



فرآیند یکپارچه برنامه ریزی، زمانبندی و کنترل پروژه

بخش چهارم:

استاندارد اجرایی: اولویت بندی و تعیین روابط بین همه فعالیتها

ارائه دهنده:

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(PhD, PMP, CMIT)

What we will learn?

☐ Introduction

☐ Constraints

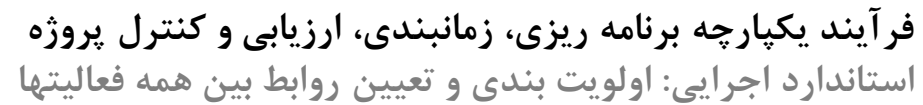
- ❖ Introduction
- ❖ Types of constraints
- ❖ Types of logics
- ❖ Date constraints
- ❖ Important points

☐ Sequencing all activities

- ❖ Development of activity sequence
- ❖ Predecessor and successor logic
- ❖ Summary logic
- ❖ Incomplete and dangling logic
- ❖ Lags
- ❖ Leads
- ❖ Path convergence

What we will learn?

- ☐ Checklist for a scheduler for sequencing all activities
- ☐ An auditor's key questions and documents for sequencing all activities
 - ❖ Key questions
 - ❖ Key documents



- ❑ This is a cyclic process
- ❑ Elaborated through rolling wave process.

A process for creating and maintaining reliable schedules

Process step	Corresponding action	Section
Capture all activities	Capturing all activities	3
Create logically sequenced activity network	Sequencing all activities	4
Estimate work and durations and assign resources	Allocating and leveling resources	5
	Determining and assigning durations to activities	6
Validate critical path and reasonable total float	Critical path determination, assessment, and validation	7
	Ensuring reasonable total float	8
Analyze schedule risk	Schedule constructability and risk analysis	9
Verify and validate traceability	Verifying that the schedule can be traced horizontally and vertically	10
Set and document baseline	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
Update, revise, and manage change	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
	Updating the schedule using actual progress and logic	12

Lags and leads

*A **major disadvantage** of lags and leads is that they are **static**.*

*If they are **prevalent** in the schedule, the **update process** requires significant manual effort and becomes **time consuming** and prone to **error**.*

- ☐ The leads and lags should be kept to **manageable durations**, probably a maximum of 5 to 10 days in **most cases**.
- ☐ Leads and negative lags are **illogical** and should be **avoided**.

Lags and leads

*In general, **splitting tasks** into logical break points that will **better model** how the work is accomplished is a preferred over using Leads.*

*Ensure to review and update the **duration** of each applicable **lead and lag** during every status cycle.*

Lags and leads

Consider *creating standard justification codes* that describe scenarios where lags/leads *may be commonly used* (such as *material lead times*).

This can increase consistency in the usage of lags and leads.

Path convergence

- ❑ Joining several parallel activities with a single successor activity is known as **path convergence**.
- ❑ It is also known as a “merge point”—causes **problems** in managing the schedule.
- ❑ Path convergence can be unrealistic in a plan because
it implies the need to **accomplish** a large number of activities on time
before a major event can **occur** as planned.

These points should be a **key project management concern** because
risk at the **merge point** is multiplicative.

Path convergence – How to solve?

- ❑ The **reasonable number** of parallel activities is **not** the **same** in large and small projects.
- ❑ Because **most work** is performed **serially**, the **majority** of the **schedule activities** should have **F–S relationships**.

*If **alternative logic** can be used to **link some predecessors** to other activities, this may be a **good solution**!*

Checklist For a Scheduler For Sequencing All Activities

- ☐ The schedule contains complete network logic between all activities so that it can correctly forecast the start and end dates of activities within the plan.
- ☐ The majority of relationships within the detailed schedule are finish-to-start.
- ☐ Except for the start and finish milestones, every activity within the schedule has at least one predecessor and at least one successor.
- ☐ Any activity that is missing predecessor or successor logic—besides the start and finish milestones—is clearly justified in the schedule documentation.
- ☐ The schedule contains no dangling logic.
 - a) Each activity (except the start milestone) has an F–S or S–S predecessor that drives its start date.
 - b) Each activity (except the finish milestone) has an F–S or F–F successor that it drives.

- ☐ The schedule does not contain start-to-finish logic relationships.
- ☐ Summary activities do not have logic relationships.
- ☐ Instead of SNET constraints, conditions of supply by an outside vendor or contractor are represented as actual activities in the schedule.
- ☐ Date constraints are thoroughly justified in the schedule documentation. Unavoidable hard constraints are fully justified in reference.
- ☐ Lags are used in the schedule only to denote the time between two activities (not risk).
- ☐ Every effort is made not to use lags and leads but to break activities into smaller tasks.
- ☐ Lags and leads in a schedule are justified by compelling reasons in documentation.
- ☐ The schedule is assessed for path convergence. Activities with many predecessors have been examined to see whether (1) they are needed and whether (2) alternative logic can be used to link some predecessors to other activities.

**An Auditor's Key Questions and
Documents for Sequencing All Activities**

Key questions

1. Have the activities and logical relationships been determined by those executing the program?
2. Are the majority of the relationships within the detailed schedules finish-to-start?
3. Are predecessor links (with the exception of the start milestone) or successor links (with the exception of the finish milestone) missing?
4. Are any predecessors or successors dangling?
5. a. Does each activity (except the start milestone) have an F–S or S–S predecessor that drives its start date?
6. b. Does each activity (except the finish milestone and deliverables that leave the project without subsequent effect on the project) have an F–S or F–F successor that it drives?

Key questions

7. Do summary activities have predecessor or successor links?
8. Do activities have start-to-finish links?
9. How much convergence (that is, several parallel activities converging at one major event) is there in the schedule? For activities that have many converging predecessors, do those predecessors have adequate float?
10. Does the schedule contain date constraints other than “as soon as possible”? Is each one justified in the schedule documentation?
11. Are lags or leads specified between the activities? Can these be more accurately characterized by improving logic or adding activity detail?

Key Documents

1. Documentation justifies using hard and soft date constraints instead of activities' duration and logic.
2. Documentation justifies using lags and leads instead of activities' duration and logic.
3. Documentation justifies any activity that has no F-S or S-S predecessor or no F-S or F-F successor.



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What we will learn?

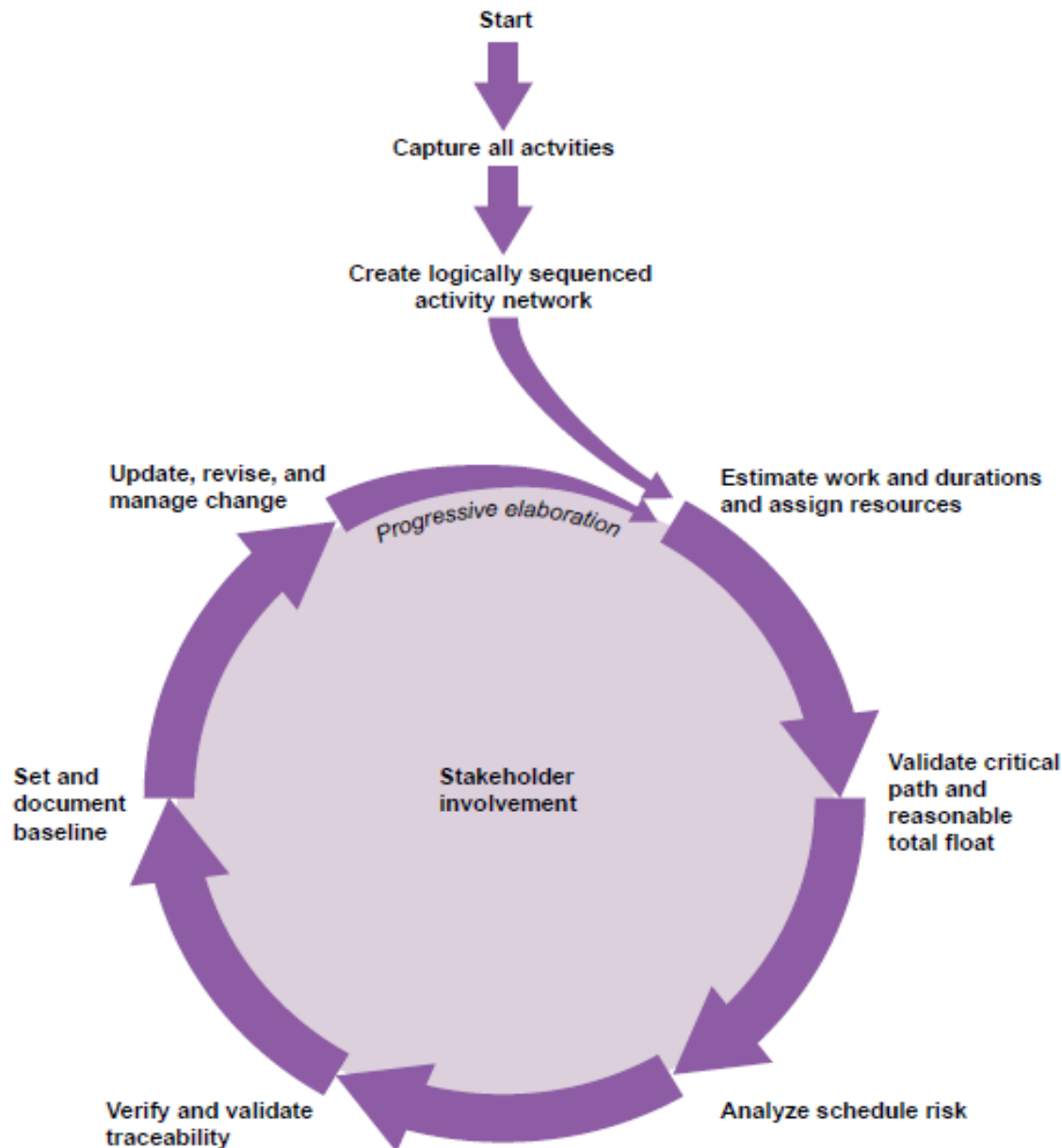
- ☐ Resource calculation
- ☐ Resource allocation
- ☐ Resource loading
- ☐ Resource leveling
- ☐ Checklist for a scheduler for allocating and leveling resources
- ☐ An auditor's key questions and documents for allocating and leveling resources



فرآیند یکپارچه برنامه ریزی، زمانبندی، ارزیابی و کنترل پروژه استاندارد اجرایی: تعریف، تخصیص، و تسطیح منابع فعالیتها

A process for creating and maintaining reliable schedules

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Introduction

☐ Important resources need more considerations:

1. Material
2. Labor
3. Equipment
4. Cash

☐ Two important parameters for resource project scheduling problem (RPSP):

1. Resource allocation
 - ✓ Resource-constrained scheduling
2. Resource leveling

Resource Calculation

General guide

- ❑ Activity owners are the best source of **resource estimates**.
- ❑ Activity owners must be able to **explain the logic** behind their resource estimates.
- ❑ Estimated resources within the schedule should also **reconcile** with the **cost estimate**.
- ❑ Assumptions for resources and related activity cost should be the **same** as those that are **used** in estimating activity duration.
- ❑ The basis of estimate (BOE) is the **connection** between cost and time and should be kept **up to date** as **assumptions change**.
 - ❖ If durations, resources, or productivity rates **change**, the **cost** is also likely to **change**, and they need to be coordinated.

*Both the **schedule** and the **cost** estimate should be thoroughly documented to include underlying resource assumptions for the entire estimated scope of work.*

Material

- ☐ Include **everything** that becomes a **part** of the **finished structure**.
- ☐ From a **variety of sources**, but the **usual procedure** is to purchase the materials from a **standard source**.
- ☐ Sometimes the **contractor produces** its **own materials**.
 - ❖ The **cost of production** should be calculated. For example, **aggregate** for **highway project**.
 - ✓ Costs of **drilling, shooting, crushing, screening, and stockpiling** should be considered in **material cost**.
- ☐ **Not unusual** for the **bidding documents** to provide that **certain materials** will be supplied by the **owner** to the **contractor at no charge**.

❑ **Difficult** to determine **because** of **productivity rate**

❖ May **obtain** productivity rate from:

1. **Similar projects**, but should include factors.
2. **Published sources**, but should include factors.

❖ Differs from one **geographical location** to another, variable with **season**, etc.

❑ **To do the best job, must:**

- ❖ Detailed quantity takeoff,
- ❖ Job conditions
- ❖ Construction methods
- ❖ Comprehensive library of:
 1. **Costs**
 2. **Productivity rates**

Equipment

❑ Like those of **labor**, are **difficult** to evaluate with any **exactness**. It is better to divide the estimate into **two categories**:

1. **Major items** such as **earth-moving machine** and **concrete plants** need **detailed studies**

❖ For major equipment, **size**, **type**, and the necessary **units provided** to the **project** and **activities** (number of hrs. will be used) should be known.

2. **Minor items** such as **power tool** and **concrete vibrators** does **not need detailed studies**

❖ **Allowance** can be used as a **small percentage** of the **total direct labor cost** for **small equipment** such as **hand tools**, **water hoses**, etc., and included on the **project overhead**

This needs to be checked by cash flow forecast

Resource Allocation

Introduction

- ❑ Resource allocation is the **process of assigning limited resources** to activities to determine when activities can occur **based on the resource availability**.
- ❑ When a **network is developed**, the **logic of the network** presumably reflects the **sequences of the activities without** regard to **limitations** imposed by the availability of resources.

In practice this is not typically the case.

- ❑ **With no regard for limitations** imposed by resources, **most activities** are intuitively scheduled on an **early-start schedule**.
 - ❖ This creates **unrealistic floats** for projects and could cause **many problems**.

Limited resources do exist and must be managed.

Resource constrained scheduling problem

- ❑ CPM scheduling procedures begin with an **assumption of unlimited availability** of resources for **each project activity**.
 - ❖ The objective of CPM is to **minimize total project duration**.
 - ✓ Therefore, **CPM** handles **only the time aspect** without consideration of resource availability and cash flows.
- ❑ The **early and late start and finish dates** **calculated with CPM** are based on (1) activity durations and the (2) relationships between activities.

*Thus, techniques including resource management and time-cost tradeoff analysis have been developed to **customize CPM schedules** in order to fulfill users' concerns about resources, cost, and time.*

Resource constrained scheduling problem

Resource constrained-scheduling problem is **different concept** compared to resource-leveling mentioned in most of the **construction textbooks and papers**.

However,

Resource constrained scheduling problem is considered as resource-leveling in **PMBOK** and many others project management textbooks.

Resource allocation methods

- ❑ Resource assignments should also be **carefully reviewed** in the scheduling software.
- ❑ Scheduling software may **ignore** resource overallocations by allowing assignments to continue **beyond** resource availability.

*A schedule without resource assignments implies an **unlimited number of resources** and their **unlimited availability**.*

*If allocating and assigning resources are **not justified**, the schedule will convey **false accuracy**.*

*This is particularly **important** where resources are used in multiple projects sharing critical resources.*

Resource allocation methods

❑ Other schedules may use two common methods:

1. Series method

- ❖ An **activity** is scheduled to **start as soon as** its **predecessors** have been **completed**, provided that the utilization of **available resources** is **not exceeded**.
- ❖ Once an **activity** has been **started**, it is **not interrupted**.

2. Parallel method

- ❖ It is **similar to the series method** with one basic difference:
 - ✓ The parallel method **permits** activities to be **interrupted**.

