project and schedule, and then working closely with the project team to help solve them.

Your organisation's teams undertake extensive reviews of schedules developed by Contractors and other stakeholders, mostly in the latter stages of the Procurement Phase (i.e. Bid schedules) and during the Delivery Phase (i.e. Contractors' Delivery schedules).

Schedule reviews help us to understand and communicate:

- schedule health – is the schedule accurate and robust?
- Change management – how is the schedule changing over time and how is this being managed?
- Progress measurement – how is the project tracking, are its deliverables being completed as planned?
- Contract compliance – is the schedule compliant with the relevant documents?
- schedule achievability – is the schedule (and project) likely to be completed on time?

Outputs of the review should strike a balance between carefully quantified data and information. Data on its own is not very useful – it needs to be organised into information to become understood and therefore useful.

Client teams should work closely with delivery Contractors, utilising the skills and experience within the client teams to add value to the Contractors' teams – it's a joint effort.

The client's role is not to simply observe but to influence and facilitate successful outcomes.

Project success is more likely when we work well together following a 'One Team Approach'.

Client planning teams should adopt the approach and behaviors below:

Establish a positive working relationship between the client and the Contractor based on genuine open communication, transparency, and a willingness to work with each other to achieve a common outcome.

Follow a 'One Team' approach by spending time at the Contractor's office and conducting joint site inspections to review progress together.

Show that you can add value to their team and be a second pair of eyes rather than an auditor.

questions that should be asked are:

- is the critical path logical and does it make sense?
- is there a parallel critical path
- assess float paths or near critical paths
- do activities have open ends ie. nil predecessors or nil successors
- Are there activities with excessive amounts of total float - a well developed network should have noncritical activities with a minimum amount of float
- can the critical path be shortened by :
    - removal of unnecessary restraints or constraints
    - overlapping or bypassing of activities
    - increase in resources ie. labor materials or equipment
    - alternative methods or methodology approach
- does the critical path pass through finishes landscaping or external works. This would be incorrect on most projects it would be unlikely that painting is a critical path activity
- does the critical path pass through the Lift motor Room or an electrical sub station on a City High rise building. For a high rise, lifts, lift motor room and permanent power are all generally critical.
- have procurement, design, approval lead times being properly linked up with construction activities
- do completion activities have sufficient time allowance for local Authority inspections, and commissioning
- have constraints being applied correctly or can they be removed
- are dependencies logical or can activities be overlapped or by-passed
- is there redundant or duplicate relationships
- compare indicated total time with committed or specified time (check contractual documents, specifications, technical requirements)

Schedule Quality

DOD Defence Contract Management Agency

In its role as the DOD executive agent for earned value management systems (EVMS), the Defence Contract Management Agency's (DCMA) mission includes conducting contractor surveillance on EVMS.46 The outcome of DCMA surveillance ensures that reported contract performance data accurately reflect the status of schedules.

In assessing contractor schedule reliability, DCMA ensures that the following ANSI/EIA-748 EVMS guidelines are followed:

• Schedule the authorized work to describe the sequence of work and identify

significant task interdependencies required to meet the requirements of the schedule.

• Identify physical products, milestones, technical performance goals, or other

indicators that will be used to measure progress.

In its assessment of the quality of a schedule, DCMA uses a 14-Point Assessment

(14PA), a collection of measures intended to assess the technical structure of the schedule as well as the contractor's ability to plan and execute work. The measures are:

1. Logic

2. Leads

3. Lags

4. Relationship types

5. Hard constraints

6. High float

7. Negative float

8. High duration

9. Invalid dates

10. Resources

11. Missed tasks

12. Critical path test

13. Critical path length index

14. Baseline execution index.

Ribbon Analyzer									
Missing Logic	Logic Density™	Critical	Hard Constrai...	Negative Float	Insufficient Detail™	Number of Lags	Number of Leads	Merge Hotspot	Score
1 (7%)	2.14	14 (100%)	0 (0%)	0 (0%)	2 (18%)	1 (7%)	0 (0%)	0 (0%)	73%