We do **not intend** to go through these methods, but let's look at **some rules!**

Resource allocation methods – General rules

- ❑ The **only** difference between the series method and parallel method is **how to deal with the started activities**.
 - ❖ In the series method, **no interruptions** are allowed
 - ❖ In the parallel method, **interruptions** are allowed
 - ✓ Assumption that all activities can be **interrupted** is not always true
 - Even if an activity can be interrupted, **what is the cost?**

*Choosing the method of resource allocation **depends on activity***

Resource allocation methods – General rules

- ❑ Schedule activities to **start as soon as** their **predecessors** have been **completed**.
 - ✓ If **more than one activity** using a **specific limited resource** can be scheduled, **priority** is given to the activity with the **earliest late start**.
 - ✓ If the activities are tied for the **earliest late start date**, give **priority** to the activity with **least total float**.
 - ✓ If the activities are tied for **least total float**, give **priority** to the activity with the **largest number of resources**.
 - ✓ If the activities are tied in the **number of resources**, give **priority** to the **activity that has already started** (top priority in the series method).

If no activity has been selected with the above rules, simply start the activity that occurs first in the input order.

Resource allocation methods – General rules

- ❑ Summary activities should **not** be assigned **resources**.
- ❑ Start Milestones and Finish Milestones **cannot** have resource assignments in Primavera.
 - ❖ Because milestones have **no duration**, they should **never be assigned resources**.
 - ❖ As it does **not support Resources Assignments** so we **cannot add a cost** through assignments.

This is different from Microsoft Project

Which one is correct?

Resource allocation methods – General rules

1. If **all tasks** in a set **leading to the milestone** **complete the list**.
 - ❖ In this case, the milestone is **automatically** considered **completed** when **all the tasks have been**, so only thing to do is **mark the milestone as 100% done**.
2. On the other hand, if a **responsible person** needs to **approve all the tasks** in a set once they have been **completed**, he/she should be **assigned to that milestone**.
 - ❖ This does **not harm** the project plan, or the work effort.

The problem occurs when an activity is considered to be a milestone!

Both approaches are correct!

So, what should we do with Primavera?

Resource allocation methods – General rules

- ❑ A primary resource (**instead of a resource**) and expenses (**instead of the costs**) can be assigned to a milestone in Primavera.
 1. An activity's primary resource is typically the resource who is **responsible** for **coordinating** an activity's work.
 2. A project expense is a cost **without** using a **resources**
 - ❖ Expenses can be transportation, consulting, training costs, wages, etc.

Resource Loading



Introduction

- ❑ **Fully loading the schedule with resources** provides the **basis** for the **performance measurement baseline (PMB)**.
- ❑ **PMB** is used to **monitor** the project using **earned value management (EVM)**.
- ❑ **When** a schedule is **fully resource loaded**, **budgets** for resources are **assigned** to
 1. Work packages
 2. Planning packages

Total costs to complete the project are identified at the outset.

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P
295426	023154240200	Excavating, bulk bank measure, 1 C.Y. capacity = 75 C.Y./hour, backhoe, hydraulic, crawler mounted, excluding truck loading	B12A	800	0.02	B.C.Y.	\$ -	\$ 1.07	\$ 1.05	\$ 2.12	\$ -	\$ 316,105.82	\$ 310,197.30	\$ 626,303.12	\$ -	\$ 475,635.86	\$ 342,694.

Introduction

❑ After the schedule is **resource loaded**, **total resources** in the schedule should be **crosschecked** with the

1. Project budget constraints
2. Contractual cost constraints

Crosschecking can be performed at the summary level by rolling up lower levels of the schedule to key high-level milestones.

Let's see!

How to perform resource loading?

1. Daily resource consumption can be **plotted** against the project duration to get the Resource Loading Diagram (Histogram).
 - i. Resource peaks should be **examined** for:
 - ✓ **Feasibility** regarding the available budget, availability of resources, and timelines.
 - ii. **Consumption** of a resources during a **specific period of time** (plan and actual)
 - ✓ Special uses in claims
2. Cumulative resources required can be **plotted** against the project duration to get a Accumulated Resource Consumption (S-curve).
 - ❖ The cumulative resources and budget can be **visualized graphically**.

Resource loading diagram (Histogram)

- ❑ Histograms **track** (1) resource feasibility and (2) consumption of **specific periods of time**
- ❑ Common resources are:
 1. Man-hours
 2. Unit of work completed
 3. Money expended
 4. Material
- ❑ Completion types can be either **planned** or **actual**
 - ❖ Planned completion can be based on:
 1. Early date
 2. Late dates
 3. Planned dates

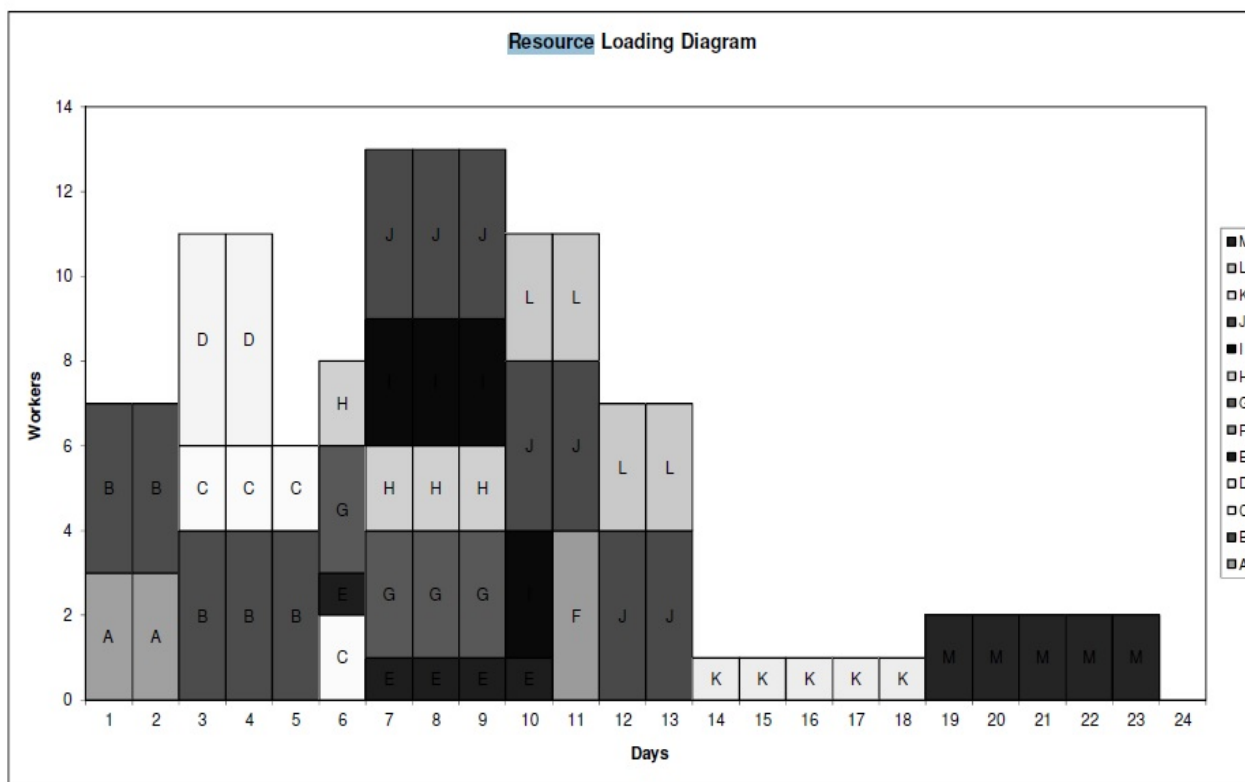
Resource loading diagram (Histogram) – Example

Workers assigned to each activity

Activity	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A		3	3																					
B		4	4	4	4	4																		
C				2	2	2	2																	
D				5	5																			
E							1	1	1	1	1													
F											4													
G							3	3	3	3														
H							2	2	2	2														
I								3	3	3	3													
J								4	4	4	4	4	4	4										
K															1	1	1	1	1					
L											3	3	3	3										
M																				2	2	2	2	2
	0	7	7	11	11	6	8	13	13	13	11	11	7	7	1	1	1	1	1	2	2	2	2	2
	0	7	14	25	36	42	50	63	76	89	100	111	118	125	126	127	128	129	130	132	134	136	138	140

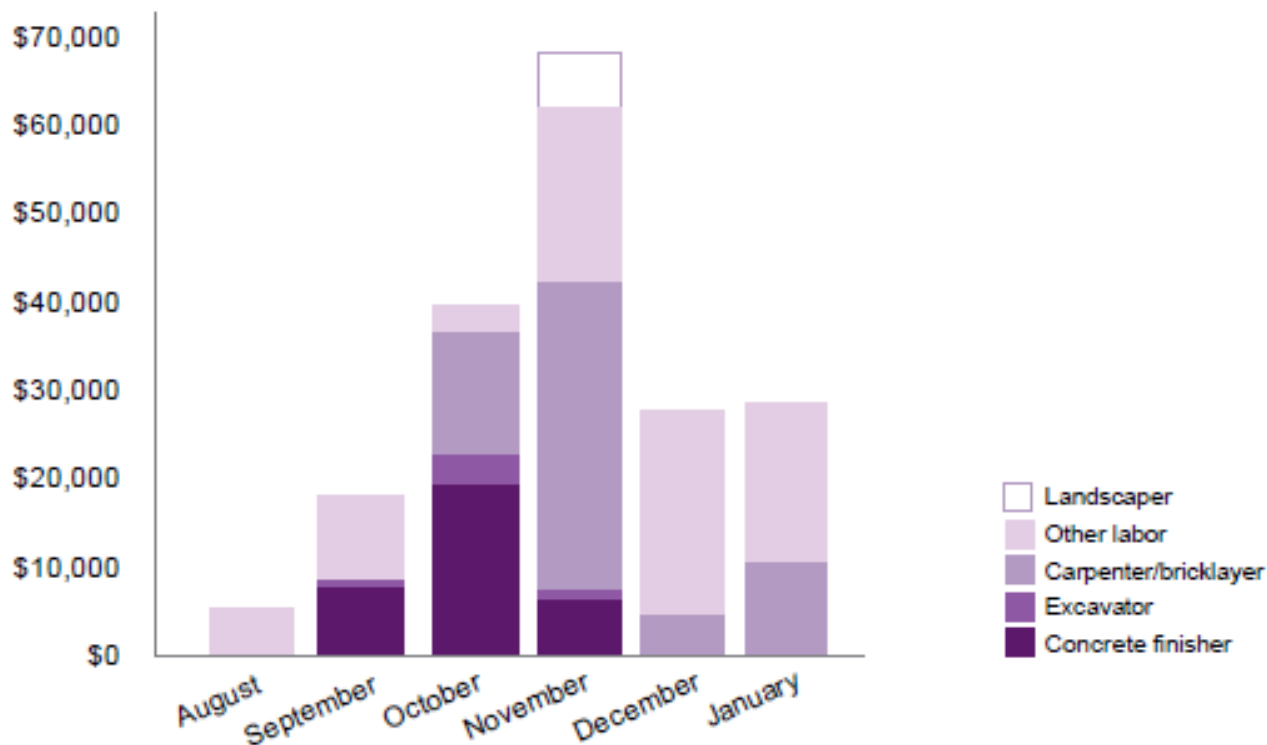
Resource loading diagram (Histogram) – Example

Resource Loading Curve



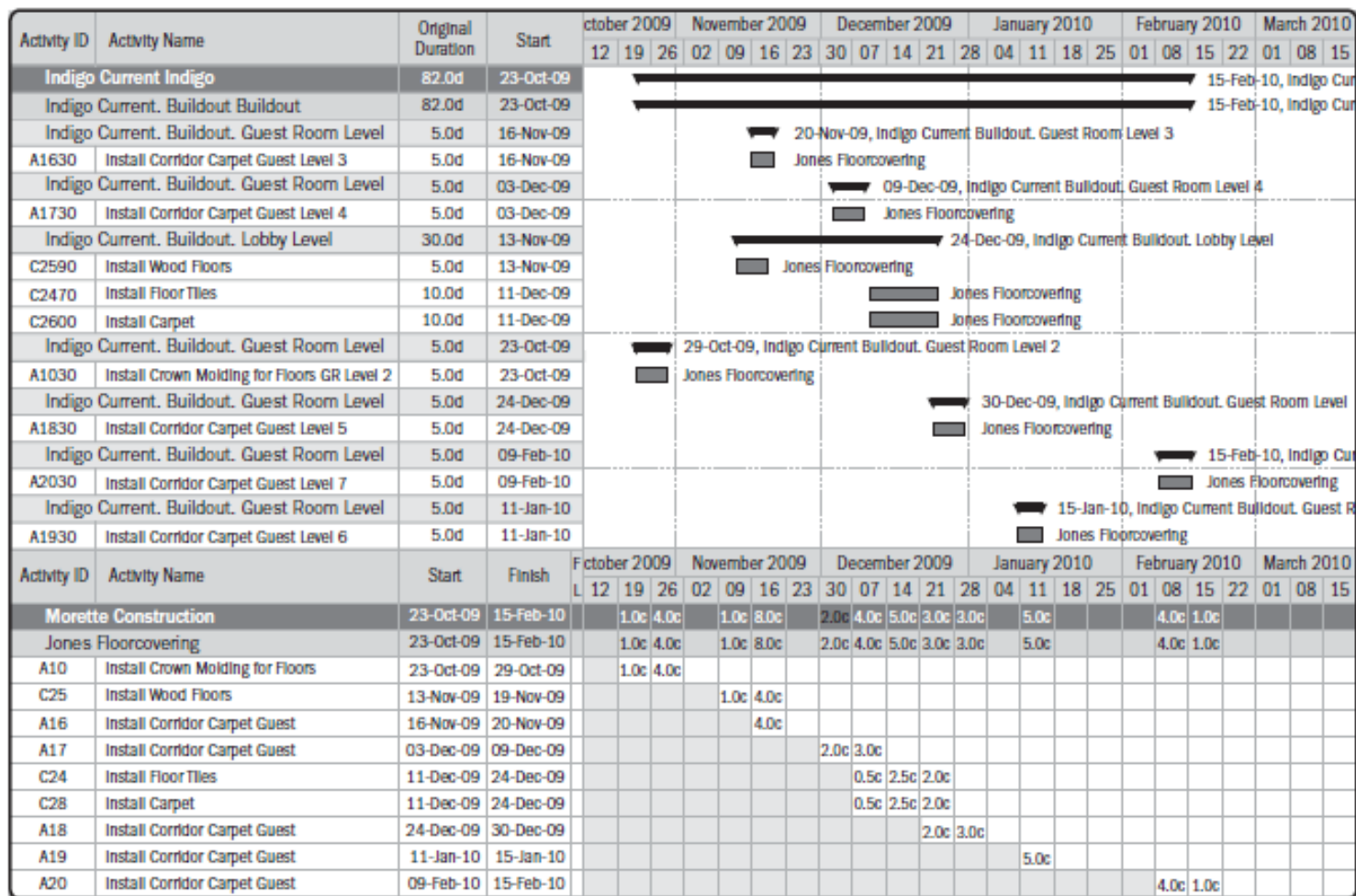
Resource loading diagram (Histogram) – Example