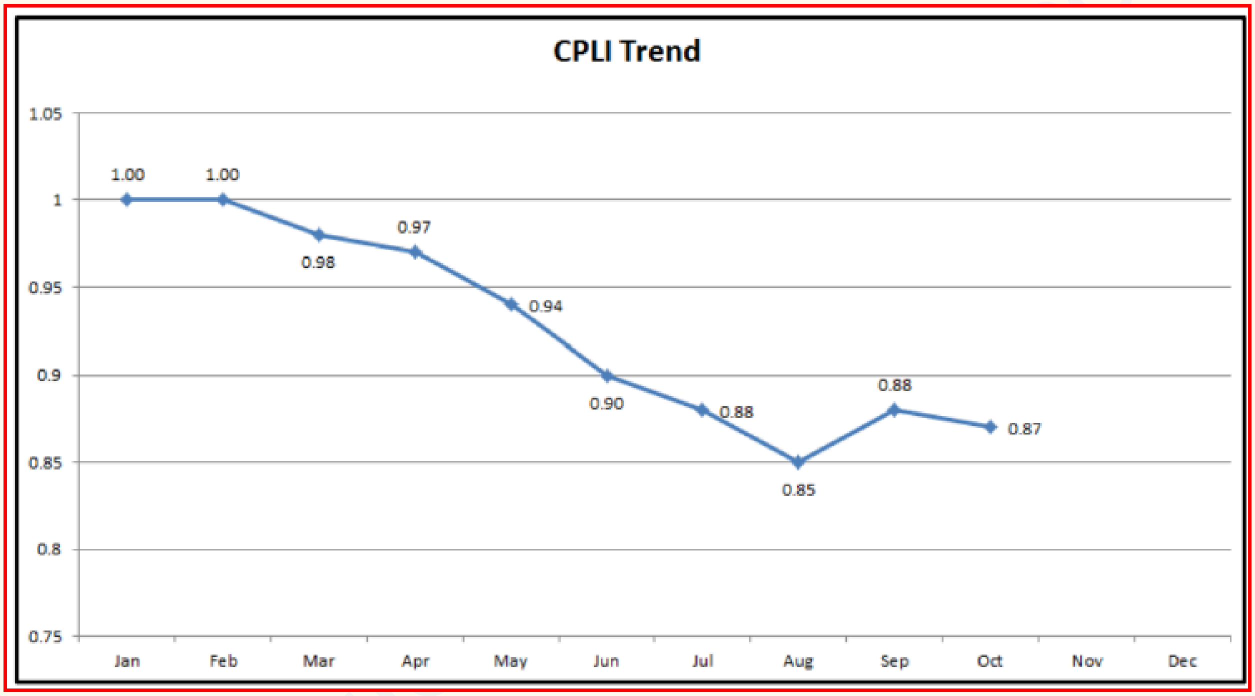
Several include thresholds; for example, no more than 5 percent of remaining tasks should be missing predecessor or successor logic.

However, DCMA's 14PA thresholds are not compliance triggers. Rather, they are used as a starting point toward an objective analysis of the schedule.

Schedule Metrics

Source PSEG

Critical Path Length Index



The Critical Path Length Index (CPLI) measures how realistic the schedule completion date is, based on the remaining duration of the critical path and the amount of total float available.

CPLI is one of the standard Schedule Health Assessment Metrics and identifies schedules that are having difficulty executing their critical path. The target for CPLI is 1.0 or greater. A lower value indicates an increased risk of being late at schedule completion.

Where Critical Path Length is the number of days from time now to the early finish date of the task or milestone representing schedule completion.

Total Float on the task or milestone representing schedule completion may be either positive or negative.

The result is an index that measures the sufficiency of the total float available relative to the remaining duration of the critical path.

For example, 20 days of float on a critical path that has 80 days remaining would result in a CPLI of 1.25 indicating a low risk of not completing on time.

However, if the critical path has 800 days remaining, a total float of 20 days would result in a CPLI of 1.03. Although this is still above the target of 1.0, it indicates there is much less room for error. To achieve a CPLI of 1.25 in this case would require 200 days of total float.

CPLI also measures the relative efficiency required to complete the schedule critical path on time. A CPLI of 1.00 means the schedule has 0 days of total float available on the critical path and therefore should accomplish one day's worth of work for every day that passes. This means the schedule should execute the critical path at a 100% efficiency rate to complete on time.

A CPLI less than 1.00 indicates that the schedule is not executing the critical path as planned and has created a negative total float condition potentially delaying schedule completion.