A Profile of Expected Construction Labor Costs by Month



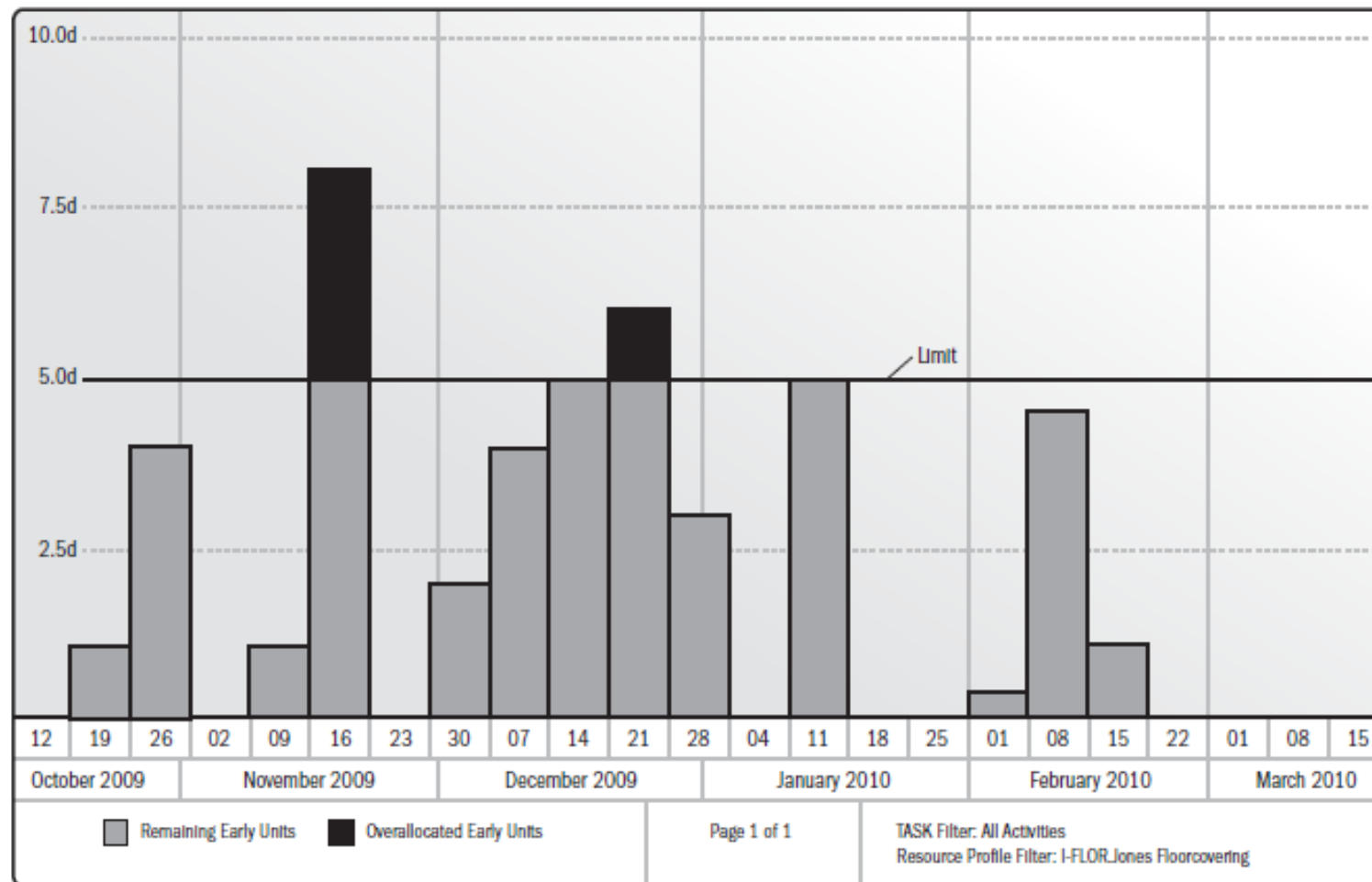
Source: GAO. | GAO-16-89G

Resource loading diagram (Histogram) – Example



Resource usage spreadsheet

Resource loading diagram (Histogram) – Example



Resource histogram

Resource loading diagram (Histogram) – Example

Weekly Labor Time Card									
Craft <u>C</u>									
Name <u>Clouten, S.</u>				Project <u>Highway Bridge</u>					
Employee No. <u>221</u>				Project No. <u>200808-05</u>					
Week Ending <u>July 21</u>				Prepared by <u>S.K.S.</u>					
Cost Code	Time Classification	Hourly Rate	Thursday	Friday	Monday	Tuesday	Wednesday	Total Hours	Total Cost
03157.10.3	ST	\$31.00	8					8	\$248.00
	OT								
03157.20.3	ST	\$31.00		8	8	8		24	\$744.00
	OT								
03311.10.3	ST	\$31.00					8	8	\$248.00
	OT								
	ST								
	OT								
	ST								
	OT								
Total Hours	ST		8	8	8	8	8	40	
	OT								
Gross Amount			\$248.00	\$248.00	\$248.00	\$248.00	\$248.00		\$1,240.00
Weather			Clear-hot	Clear-hot	Cloudy-gusty	Cloudy-windy	Cloudy-windy		

Highway bridge, weekly labor time card

Resource consumption (S-curve)

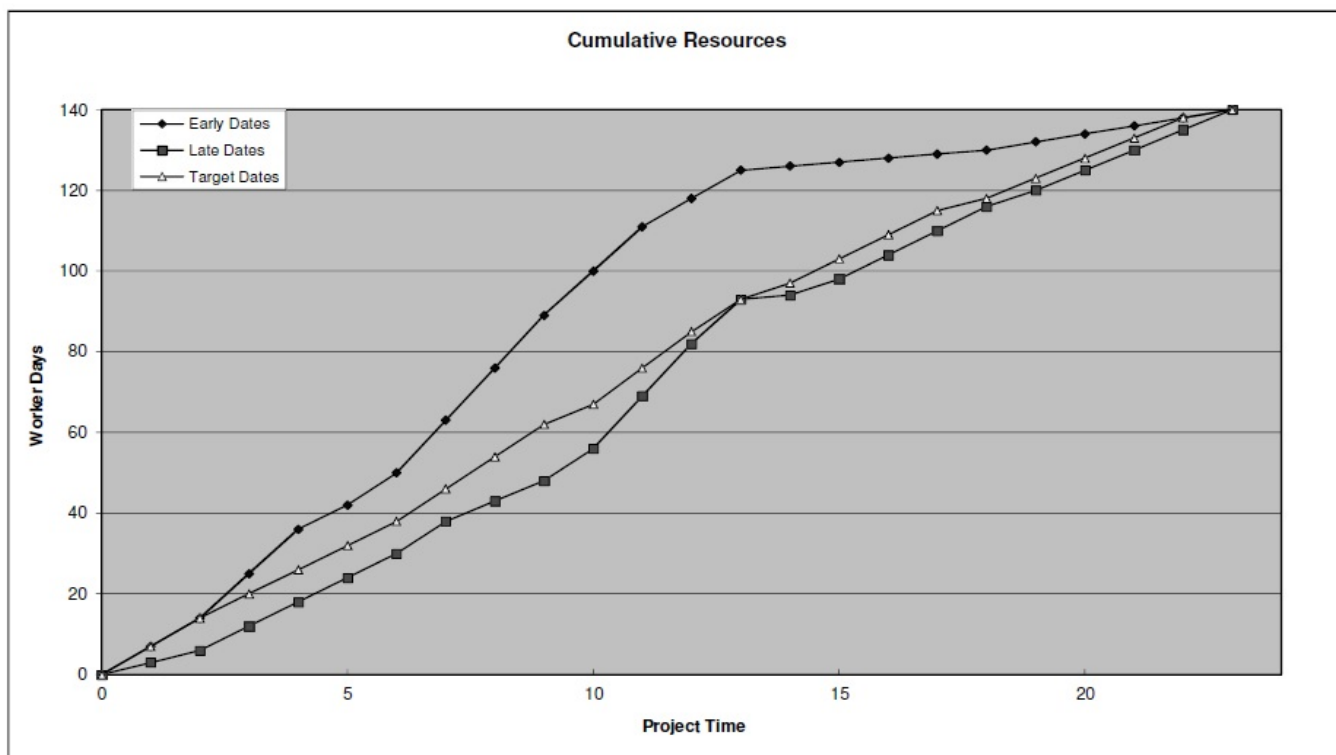
- ❑ **S-Curves track the accumulated resource usage over the entire project**
 - ❖ Total resources vs. time-scale
- ❑ **Common resources are man-hours, material, unit of work completed, or money expended**
- ❑ S-curves are sometimes called **completion curves**
- ❑ **Completion types can be either planned or actual**
 - ❖ **Planned completion** can be based on:
 1. Early date
 2. Late dates
 3. Planned dates

S-curves allow for easy monitoring of a project by simply comparing the planned to the actual

Resource consumption (S-curve)

- ❑ The beginning and end of the project has fewer activities than during the middle.

Resource Consumption (S-Curve)



S-curve shapes

- ❑ Some curves may have **different shapes** depending on the **distribution of work activities**:

1. Front-loaded
2. Normal
3. Back-loaded

- ❑ **S-curve used to report:**

1. Quantity S-curve (Quantity vs. Time)
2. Man-hour S-curve (Man-hours vs. Time)
3. Cost S-curve (Cost vs. Time) **(not recommended to check progress)**

S-curve shapes

S-curve Shapes



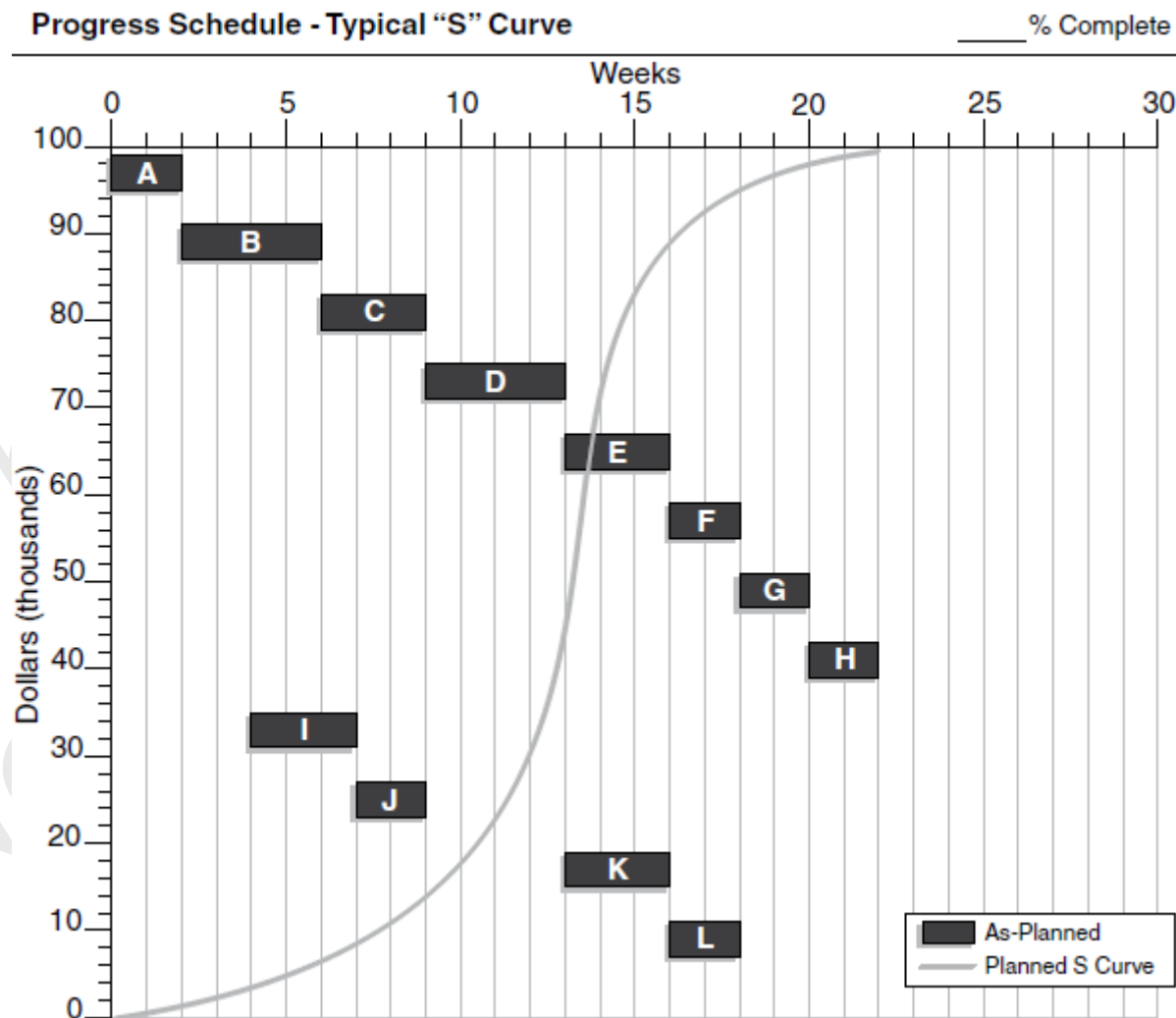
Cost S-curve (Cost vs. Time) – Example

❑ S-Curves

1. The **Contractor** provides a bar chart of the major activities on the job and applies the **dollar value** from the **schedule** of **values** to the bar chart.

- ❖ By summing the **dollars over time**, an “S” curve is **generated**.

Progress Schedule - Typical “S” Curve

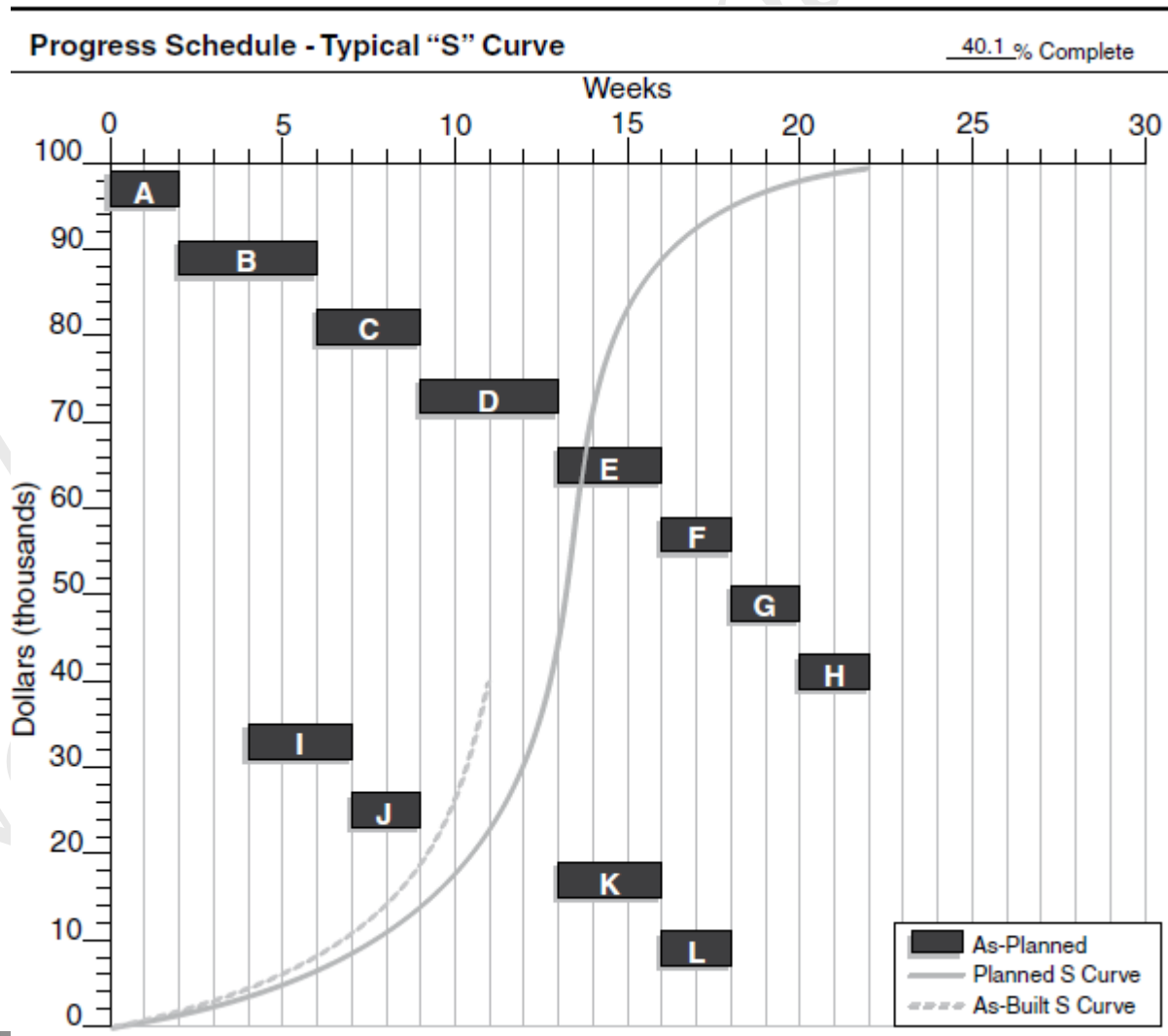


Cost S-curve (Cost vs. Time) – Example

❑ S-Curves

2. The **Contractor** must then submit an **updated “S” curve** with each monthly pay request.

❖ Unfortunately, the monthly submission also has an entry for “progress to date,” **recorded** as a percentage.