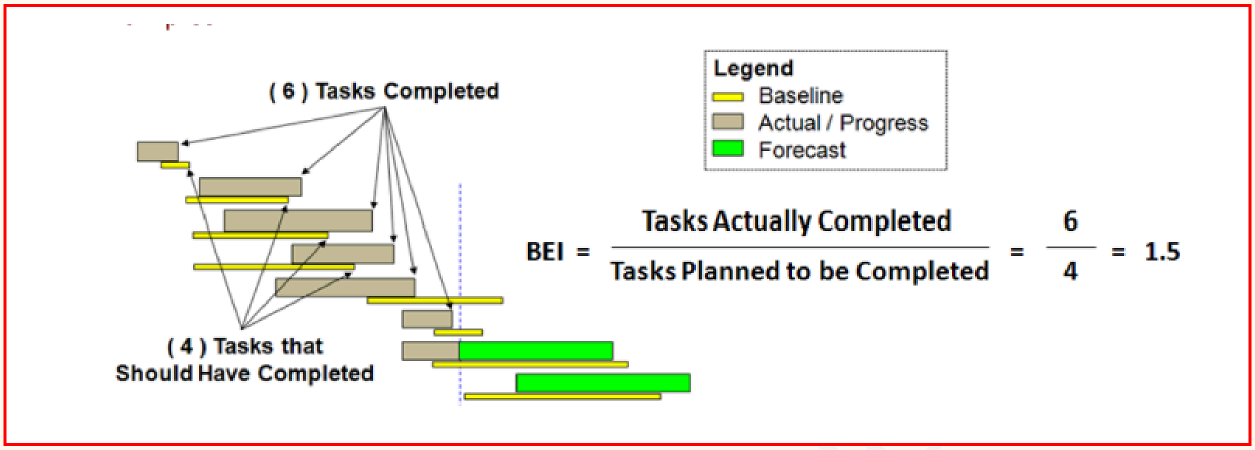
To prevent this from happening, the schedule should now accomplish more than one day of work for every day that passes. This means the schedule should now execute the critical path at an efficiency rate higher than 100%.

Likewise, a CPLI greater than 1.00 indicates that the schedule is executing the critical path ahead of plan and still has positive total float remaining. As a result, the schedule has a lower risk of delaying schedule completion since they can operate at an efficiency rate of less than 100% and still complete on time

Typically, schedules calculate CPLI to schedule completion or an interim milestone. Any activities on or near the schedule critical path can directly impact this metric if not completed as planned.

Note: CPLI will not work correctly, if the network does not have a constrained finish date on the task representing schedule completion, because the result would be a Critical Path that has zero total float and a CPLI of 1.00 at all times.

BEI baseline execution index



BEI is a summary level snapshot measuring how well the schedule (or a portion of the schedule) has actually performed to the baseline plan.

The BEI is a simple index measure of a count of completed tasks with a count of tasks scheduled to be completed. As with most indices, 1.0 is ideal, a number greater than 1.0 indicates more task completions than planned and a number less than 1.0 indicates fewer completed tasks than planned.

Management can use this metric to evaluate schedule progress towards the baseline plan. BEI is similar in function to the Schedule Performance Index (SPI), except it is a ratio based on a simple task count.

Tasks Actually Completed - Count of activities with a status updates for Actual Finish dates on or before the status date of the IMS

Tasks Planned to be Completed - Count of activities with a Baseline Finish date on or before the status date of the IMS

Note: While there may be exceptions under certain circumstances, schedules typically exclude the following activity categories from BEI counts and calculations: Level of Effort (LOE) and Milestones.

schedules can calculate BEI as often as the schedule has its status updated (typically weekly or monthly).

Current Execution Index

$$CEI = \frac{\#\ of\ tasks\ that\ finished\ in\ the\ window\ (of\ the\ tasks\ forecasted\ to\ finish)}{\#\ of\ tasks\ forecasted\ to\ finish\ in\ the\ defined\ window}$$

The goal of this metric is to measure and indicate how well the near-term schedule represents what actually takes place through execution. This measurement provides insight into the accuracy of the forecast schedule and its abilities as a predictive model.

The index maximum is 1.00, but a sound forecast schedule will consistently trend in the greater than 80th percentile range. There is a direct correlation between the lower probability (less than 80 % probability of completion) and the schedule's ability to manage the projected near-term tasks. This indicates that work is slipping to the right and possibly adding to the "bow wave" of unachievable work.

Use of the CEI metric drives ownership and accountability behaviours that are necessary for schedule success when consistently used by schedule management.

You can derive CEI by comparing the number of tasks forecasted to finish within the status period to the number of those tasks that actually did finish within the status period.

The process for collecting the data necessary to calculate CEI is as follows:

1. At the beginning of the status period, create a "snapshot" of the status period (capturing

Forecast Finishes).

2. Execute through the status period.

3. Retrieve initial "snapshot".

4. Compare actual finish dates to the initial "snapshot".

schedule teams that can effectively manage the road ahead have a higher percentage of success. The intent of CEI is to focus the schedule team on ensuring the forecast schedule is accurate and then executing to it as effectively as possible.