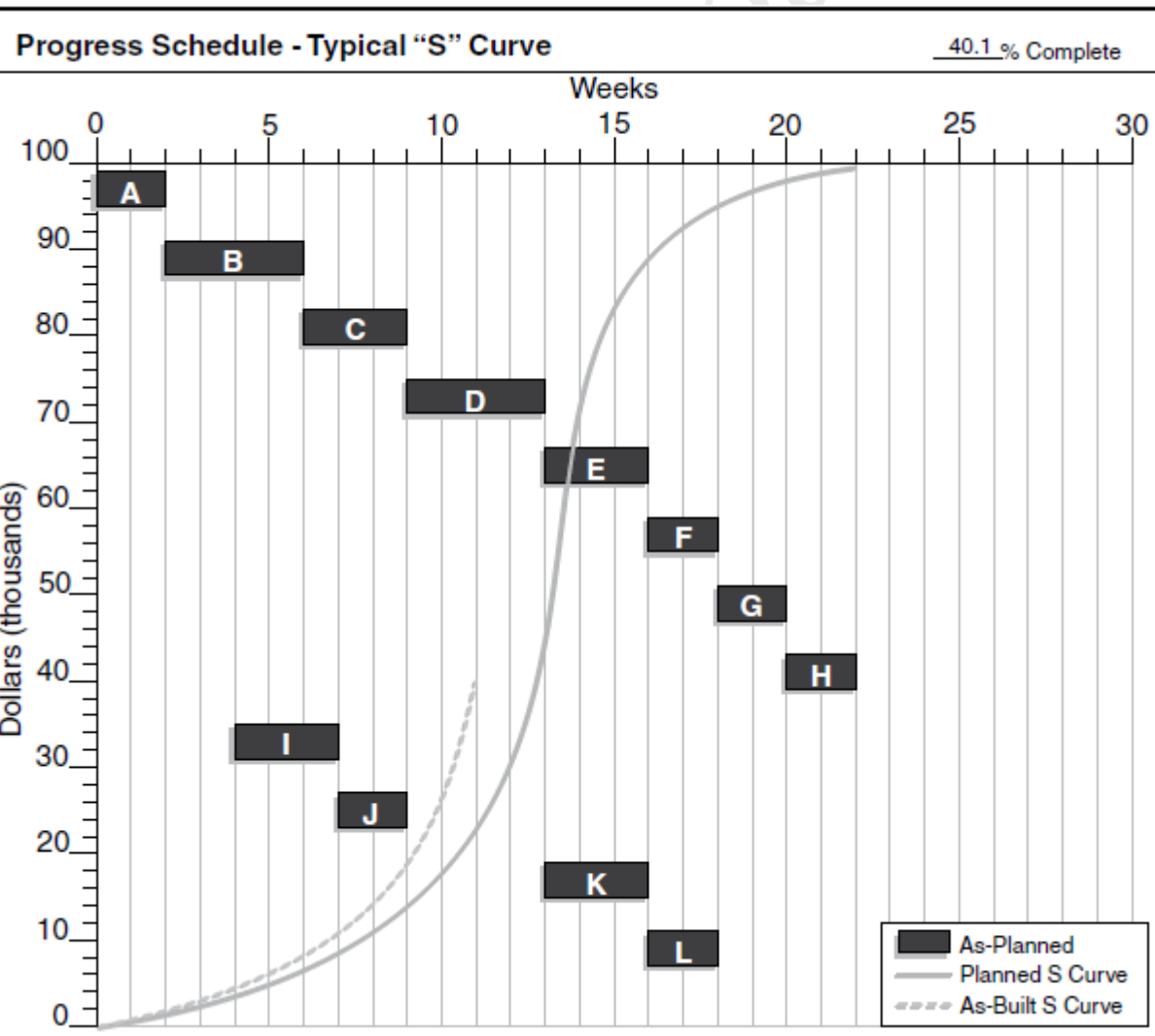


Cost S-curve (Cost vs. Time) – Example

❑ S-Curves

❖ This update has often been used to measure the Contractor's progress in time, which is **very often misleading**.

❖ "S" curves developed from a **Contractor's total billing dollars** do not measure the time progress of the Project but merely **show** the progress of billings over the course of time.



Cost S-curve (Cost vs. Time)

- ❖ There are **several** reasons why we do not recommend using this kind of **“S” curve** for **determining job progress**.
1. The **actual cost** may **not be up to date** and accurate.
 2. The original planned “S” curve **might not** be accurate due to **“front end loading,”** or other factors.
 3. The updated “S” curve information **might** be **misleading** because of **payments** for stored materials and equipment.

*The Contractor could **overbill** or **“front end load”** its bid items to **recover its costs** as **early as possible**, and, therefore, **reliance** on the **“S” curve** could **portray more “progress”** than had **actually occurred**.*

Where to keep information?

☐ Resource information can be stored

1. Within the schedule files
2. Externally in separate software such as in systems devoted to financial management or manufacturing resource planning.

☐ A best practice is to store the resource **information in the schedule**.

- ❖ Managers and auditors can more easily identify and verify **critical resources** if resources are **stored in the schedule file**.
- ❖ If resources are not stored in the schedule, **resource leveling** will be **difficult**.
- ❖ If resources are not stored in the schedule, **updating resources** may be **difficult** and subjected to **error**.

Resource leveling

Why resource leveling is important?

- ❑ Resource leveling tends to **reduce** the **maximum demands** for a given resource on **any given day** if resources are **not limited** by constraints.
- ❑ On some projects and in some locations, it may be **difficult** to **locate skilled workers**.
- ❑ Newly hired workers are also **less efficient** in performing the work.
- ❑ Because of the changing needs of a project, it is **not uncommon** for the **job demands** for a **particular craft** or trade to fluctuate widely.
 - ❖ This can be **costly to the employer**.

Why resource leveling is important?

❑ The **physical realities** of putting

1. **Too many people** in the **same space** at the **same time** (space stacking), or

2. **Too many people** for the **available resources** (trade stacking),

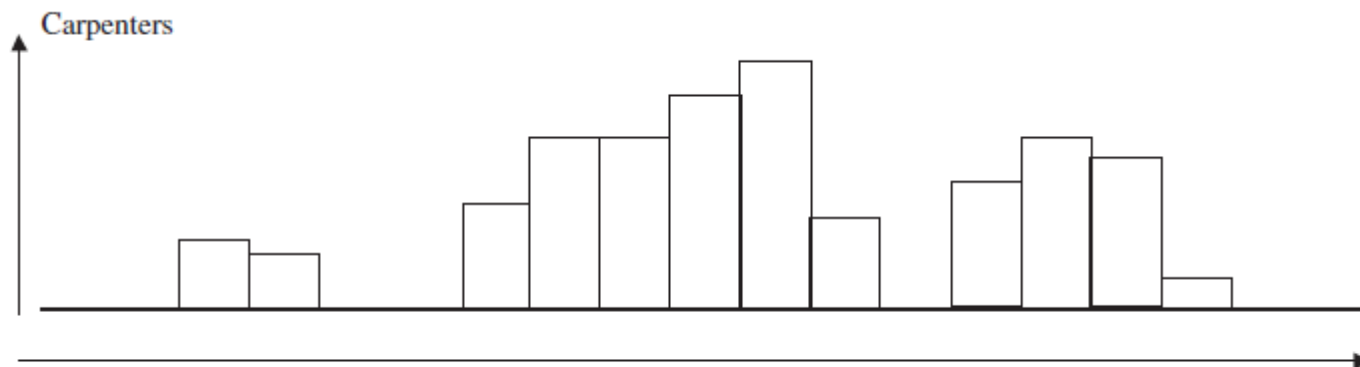
can easily cause delays and disruptions in the work.

❑ **Resource conflicts** may be managed on a **case-by-case basis**

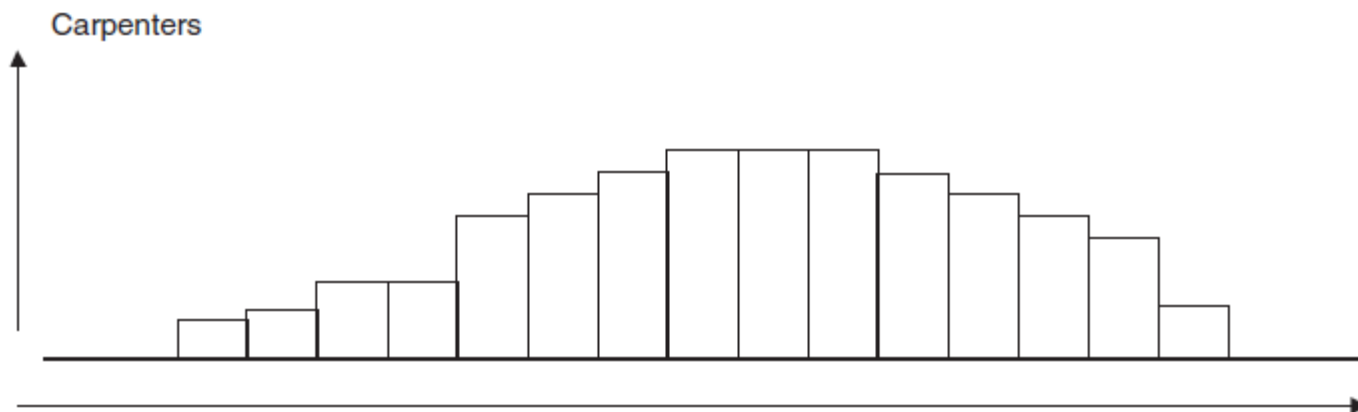
by taking steps in the **field** at the **time of the conflict**,

which often includes **increased costs** to perform the work.

Why resource leveling is important? – Example



Project duration
Utilization of Carpenters on a Project.



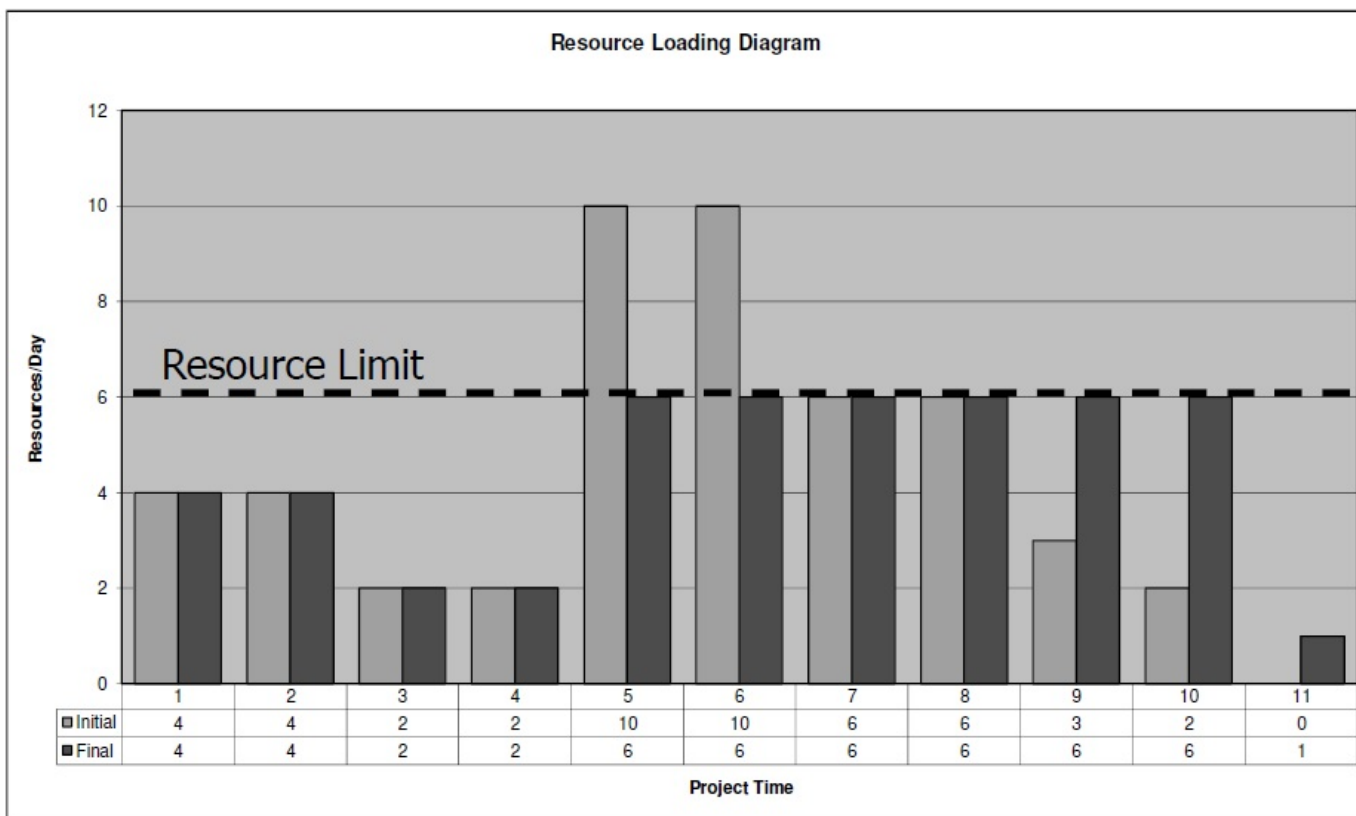
Project duration
Distribution of Carpenter Utilization After Leveling.

General rules for resource leveling

- ☐ Resources should be **leveled only** in detailed schedules that include detailed resource exist and **supported** by
 1. Historical data
 2. Sound estimating methodologies
- ☐ If a schedule is resource leveled, it is important to **check** the date of the **last leveling** against the date of the **last changes** to resources and **resource availability**.
- ☐ Resource leveling should **never** be applied to summary schedules

Resource leveling – Example

Resource Leveling Example



Resource leveling method

- ☐ A number of **different approaches** can be used for resource leveling.
- ☐ **Resource leveling** can
 - ❖ **Have little to no effect** on a **schedule**, or
 - ❖ **Severely delay** the **forecasted end date** of the project.
- ☐ Resources should be **leveled only** to reallocate resources to **reduce spikes** by **absorbing available float**.
- ☐ Resources can be leveled
 1. **Automatically** with scheduling software
 2. **Manually** by managers and planners
 3. **Both**

Resource leveling method – Software

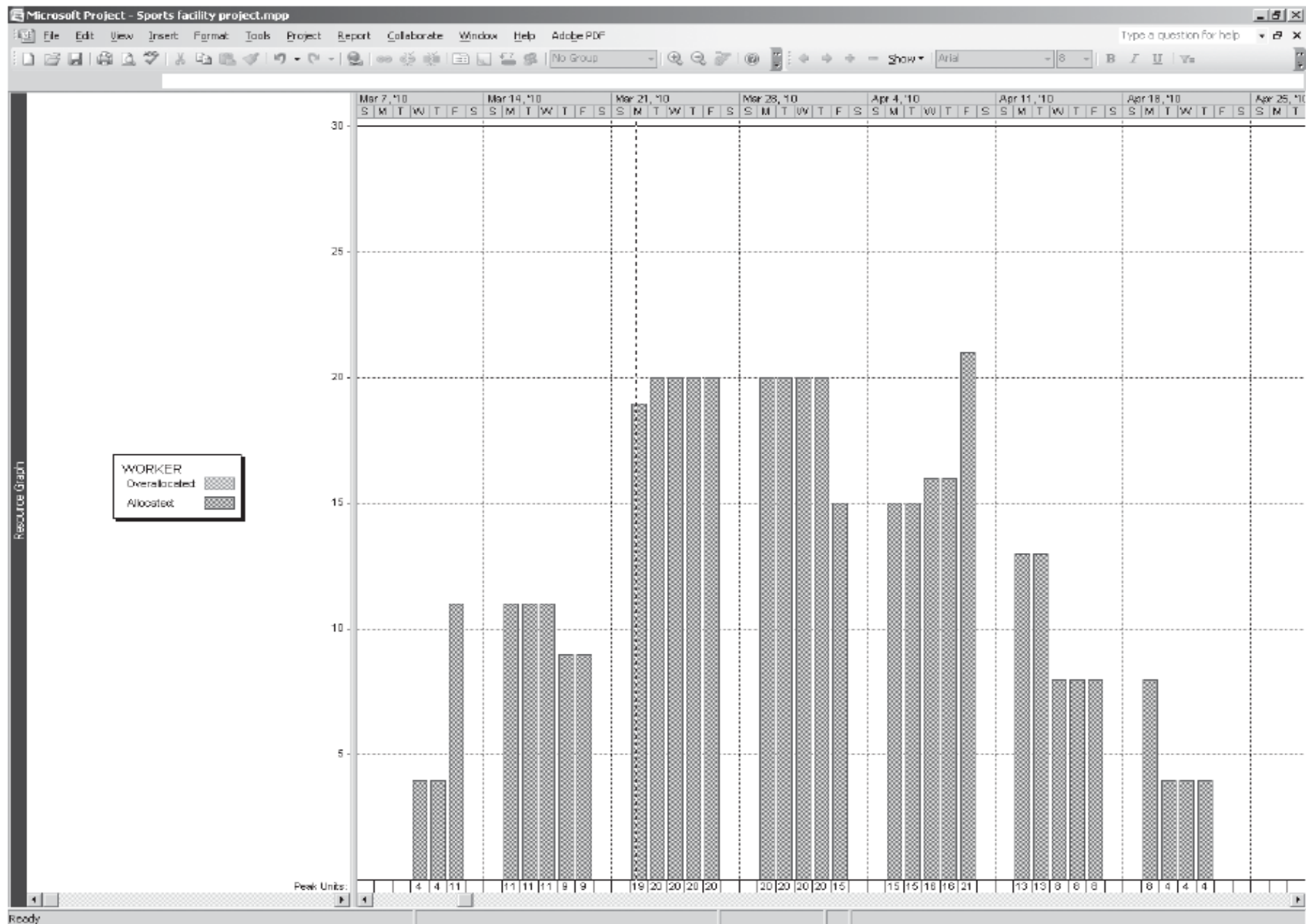
- ❑ Computers can solve these problems much **more readily**
- ❑ It is **important** that changes to resolve the **resource conflicts** be thoroughly documented and that everyone understand them
 - ❖ Because changes to the schedule from limited resource availability can **alter** float and critical path calculations,.
- ❑ Always carefully **examine** output from automatic **resource-leveling routines** and it should be **adjusted** where **necessary**.
- ❑ Automatic leveling may **prove inefficient**, as when it **delays activities** when resources are **only partially available**.

Resource leveling method – Software

Set limits for all resources—Limits must be established for each resource of concern, such as the number of units available and the time periods associated with the specified level of availability. Other characterizations such as the degree to which overtime can be employed may also be specified.

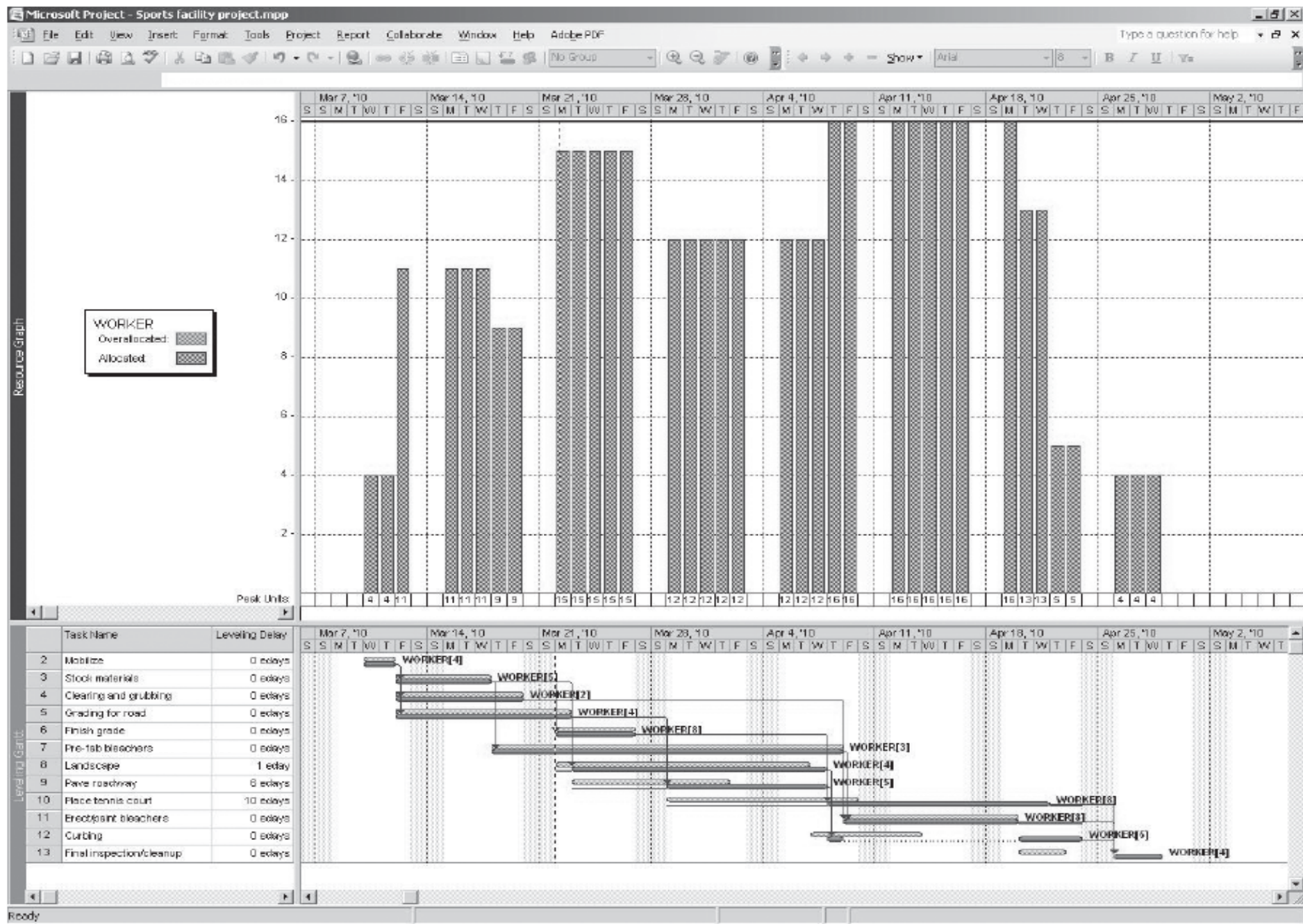
Select resources to level—In many instances a single resource will pace many, or a sequence of trades. All the resources may appear to be over-allocated. But once the driving resource is leveled the conflicts for multiple resources are also resolved. In other instances, level of effort resources may be assigned over a wide range of activities alongside driving resources. These will sometimes stack and appear over-allocated. The scheduler will likely choose not to level the level of effort or hammocked resource. At the other extreme, the project management applications often provide the option to “level all.” This can result in relatively short-term projects exploding into multiyear behemoths. Suffice it to say, use this option with caution.

Define the limits/approaches to leveling—Resolving resource conflicts by leveling will not always extend the length of the project, but the expectation is that it will. Project management applications provide options to limit the extent to which the algorithm is allowed to reschedule activities. One popular option is to “level within available float.” This limitation will allow the algorithm to reschedule activities and spread out the effort, but not extend the overall duration of the project. In the end, you may still have some resources over-allocated, but overall the resource allocations will be more tolerable. The option to globally level all resources is available in all the software applications cited above. This frequently results in unrealistically long schedules due to limited availability of an obscure resource that could be closely managed and its impact mitigated in a manual leveling scenario.



Resource Utilization of Labor on the Sports Facility Project with Early-Start Schedule.

(Microsoft Office Project®) (Used with permission from Microsoft.)



Resource Utilization of Labor on the Sports Facility Project After Leveling.

(Microsoft Office Project®) (Used with permission from Microsoft.)

Resource leveling method – Minimum moment algorithm

- ❑ The **Minimum Moment Method** is a **manual solution**
- ❑ This method **identifies** the **highest improvement** gained in leveling resource based on **moving one activity**.
- ❑ It requires **many calculations** and is **not** typically used in **practice**.
- ❑ **General rules:**
 - ✓ The **activities** are **first arranged** by an **early start schedule**.
 - ✓ It **holds** the **duration** of the project **constant**.
 - ✓ **Activities cannot** be **interrupted**.
 - ✓ **Only one activity** can be **leveled** at a **time**.
 - ✓ **Only one type of resource** can be **leveled** using this **process**.

Resource leveling method – Minimum moment algorithm

❑ In the effort to **produce** a realistic schedule in a resource-constrained environment, many schedulers will choose **manual schedule techniques**.

1. Adjusting resource dependencies is the **primary approach** to manual leveling of resources.

❖ Out of sequence problem

2. Use of lags to push the work out of the resource can also be an approach, although **best practices** should be followed for use of **lags**

❖ **Pushing** the effort out into the **future tends to bump the over-allocation** from one time period to the next

3. Use constraints to limit or adjust resource consumption, but this is **not recommended**.

❖ This approach is fairly straightforward, but requires **adding numerous constraints** that may **not be permitted** under the scheduling specification.

Let's see the best practice in PMI Scheduling reference!

Resource leveling method – Minimum moment algorithm

- ❑ In **most construction projects**, the best practices primarily include the use of manual resource leveling,
 1. **Performed** during scheduling development, and
 2. **Verified** and adjusted during the quality control check of the **baseline schedule**.
- ❑ One **good solution** for the **complexities of individual resources** is the use of crew resources.
 - ❑ This is accomplished by **defining crews for each of the trade contractors** to include the number and types of worker planned for **each crew**.

Let's see an example!

Resource leveling method – Minimum moment algorithm

❑ An **asphalt paving crew**, for example, might include a paving machine, a number of dump trucks to supply asphalt, a foreman, 10 laborers, as well as a roller and operator, and several flagmen.

❖ But the **realities** are that each paving **subcontractor** will operate their work **using a different number of these resources**, and

attempting to acquire the details for each activity related to paving can be **time-consuming and difficult**.

With crew resources, the project management team recognizes that it takes one crew for each paving activity, so when multiple paving activities overlap the number of crews required concurrently goes up.

This is a reasonable and appropriate method to plan for manual leveling of resources, allowing quick loading, accurate and simple totals, practical reviews, and reasonable discussions of the number of crews available to work the tasks.

Resource leveling method – Minimum moment algorithm

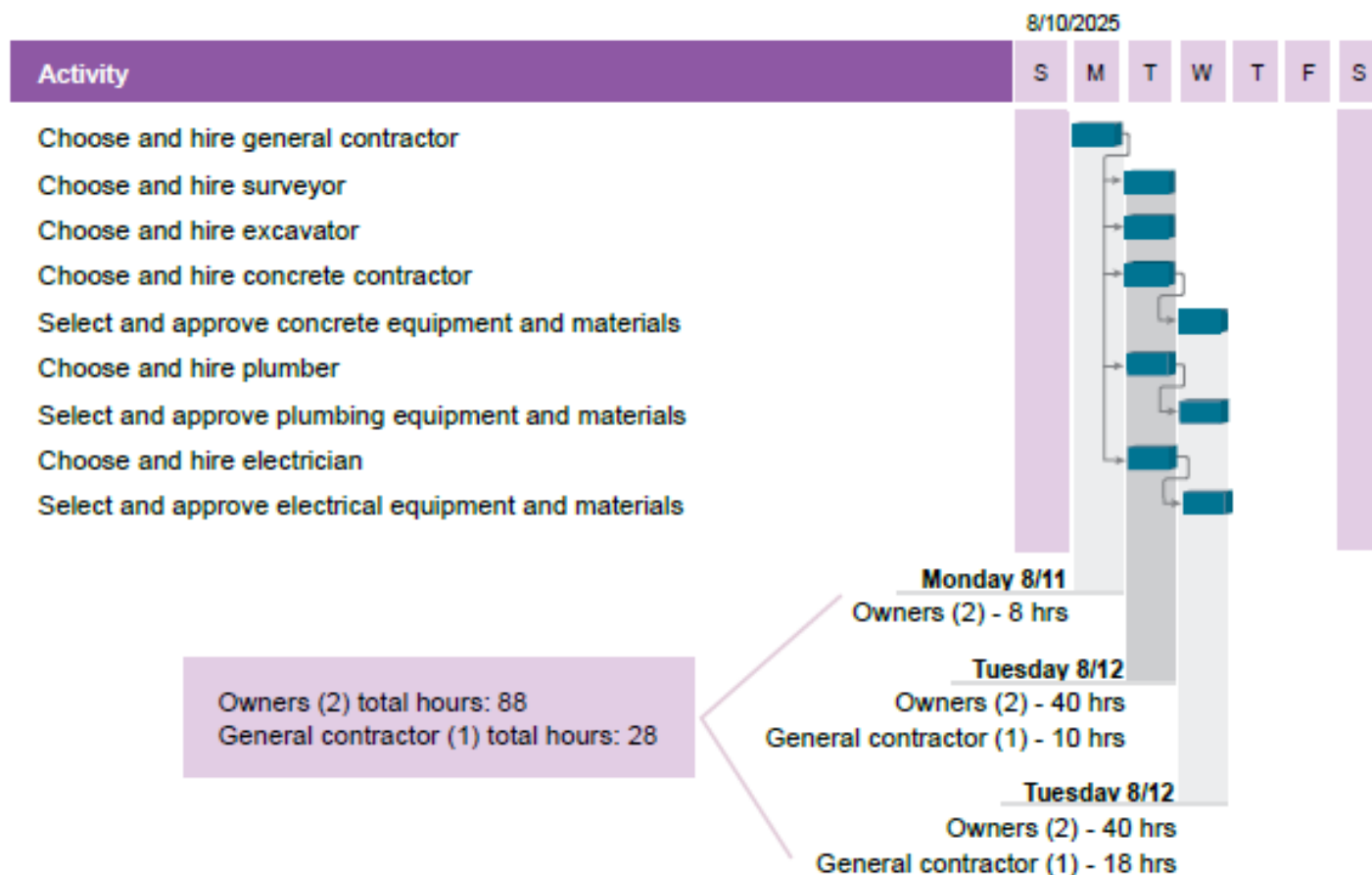
- ❑ The **network logic** is **not questioned** when **resource leveling** is **done**.
- ❑ This **method** will **not alter** the **critical activities**
but will **focus** on the merits of **shifting any noncritical** activities by
reducing their float.