Note: Tasks in this formula should exclude LOE and Summary lines (but should include all other tasks/milestones). Be careful when establishing the parameters of this metric, unlike BEI, the numerator should contain only tasks that were previously forecasted to finish and did finish

in the defined window.

Example

37 = # of tasks forecasted to finish in the window

29 = # of tasks that finished in the window (out of the 37 forecasted to finish in

the window)

CEI = 29/37 = .78

Total Float Consumption Index

$$TFCI = \frac{Actual\ Duration + Critical\ Path\ Total\ Float}{Actual\ Duration} = \frac{763 + (-23)}{763} = 0.97$$

The focus of the TFCI is to provide a duration-based performance index calculating total float consumption as an efficiency factor.

The TFCI can be used to assess the achievability of the project completion date in any network schedule rather than just using the total float as a static indicator of projected completion. schedule personnel use TFCI to estimate a projected forecast finish date.

Note: If the Critical Path Total Float is not being calculated to the baseline finish of the project, Baseline Finish Variance should be used in place of CPTF.

For any schedule using the critical path method, such as an IMS, total float is created or consumed based on network logic, completion of activities, and constraints within.

This is commonly referred to as total float management. Managing a schedule by total float allows Applied Project Status to be quantified, Predicted Critical Path Total Float to be calculated, and a forecast finish date to be pinpointed.

A TFCI of less than 1.00 indicates that a project may not complete on-time and applying that indicator to the total schedule duration (as depicted in steps #1 through #4 below) predicts where a project would complete if trends persist or corrective action is not taken.

Example

Step 1: Find the TFCI

How is the schedule doing so far? If the TFCI is below 1.0, then the schedule may not complete on-time without mitigation.

Project Actual Duration = span of actual working time accrued (in days or like unit of measure), from the beginning of the schedule through the status date.

Step 2: Find Predicted Critical Path Total Float

This provides a quantitative assessment of future total float management using the total float consumed to date as an efficiency factor. How much total float will the project have by the baseline schedule finish date?

CCCC = DD (TT − 11) = 22 22 (. 99 − 11) = −77

If the TFCI trend of 0.97 persists, then the project will be -71 days behind schedule at project completion instead of -23 days at the baseline schedule finish date.

Step 3: Find the Predicted Forecast Finish Date

Using the project calendar (which includes non-working days) add 71 working days to the baseline finish date to calculate a Predicted Forecast Finish date

Avoid exaggerating the predicted impact. TFCI functions on the premise that downstream forecasts are not adjusted based on past performance. If proper attention is given to accurate forecasting, TFCI can "double dip" the projected impact and predict a slip larger than past performance would suggest. Depending on how the IMS is modeled, the CPTF may not ever be greater than zero, even if the project is forecasted to complete earlier than planned. Because of this, TFCI is intended to be used to analyse delinquent projects only.

An inherent property of the TFCI formula is early project instability. When a project is newly underway, its Actual Duration (AD) will be small. Since AD is the denominator of the TFCI equation, any change in CPTF in the numerator will have a magnified effect on the outcome of the metric. Because of this, less emphasis should be placed on TFCI during the first few months of a project.