Resource leveling – Example

- ❑ Once the **owners select a general contractor**, they can confer with the general contractor to **select the subcontractors**.
 - ❑ Once an **individual subcontractor is selected**, the owners and general contractor can **select and approve the necessary material**.
 - ❑ These activities are planned to occur
while the **owners wait** for the **general construction permit**
to be granted, which is expected to **take 20 days**.
- From a network perspective, all subcontractors can be selected at the same time once the owner selects the general contractor and, once each subcontractor is selected, the respective materials can be selected.*

Resource leveling – Example

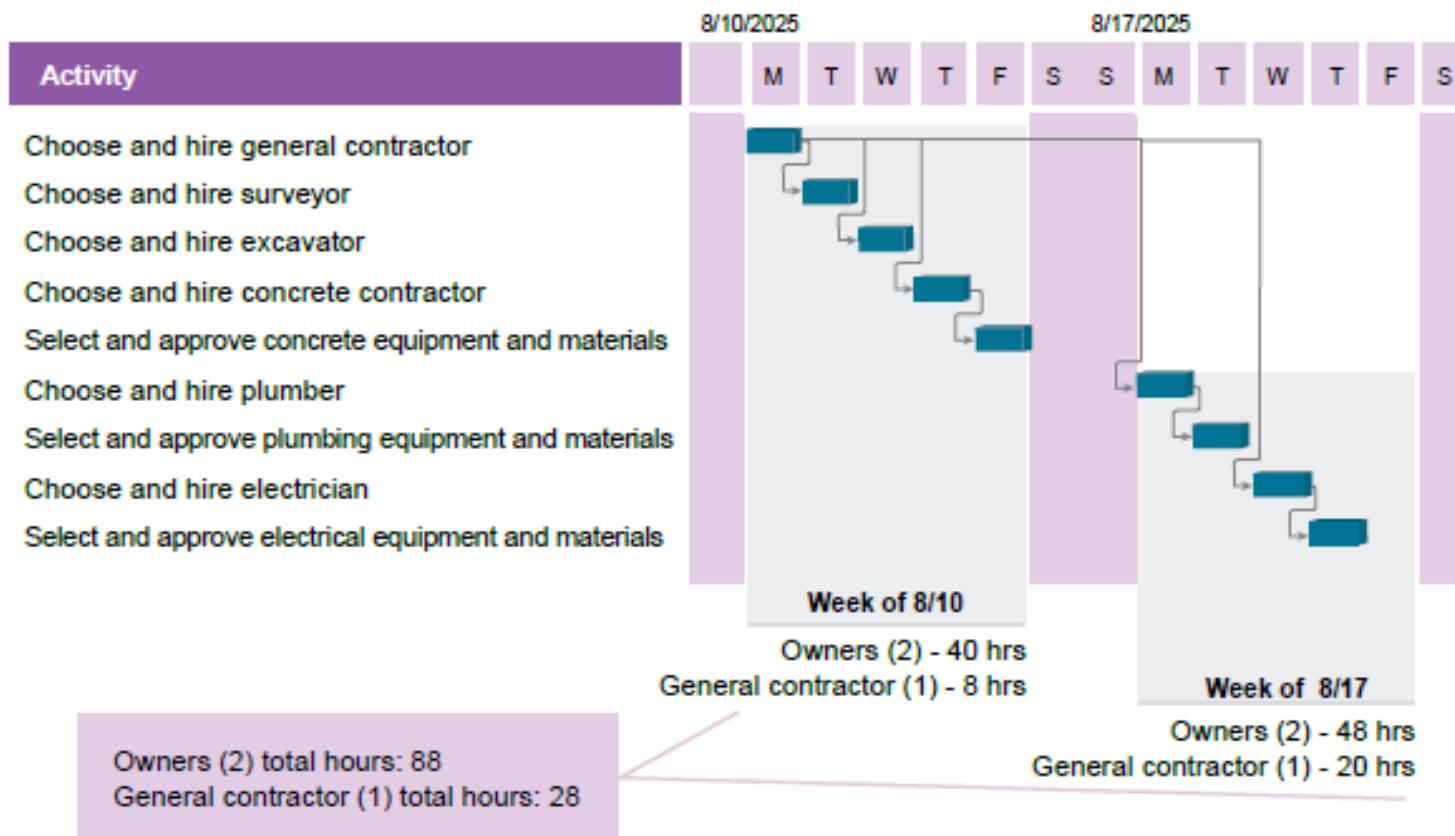
Resource Overallocation in a Correctly Sequenced Network



Source: GAO. | GAO-16-89G

Resource leveling – Example

Resource Leveling in a Correctly Sequenced Network



Source: GAO. | GAO-16-89G

Checklist For a Scheduler For Allocating and Leveling Resources

- ☐ The amount of available resources calculated appropriately.
- ☐ The schedule should realistically reflect the resources that are needed to do the work and—compared to total available resources.
- ☐ Significant material and equipment resources are captured within the schedule along with other equipment resources that facilitate the project.
- ☐ Budgets for direct labor, travel, facilities, equipment, material, and the like are assigned to both work and planning packages so that total costs to complete the program are identified at the outset.
- ☐ Summary activities and milestones are not assigned resources.
- ☐ If EVM is used to monitor the program, the fully loaded schedule, including materials, equipment, direct labor, travel, and LOE activities, is the basis for the PMB.

- ☐ Activity owners are able to explain the logic behind their resource estimates.
- ☐ The same assumptions that formed resource estimates for the cost estimate are applied to the estimated resources loaded into the schedule and are documented.
- ☐ Underlying resource assumptions for the entire estimated scope of work are documented in the schedule basis document in appropriate detail.
- ☐ If resource management is performed outside the schedule, a documented process feeds resource assignments back into the schedule so that it reflects the resolution of resource issues conducted separately.
- ☐ Once the schedule is resource loaded, all resources in the schedule are crosschecked with the project budget and contractual cost constraints.
- ☐ Resource peaks are examined for the feasibility of the available budget, the availability of resources, and the timeliness of the peaks.

- ☐ If the cumulative overlay of resources against major milestones shows resource peaks just beyond major milestone points, resources may have to be reallocated.
- ☐ Resources have been leveled—that is, the scheduled time of activities or the assignment of resources has been adjusted to account for the availability of resources.
- ☐ If critical resources delay the entire project, changes to resolve the resource conflicts are thoroughly documented in the schedule narrative and understood by all.
- ☐ Resources are leveled only on detail schedules supported by historical data and sound estimating methodologies.

An Auditor's Key Questions and Documents for Allocating and Leveling Resources

Key questions

1. What resources are specified and assigned to the activities?
2. At what level of detail are resources specified (for example, as labor categories, organizations, or individual names)?
3. Are significant material and equipment resources described in the schedule?
4. Do summary activities or milestones have resource assignments?
5. How were resource estimates developed for each activity?

Key questions

5. Has analysis ensured that resources are sufficient and available in each work period when needed?
 - a) Is obtaining scarce resources to accomplish the work potentially difficult?
 - b) Are more resources required than are available for some work periods?
 - c) What is the plan for resolving resource deficiencies?
6. Has resource leveling been performed?
7. To what extent are the resource estimates in the schedule consistent with those in the project cost estimate?

Key Documents

1. Basis of estimates for resource assumptions that align with resource estimates within the cost estimates.
2. A resource allocation planning document that defines resource profiles and tables for unique resources derived from the schedule.
3. Resource output from scheduling software across all project schedules.



فرآیند یکپارچه برنامه ریزی، زمانبندی و کنترل پروژه

بخش ششم:

استاندارد اجرایی: تعیین زمان برای همه فعالیتها

ارائه دهندگان:

سید محمدرضا علوی پور

(PhD, PMP, CMIT)

What we will learn?

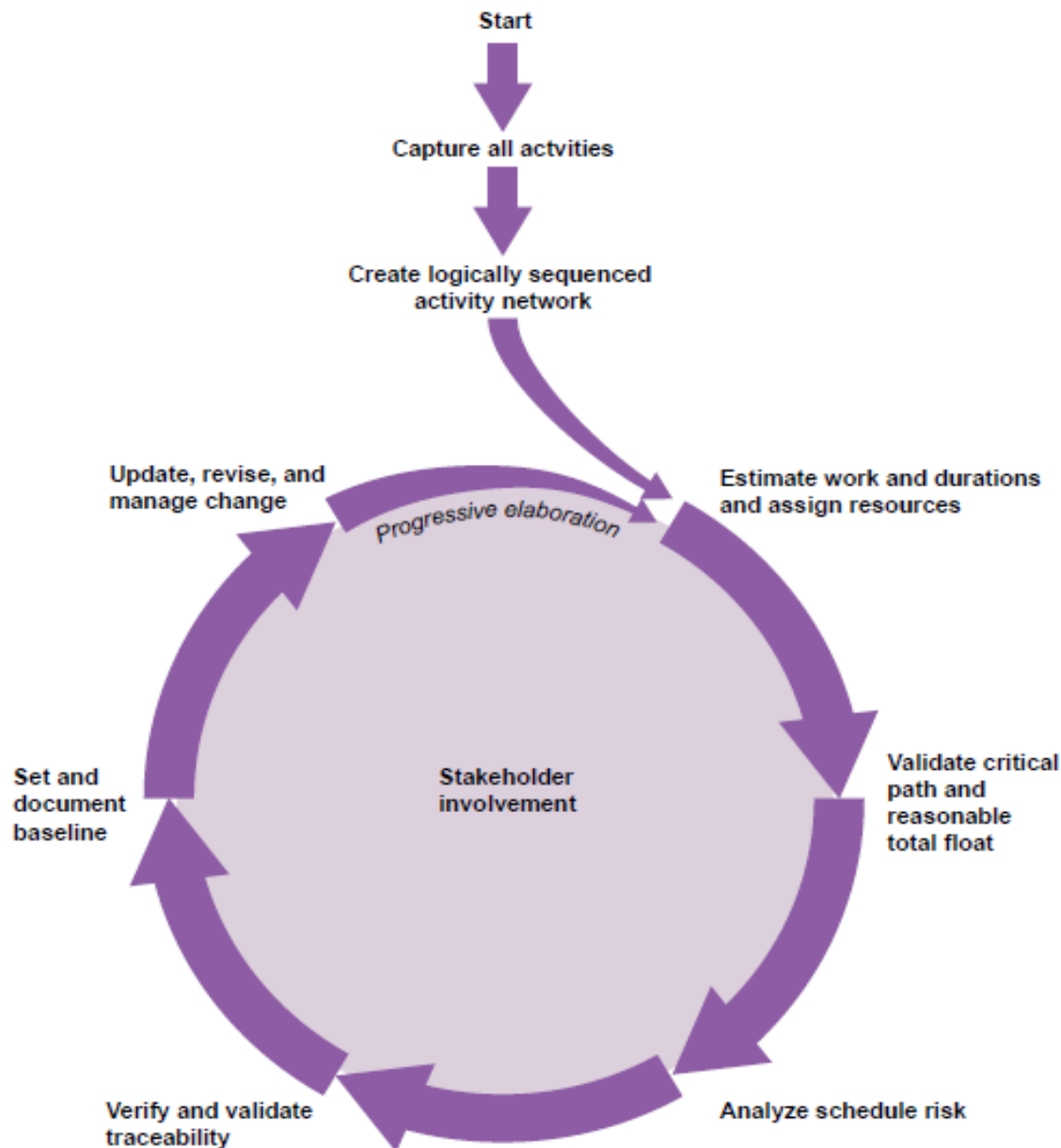
- ☐ Determining activity durations
- ☐ Assigning durations to activities
- ☐ Calendars
- ☐ Early and late dates
- ☐ Time-cost tradeoff analysis
- ☐ Checklist for a scheduler for determining and assigning durations to activities
- ☐ An auditor's key questions and documents for determining and assigning durations to activities



فرآیند یکپارچه برنامه ریزی، زمانبندی، ارزیابی و کنترل پروژه
استاندارد اجرایی: تعیین زمان برای همه فعالیتها

A process for creating and maintaining reliable schedules

- ❑ This is a cyclic process
- ❑ Elaborated through rolling wave process.



A process for creating and maintaining reliable schedules

Process step	Corresponding action	Section
Capture all activities	Capturing all activities	3
Create logically sequenced activity network	Sequencing all activities	4
Estimate work and durations and assign resources	Allocating and leveling resources	5
	Determining and assigning durations to activities	6
Validate critical path and reasonable total float	Critical path determination, assessment, and validation	7
	Ensuring reasonable total float	8
Analyze schedule risk	Schedule constructability and risk analysis	9
Verify and validate traceability	Verifying that the schedule can be traced horizontally and vertically	10
Set and document baseline	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
Update, revise, and manage change	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
	Updating the schedule using actual progress and logic	12

Determining Activity Durations

General rules

- ❑ Defining durations is **less of a science** than it is **an art**, largely due to the **range of variables** that can impact a project and progress on it.
- ❑ Activity durations should be estimated under **most likely or “normal” conditions**, **not under optimal**, “success-oriented” conditions.
 - ❖ Most likely conditions for estimated durations imply that duration estimates do **not contain padding or margin for risk**.
 - ✓ Rather, **risk margin** should be introduced as **separate schedule contingency** activities.

Who should estimate?

- ☐ **Scheduler creates** estimates.
- ☐ **Activity owners is responsible** and **check** estimating durations for **their activities**.

Underlying assumptions and durations should be acceptable to the activity owners.

How to estimate?

❑ **Activity duration estimates** for a **WBS element** in the schedule should **clearly map** to and correspond with the basis of the **cost estimate** for the same **WBS element**.

❖ *For example, assumptions for the number of plumbing workers underlying the **cost estimate** for a WBS element*

*should also underlie the **duration estimates** for the WBS element in the schedule.*

How to estimate? – Working and planning packages

Rolling Wave planning can be especially beneficial to programs where the

Statement of Work (SOW) is likely to change.

How to estimate? – Working and planning packages

1. Detailed activities reflect **near-term** and **well-defined effort** and represent working packages.

- ❖ These work packages are **shorter in duration**
- ❖ Duration estimates for near-term detail activities should be related to the

(1) Quantity

(2) Specific resource availability

(3) Resource productivity

- ❖ These work packages have **necessary logic** ties to **all other tasks**.
- ❖ These elements are either **resource loaded** or linked to resource and **cost budgets**.

How to estimate? – Working and planning packages

2. **Less well-defined effort** beyond the near term is represented within the schedule as **planning packages**.

❖ **Long-term planning packages** naturally have **less-accurate resource availability** and **productivity information** because they can be **several months or years long**.

❖ Estimates for the durations of **planning packages** are **most likely** to be based on

1. Analogies to historical projects
2. Planners' experience
3. Standard productivity rates.

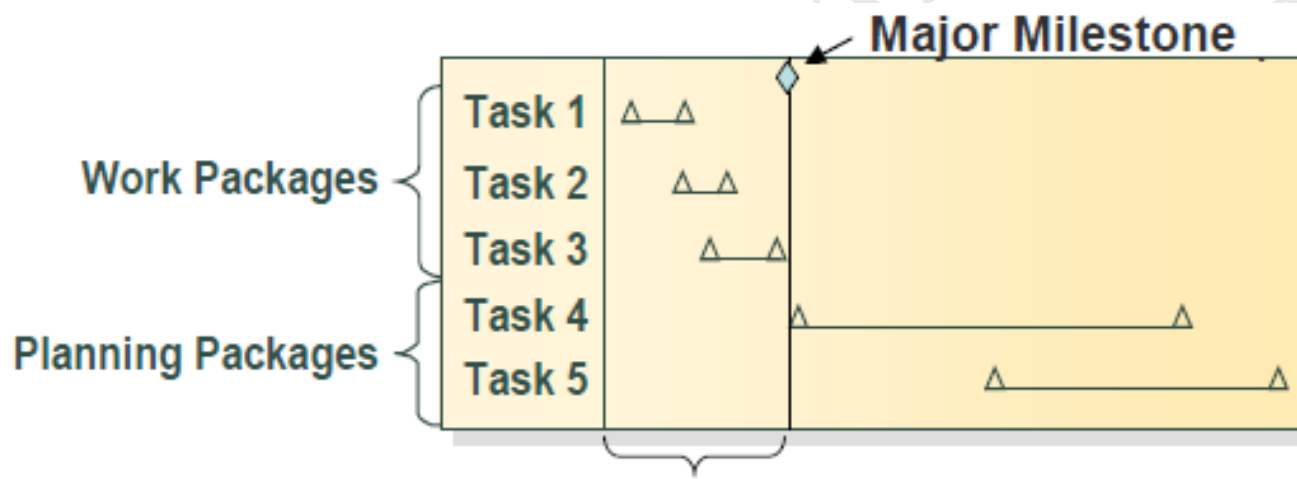
Primary issue here is the reliability of the productivity factor (quantity/crew-hour).

How to estimate? – Working and planning packages

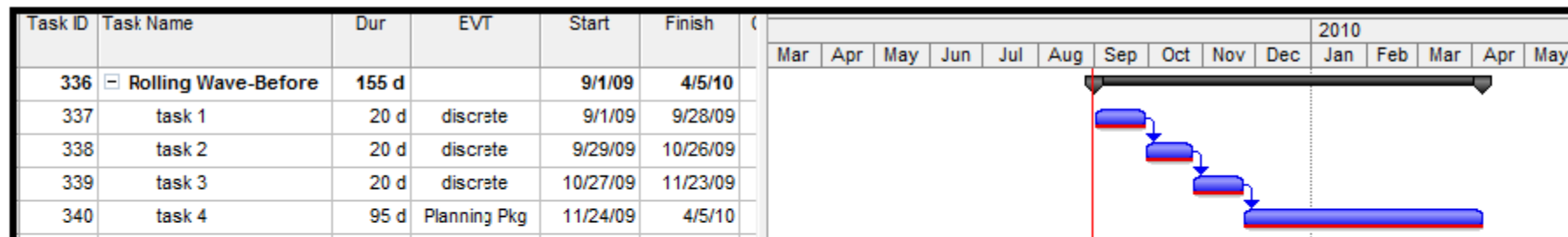
2. Less well-defined effort beyond the near term is represented within the schedule as planning packages.

- ❖ **Planning Packages** have almost all the same characteristics of work packages.
- ❖ Like detail tasks, they also have logical relationships with other tasks in the IMS so a **Critical Path** may be determined.
- ❖ They have associated **resource** and **cost budgets** and forecasts to support the scope they represent, providing that **information in the EVM System** to maintain the **PMB and forecast**.
- ✓ However, because Planning Packages lack sufficient detail for measured progress, EVM performance data is **limited** until the detailed planning is available.

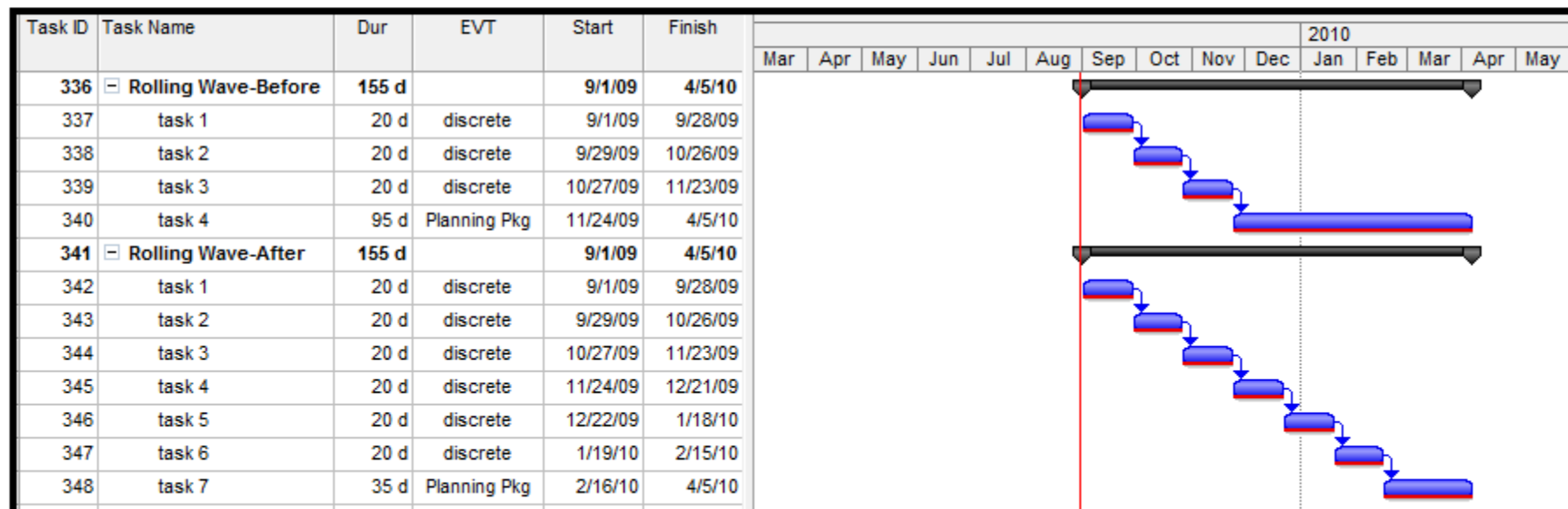
How to estimate? – Working and planning packages



How to estimate? – Working and planning packages



3 months of detail tasking and a Planning Package.



After detailing Task 4 , we have 6 months of discrete tasking and a newly created Planning Package for the balance of the Period of Performance.

How to estimate?

- ❑ In the absence of sound **quantitative data**, the scheduler often **“guesstimates”** activity durations based on **his or her experience**.
- ❑ **Automated algorithms (procedures)** developed for **Larger owners**, such as public agencies, and contractors involved in **large number of similar projects**.
- ❑ The **soundness of the completed estimate** depends on the following **Three factors**:
 - (1) **Accuracy** of the **quantity take-off**
 - (2) **Judicious selection** of the **unit costs**
 - (3) **Judicious selection** **production rates** to be used

How to estimate?

AACE 32R-04

Recommended Practice No. 32R-04, "Determining Activity Duration" (AACE International, 2012) suggests that there are three phases to determining durations: determining unconstrained activity durations, adjusting activity duration based on constraint impact, and revising activity original durations to meet project requirements. These phases are described in detail in the Recommended Practice, and the concept is very useful as an approach to deterministic duration estimating.

How to estimate?

- ❑ **Construction estimates** may be divided into at **least two different types**, depending on the purposes for which they are prepared:

1. **Conceptual estimates**

- ❖ Prepared by owner in preconstruction phase to be used for cost estimate

2. **Detailed estimates**

- ❖ Could be prepared by both owner and contractors
- ❖ Generally prepared by contractors prior to submitting bids.

Conducting a detailed estimates – Quantity takeoff

- ❑ The **process** begins with a **thorough analysis** of the various **physical quantities** that must be incorporated in the **final project**.
- ❑ This information is **obtained** through a **detailed quantity take-off**.
- ❑ The **quantity take-off** is generally **recorded** on a **standard sheet** that includes information about the various items (numeric designation, description, and quantity).

Will be taught in Financial Management course!

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P
295426	023154240200	Excavating, bulk bank measure, 1 C.Y. capacity = 75 C.Y./hour, backhoe, hydraulic, crawler mounted, excluding truck loading	B12A	800	0.02	B.C.Y.	\$ -	\$ 1.07	\$ 1.05	\$ 2.12	\$ -	\$ 316,105.82	\$ 310,197.30	\$ 626,303.12	\$ -	\$ 475,635.86	\$ 342,694.

Estimating durations

❑ **Determine** an **anticipated duration** based on two approaches:

1. Budget and cost rate
2. Production rate

Estimating durations – With budget and cost rate

Assume the work task involves hand excavation on a relatively small project with no viable means of using heavy equipment. The volume of material to be excavated consists of 9 cubic meters (11.8 cubic yards). The **budgeted amount** and the **hourly costs are known**, and from this, the minimum duration can be determined. If the duration is exceeded, the cost of the activity will also overrun the budget.

Quantity of excavation = 9m^3 (determined in the estimate)

Budgeted amount = \$950 (provided in the budget)

Hourly cost per worker: \$33.20 (includes general conditions and overhead $\approx$ 50 percent)

Cost rate = budgeted cost/quantity of earth = $\$950/9\text{m}^3$
= $\$105.56/\text{m}^3$

Production rate = cost rate/hourly cost
= $\$105.56/\text{m}^3 / \$33.20/\text{hr} = 3.18\text{hr}/\text{m}^3$

Excavation time = production rate $\times$ quantity
= $3.18\text{hr}/\text{m}^3 \times 9\text{m}^3 = 28.6\text{hr}$

If one worker is employed, duration = 3.6 days (use 4 days)

If two workers are employed, duration = 1.8 days (2 days)

Estimating durations – With production rate

The scheduler might use the production rates directly rather than determine the production rates that must be achieved to finish an activity within the budget. The following example assumes that the production rates for erecting 47 square meters (506 sq. ft.) of concrete formwork are well documented.

$$\text{Quantity of forming} = 47 \text{ m}^2$$

$$\text{Production rate} = 1.8 \text{ hr/m}^2 \text{ (obtained from historical data)}$$

$$\begin{aligned} \text{Forming time} &= \text{production rate} \times \text{quantity} \\ &= 1.8 \text{ hr/m}^2 \times 47 \text{ m}^2 = 84.6 \text{ hr} \end{aligned}$$

If one worker is employed, duration = 10.6 days (use 11 days)

If two workers are employed, duration = 5.3 days (5 or 6 days)

If three workers are employed, duration = 3.5 days (4 days)

If four workers are employed, duration = 2.6 days (3 days)

Estimating durations – Scheduler with no experience

❑ How is the **duration determined** if the scheduler has **no experience**?

1. **Ask someone with experience.**

❖ **Talk** with the **estimator** or the **job superintendent**.

❖ The only **note of caution** here is that **superintendents** are often **very optimistic**.

✓ They often **fail to include** the **transition time** between activities.

Estimating durations – Scheduler with no experience

❑ How is the **duration determined** if the scheduler has **no experience**?

2. Use reference guides

- ❖ If the firm has **no individuals to contact**
- ❖ Use reference guides with **some degree of caution**.
- ❖ These guides are generally **conservative** in their estimates, but they can be very **helpful if no other resources are available**.
- ❖ Note that **each project has unique characteristics** and that the reference guides **cannot be expected to anticipate all conditions**.
- ❖ Before using published references, **explore historical data** in the company.

Estimating durations – Subcontractors

- ❑ It would **not be realistic** to expect each **subcontractor** to be on the **job site** at a **precisely designated time**.
- ❑ If a **subcontractor** is told to be on site at **noon on a particular day** but is **unable** to **begin work** because another crew has **not yet completed its work**, that subcontractor's crews are **unlikely to wait**.
 - ❖ **What is even worse**, that **subcontractor's crews** may **not be assigned to show** up the **next day**.
- ❑ It is **costly for a subcontractor** to be on a project at a **stated time** and then **not be able to begin work**.

What should be done?

Estimating durations – Subcontractors

- ❑ It is **generally a good idea** to allow some **time to transition** smoothly from **one activity to another**, especially when **different specialty contractors** are involved.

*This will allow time to **contact the subcontractors to inform them of the specific needs of the project for their services.***

BUT THIS MAY CREATE PROBLEM!

Estimating durations – Factors influencing choice of activity schedules

- ☐ An activity may be considered likely to experience problems that will extend its duration.

WHAT SHOULD BE DONE IN THIS SITUATION?

What if delay may occur to activity durations – Method 1

1. This **activity** might be scheduled toward its **early start** to **minimize** the **chance of project delay**.

❖ Subsequent activities might be set to **later-scheduled starts** so that **arrangements made** for the start of these activities would be **less likely to be altered**.

- ✓ It should be noted that weather is a more serious consideration for the scheduler.
- ✓ Weather-dependent activity is scheduled **earlier** and succeeding activities **later**.

PROBLEM IN THIS METHOD:

If the weather activity is **early in the schedule**, essentially **all activities** will be **scheduled later** than they **would normally occur** and the accuracy of the schedule will probably **suffer if** the weather activity is inserted early and no adverse weather occurs.

What if delay may occur to activity durations – Method 2

2. An alternative would be to **increase the duration** of the **initial activity** to account for the **amount of delay** that **might be expected**.
- ❑ Alternatively, the **durations** of **weather-dependent activities** could be **increased prior to network calculations**.
 - ❖ The **amount** by which the **activity's duration** would be **increased** would be based on:
 1. **Likelihood** that a **delay would occur**
 2. **Extent** of the **delay**
 - ✓ *For example, if history indicated that rainfall could be expected 10 percent of the time (1 out of 10 days) during the period this activity would occur, then the duration would be increased by 10 percent.*

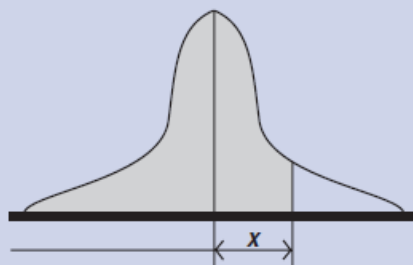
What if the delay to activity does not occur?

Having information may be rare case

What if delay may occur to activity durations – Method 2: Bell-shaped curve

Area Under a Standard Normal Curve

x = the number of standard deviations to the right of the mean



The area under the curve (as shown in the table) always includes the portion containing the mean.

X	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449

What if delay may occur to activity durations – Method 2: Example

- ❑ The estimate from the masonry contractor, and the estimate from the carpet installer was 20 days.
- ❑ Both used data on seven prior projects that were **similar** to the one being constructed.

Masonry Data			Carpet Data	
Project #	Duration (Dur)	(Dur-Mean) ²	Duration (Dur)	(Dur-Mean) ²
1	14	36	18	4
2	17	9	21	1
3	27	49	19	1
4	16	16	22	4
5	18	4	17	9
6	25	25	22	4
7	23	9	21	1
	Sum ₁ = 140	Sum ₂ = 148	Sum ₁ = 140	Sum ₂ = 24
	Mean ₁ = 20	(Sum ₂ /n-1) ^{1/2} = 4.97	Mean ₁ = 20	(Sum ₂ /n-1) ^{1/2} = 2
	n = 7	Std. Dev. = 5 (approx.)	n = 7	Std. Dev. = 2

- ❑ 95 percent confident, the estimate must be 1.645 standard deviations beyond the mean.
 - ❖ About 28 days for the masonry work (20 + 1.645 * 5 = 28.2).
 - ❖ About 23 days (20 + 1.645 * 2 = 23.3) for carpet.

What if delay may occur to activity durations – Method 3

3. Another method is to **insert one or more specific activities** into the network labeled as delays.

- ❖ These activities would be **inserted into activity chains** that **contain** for example **weather-dependent activities**.

PROBLEM IN THIS METHOD:

One drawback of this technique is that **schedule monitoring** is made **more difficult** because the **extra activities** make the schedule appear to be **artificially tight** (**containing less float**).