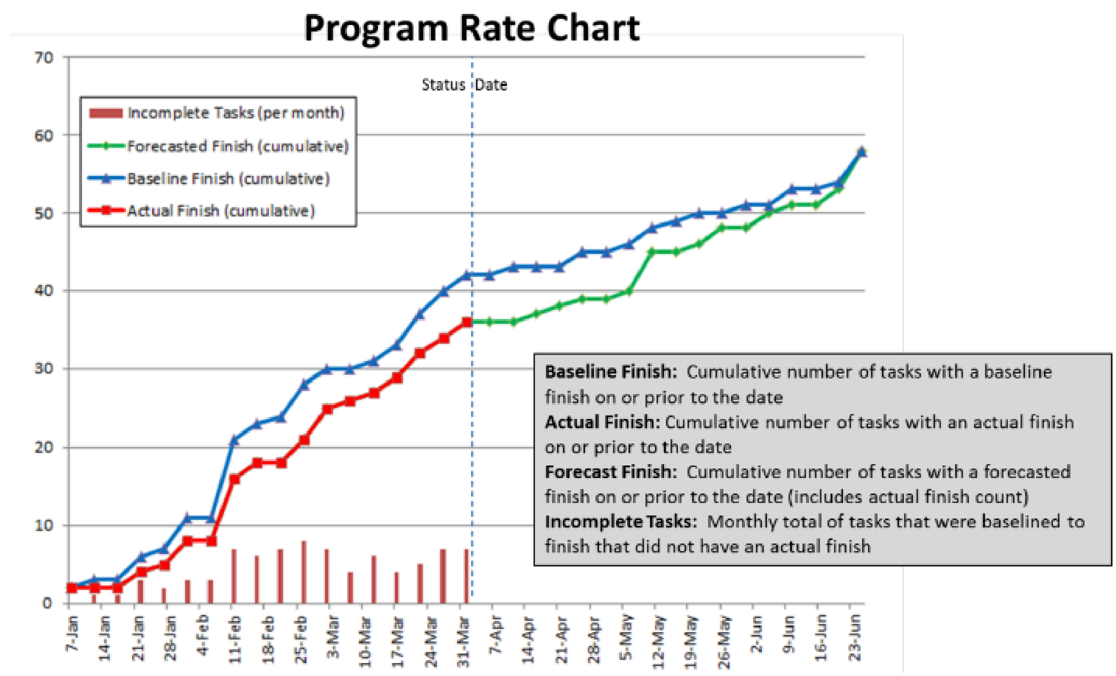


Figure 10.4.8-1 Program Rate Chart, showing actual data through March 31st, and ETC projections thereafter

Schedule Rate Chart

Actual Finish v. Baseline Finish

Compare the number of cumulative tasks with Actual Finish dates in each past period to the number of cumulative baselined tasks planned to finish in the period.

This indicates the difference between the planned and actual task completion rate. schedules conduct further analysis to understand the reasoning behind the variance, which could include the type of tasks, complexity of tasks, or resource availability.

Forecast Finish v. Baseline Finish

Compare the number of cumulative tasks with Forecasted Finish dates in each future period to the number of cumulative baselined tasks planned to finish in the period.

This indicates the difference between the planned and forecasted task completion rate. schedules conduct further analysis to understand the reasoning behind the variance, which could include the type of tasks, complexity of tasks, or resource availability.

Bow Wave Analysis

A schedule bow wave occurs when tasks continually slip into the future. If this continues to happen as the schedule progresses, it could result in an insurmountable number of tasks forecasted for completion in one or more status periods.

schedules should identify potential bow waves by comparing historical monthly completion rates to forecasted monthly completion rates.

Calculations

Actual Finish (Cumulative) – Total number of tasks with an Actual Finish prior to the end of the status period.

Forecast Finish (Cumulative) – Total number of tasks with Forecast Finish prior to the end of the status period.

Baseline Finish (Cumulative) – Total number of tasks with Baseline Finish prior to the end of the status period.

Incomplete Tasks (Status Period) – Number of tasks in the status period with an Actual Start date prior to the end of the status period and no Actual Finish date.

Things to Promote

Every task in the schedule has to be baselined for the chart to be useful Rate Chart should be created based on a statussed and validated IMS Data in this chart should be analysed and compared to the data in the SPI, CPLI, and BEI to make informed choices and drive action Investigate and understand any unusual changes in the slope of the lines at or near "Time Now".

Sharp inclines may be an indication of an unachievable "bow wave" of effort that has been allowed to accumulate.

Avoid using LoE tasks

Schedule Diagnostics

There are numerous schedule indices, as indicated above, however these checks lack information about the "quality" of a schedule, as they do not assess the scope of work that the schedule represents, logic, methodology or resources.

The following 'diagnostics' can assist the discussion on 'schedule quality' :

Activity count - Count of Activities in progress over time periods, the number of critical activities in each time period and the cumulative number of activities starting and finishing in each time period.

Duration Analysis - Duration of activities occurring over time periods by category and the number of critical activities in progress in each time period

Duration Vs Float - Duration and Float for all activities in schedule, Depends on the 'Set thresholds' for acceptable duration and float values and the number of activities that meet those thresholds

Constraint Analysis - Indicates constraints in schedule including, current schedule date vs constraint date, indicates type of constraints applied and balance line indicating whether activity date is on constraint date or earlier/later.

Logic Type - Type of logic used in schedule, distribution of logic time over time periods, and total count of logical relationships over time period.

Logic Analysis - Indicates the number of relationships occurring over time periods, indicates activities with no predecessors or no successors and when these occur, and a measure of Logic density.

Lag Analysis - Indicates relationships with lag values, Indicates use of lags over time periods, and Indicates the value of the lag for each relationship.

Logic Density - Activities with a high number of relationships , when these high relationship activities occur in time and an indication of how many of the relationships are driving relationships.

All of this information is available from exporting schedule data to excel, analysing data within Excel and using Microsoft Power Queries & Apps to create visual dashboards of key metrics.

Interested in diving deeper into Planning and Scheduling Fundamentals? Learn more about delays, Earned Value, Schedule Risk Analysis, template downloads & more.

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