What if delay may occur to activity durations – Method 4

4. One other scheduling consideration is to **use different resource and task calendars** that consider **unavailability of resources** or **adverse weather** for example.

What if delay may occur to activity durations – Method 5

5. A **stronger case** can probably be made for placing the activity **at the end of the network**.

In this way, **if** for example **no adverse weather is encountered**, the schedule **remains intact** and the project can be **completed with fewer revisions** of the network.

What if delay may occur to activity durations – Conclusion

- ❑ In **deterministic CPM scheduling**, each activity duration is achieved by
 1. **Single quantity** for that activity scope of work
 2. **Production rate** for that activity scope of work
- ❑ There are **risks in duration estimating** that are based on the uncertainty of achieving the **planned production rates**, and
 - ❑ when considered significant, those risks are **managed by replacing** the deterministic calculations by probabilistic modeling through the use of a **Monte Carlo simulation tool**.

Assigning Durations To Activities

Introduction

❑ **Durations** are expressed in **business units**, such as:

1. Work days
2. Workweeks

❑ **Time** might also be measured in **months, weeks, shifts**, or even **hours**.

*Typically, in construction, the unit of time is **days**, and it is assumed that work is performed on a continuous and uniform basis within the **standard workday** and **workweek**.*

Assigning durations based on project duration

1. Short-term projects:

❑ **Hours** would typically be used for **shorter projects** lasting only several days.

❖ **Because** these types of projects frequently have a large number of workers on the project and the work is performed in **shifts**, with work being performed continuously (7 days a week) until the project is completed.

2. Long-term projects:

❑ For **long-term projects** that last for several years, **days**, **weeks**, or **even months** may be more appropriate.

Assigning durations for long-term projects

Durations should be reasonably short and meaningful and should allow for discrete progress measurement.

Schedules that contain

1. **Working packages or detailed activities** reflect **shorter durations** (probably days)
2. **Planning packages (Less defined activities)** reflect **longer durations** (probably weeks or months) until broken Work.

Assigning durations in long-term projects – Working packages

- ❑ Work packages are **detailed activities** and are also called near-term effort.
- ❑ Shorter duration needed for **detail activity** to have **more precise measurement**.
 - ❖ Especially, **shorter durations** are needed for areas of work associated with high cost or high risk.
- ❑ Within detailed schedules, **LOE activities** such as **management**
 1. Should be **clearly marked** in the schedule
 2. Should **never appear** on a **critical path**.

Keeping activity durations shorter than the reporting period has additional benefits to tracking progress.

Let's see!

Assigning durations in long-term projects – Working packages

❑ Should be **no longer than the reporting period** established by the project.

1. **Weekly update:**

✓ **Near-term activity durations** should be **one working week or less**.

2. **Monthly update:**

✓ **GAO: Near-term activity durations** should be about **22 working days or less**.

✓ **SCL: Near-term activity durations** should be about **28 working days or less**.

✓ **PMI: Near-term activity durations** should be about **half reporting period** (10 to 20 working days on a **monthly basis**).

If activities are longer than the reporting period, activities should have at least one quantitative measurable event within the reporting period.

Assigning durations in long-term projects – Working packages

Advisories

Large update windows limit the need to update and, therefore, limit the accuracy of each update. Large update windows also limit the usefulness of the schedule if in a dispute situation, and a more costly approach is then required for the forensic analysis.

Too much detail may cause resistance from the users and can limit the usefulness of the schedule if the users cannot manage and understand it.

Too little detail may result in an unreasonable schedule and inappropriate duration estimates. Appropriate duration sizes and update frequency helps to minimize potential analysis problems in a disputed situation.

Resources that are not segregated will reduce the accuracy of duration calculations. If, for example, the schedule has mechanical, electrical, and plumbing trades lumped together as one activity, the duration estimating likely did not take into account the sequencing of the three trades. This may be acceptable for a summary level schedule, but should be avoided for a more detailed schedule. Each of these trades is separate and should have its own activities and durations.

Assigning durations in long-term projects – Working packages

❑ What to do with long durations?

- ❖ Long durations should be **broken** into shorter activities if logical breaks can be identified.
- ❖ If it is **not practical** to divide the work into smaller activities or insert intermediate milestones:
- ❖ Justification should be given in the schedule basis **document**.

One **rule of thumb** is to break long activities into enough detail that finish-to-start logic relationships can be identified.

*Greater activity detail might be necessary if it helps **management** understand and address the implications of **risk** and **uncertainty**.*

Assigning durations in long-term projects – Working packages

❑ What to do with long durations?

- ❖ In some circumstances, it may be **beneficial** to use **long-duration activities** in a schedule to **reduce complexity**.
 - ✓ *For example, if 30 units of some item need to be constructed and each item has 15 individual steps, the complexity of the schedule can be reduced by creating 30 construction activities rather than 450 step activities.*
- ❖ To ensure that **long-duration activities** can be **effectively progressed**, they should be **monitored** using **incremental milestones**.

What is incremental milestone?

Assigning durations in long-term projects – Working packages

❑ What to do with long durations?

- ❖ Incremental milestones—also called **inch-stones**.
- ❖ Used to **track** the **completion** of a **long-duration activity**.
- ❖ Should be **managed** under a **control process**.
- ❖ Used to **calculate performance** for **long-duration activities** are sometimes referred to as **quantifiable backup data (QBD)**.

So how do you calculate this data?

Assigning durations in long-term projects – Working packages

☐ What to do with long durations?

- ❖ Incremental milestones—also called **inch-stones**.

So how do you calculate this data?

The calculation is built on each single item step and the budgeted amount of time (labor hours) that is needed to complete the task by the construction crew. As each step is completed, that is documented as a mini-milestone which represents a percentage of the total installation process. The percentage given for each subtask can vary based on the project and this progress is usually agreed on to be used as a measuring tool beforehand.

A good way to implement this method in Primavera P6 is using Activity Steps.

Assigning durations in long-term projects – Working packages

❑ What to do with long durations?

❖ Incremental milestones—also called **inch-stones**.

Discrete Effort Incremental Milestone Method

(Vessel Installation Example)



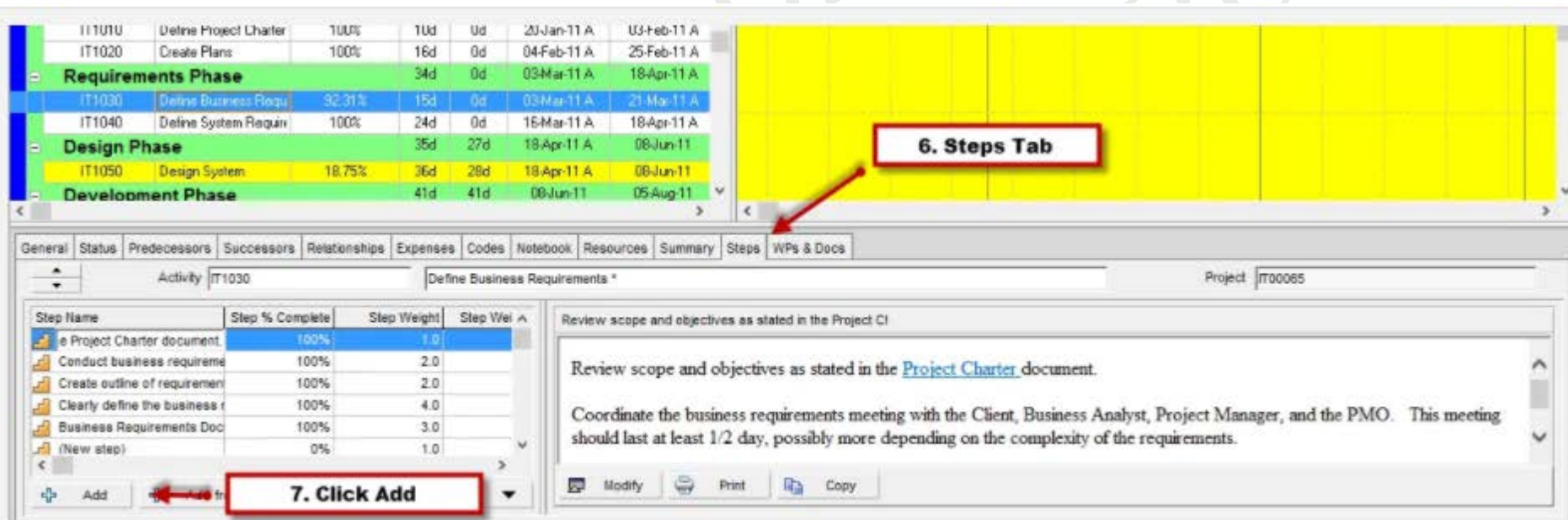
Received at Site	15%
Set	30%
Aligned	50%
Internals Installed	70%
Tested	85%
Turned Over	100%

Assigning durations in long-term projects – Working packages

❑ What to do with long durations?

❖ Incremental milestones—also called **inch-stones**.

A good way to implement this method in Primavera P6 is using Activity Steps.



Activity	Define Project Charter	Create Plans	Requirements Phase	Design Phase	Development Phase
IT1010	100%	10d	0d	20-Jan-11 A	03-Feb-11 A
IT1020	100%	16d	0d	04-Feb-11 A	25-Feb-11 A
IT1030	92.31%	15d	0d	03-Mar-11 A	21-Mar-11 A
IT1040	100%	24d	0d	15-Mar-11 A	18-Apr-11 A
IT1050	18.75%	36d	26d	18-Apr-11 A	08-Jun-11
		41d	41d	08-Jun-11	05-Aug-11

Step Name	Step % Complete	Step Weight	Step Wei
Review Project Charter document	100%	1.0	
Conduct business requirements	100%	2.0	
Create outline of requirements	100%	2.0	
Clearly define the business requirements	100%	4.0	
Business Requirements Document	100%	3.0	
(New step)	0%	1.0	

Review scope and objectives as stated in the Project Charter document.

Coordinate the business requirements meeting with the Client, Business Analyst, Project Manager, and the PMO. This meeting should last at least 1/2 day, possibly more depending on the complexity of the requirements.

Add Activity Steps

Assigning durations in long-term projects – Working packages

All activity durations in the schedule should be defined by the same time unit (hours, days, weeks) to facilitate calculating and monitoring the critical path.

The day is the preferred time unit.

Assigning durations in long-term projects – Planning packages

- ☐ **Often created** before **detailed engineering** is **complete**.
- ☐ **Summarized** or **less-defined future work** can be **several months long**.
- ☐ **Durations** might be **longer than 1 or 2 months** and **lags might be more common**.
- ☐ **Duration** of the **planning packages** must be **estimated** and they should still be **integrated into network logic**.

Calendars

Introduction

PMI Best Practice

- ❑ **Calendars** provide information on working and non-working days in a project.
- ❑ All **engineering activities** in a project are **usually** carried out at the home office (HO) or head office of a company, so the calendar defined for such activities should incorporate **working days** accordingly.
- ❑ If a **procurement** team is also stationed in HO it will have the **same calendar**.
 - ❖ However, activities like **delivery of material** (long lead items) usually require another type of calendar with **a seven-day work week**.

Introduction

PMI Best Practice

- ❑ For **construction**, it is important to identify and mark all **holidays** declared by the government of the country where the project is being undertaken.
 - ❖ This does **not need to be an exhaustive description**, but the idea is to call attention to and explore each phase of a project while defining a calendar.
- ❑ In some cases, the **contract** also specifies **working days** for each phase;
hence, that information is also to be considered **while identifying and defining**.

Types of calendars

❑ Calendars in schedules specify **valid working times** for programs, resources and activities.

1. **Project calendars**: Project calendars identify working days and hours for **entire programs** and usually represent a **program's typical schedule**. Days off, such as **company holidays**, should be specified.
2. **Resource calendars**: Resources (labor and equipment) can be assigned to calendars to define **their availability**.
3. **Task calendars**: Task calendars define the working and nonworking days and times for **tasks**. Activities should be **directly** tied to **task calendars**, which will **define** the **valid times** an activity can be **worked**.

Types of calendars

❑ Calendars are defined by:

1. Number of work days per work week
 2. Number of hours available each work day
- ❖ Special nonwork days, known as exceptions, are defined in resource and activity calendars.
- ✓ **Holidays** and **plant shutdown** periods are examples of exceptions at the activity calendar level.

Resource calendars

- ❑ Proper use of resource and task calendars **precludes** need for **soft constraints**.
 - ❖ *For example, a SNET constraint may be used to prevent a testing activity from beginning too soon while the testing facility is in use for an unrelated project.*
 - ✓ **Instead of a SNET constraint**, the test facility should be defined as a resource within the schedule and assigned to a calendar whose exceptions represent days other projects are using the facility.
 - If the **testing facility** becomes **available sooner or later** than originally planned, the scheduler need only update the exceptions within the testing facility **resource calendar**.*
- ❑ Resource calendars must also be **adjusted** for planned overtime—to allow a resource to **work** in an otherwise nonworking period.

Resource calendars

PMI Best Practice

- ❑ It is useful to insist on having **separate calendars** for each resource, as well as for every point in the project where there is a **change in responsibility**.

Why?

Resource calendars

PMI Best Practice

When **multiple calendars** are combined in a single calendar,
it is **difficult or impossible** to establish **who or what is responsible** for the event
delaying the schedule.

- ❑ Likewise, if **any events** are missing,
such as **non-work periods** during the winter for **installing asphalt**,
it is possible that the **critical path is inaccurate**.

Default Condition

If there is no resource calendar, the software will assume that the resource is available to do work full time with 100% availability for the duration of the project, as per default number of hours/day defined in the base or project calendar.

Task calendars

❑ **Task calendars** may also be employed to represent a **suspension of effort**.

❖ For example, if **severe weather** requires the **suspension of pouring concrete**, the **activity** can be **assigned** to a **specific calendar** that prevents the work from **being performed on certain days**.

Advantages and disadvantages of defining resource and task calendars

□ Advantages:

- ❖ Defining calendars in this way allows for properly scheduling activities **automatically** according to network logic.
- ❖ Automatically updating the schedule gives greater **confidence** in float calculations and the derived critical paths.

□ Disadvantages:

- ❖ Having too many calendars may **interfere** with **critical path analysis** because calendars can **affect float calculations**.
- ❖ Administration necessary to **build and maintain many resource calendars** may be necessary.

Early and Late Dates

Introduction

- ❑ Once the **logic** that creates a network has been **established**, the **scheduling software** can calculate a **set of start and finish times** for each activity.
- ❑ **Network logic** calculates **activity dates** that define
 1. **When** an activity **may** start and finish
 2. **When** an activity **must** start and finish

These are known as early and late dates.

Early dates

- ❑ Each activity has an **early start date** and an **early finish date**.
- ❑ Unless otherwise, “**start**” and “**finish**” refer to an activity’s **early start** and **early finish** dates.
 - ❖ Early start defines the earliest time when an activity may start.
 - ❖ Early finish defines the earliest time when an activity may finish.
- ❑ The early start and early finish dates for each activity are calculated by the “forward pass” method.

Late dates

- ❑ Each activity also has a **late start date and a late finish date**.
 - ❖ Late start defines the **latest time** when an activity **must start** in order for the project to be **completed on time**.
 - ❖ Late finish defines the **latest time** when an activity **must finish** in order for the program to be **completed on time**.
- ❑ The late start and late finish for each activity are calculated by the “**backward pass**” method—the **opposite** of the **forward pass**.

Forward Pass: calculates the early dates

Backward Pass: calculates the late dates

Total Float: difference between the early and late finish date

Time-Cost Tradeoff Analysis

Project schedule data and activity acceleration method inputs

1. All normal
2. Least cost
3. Least time
4. All crash

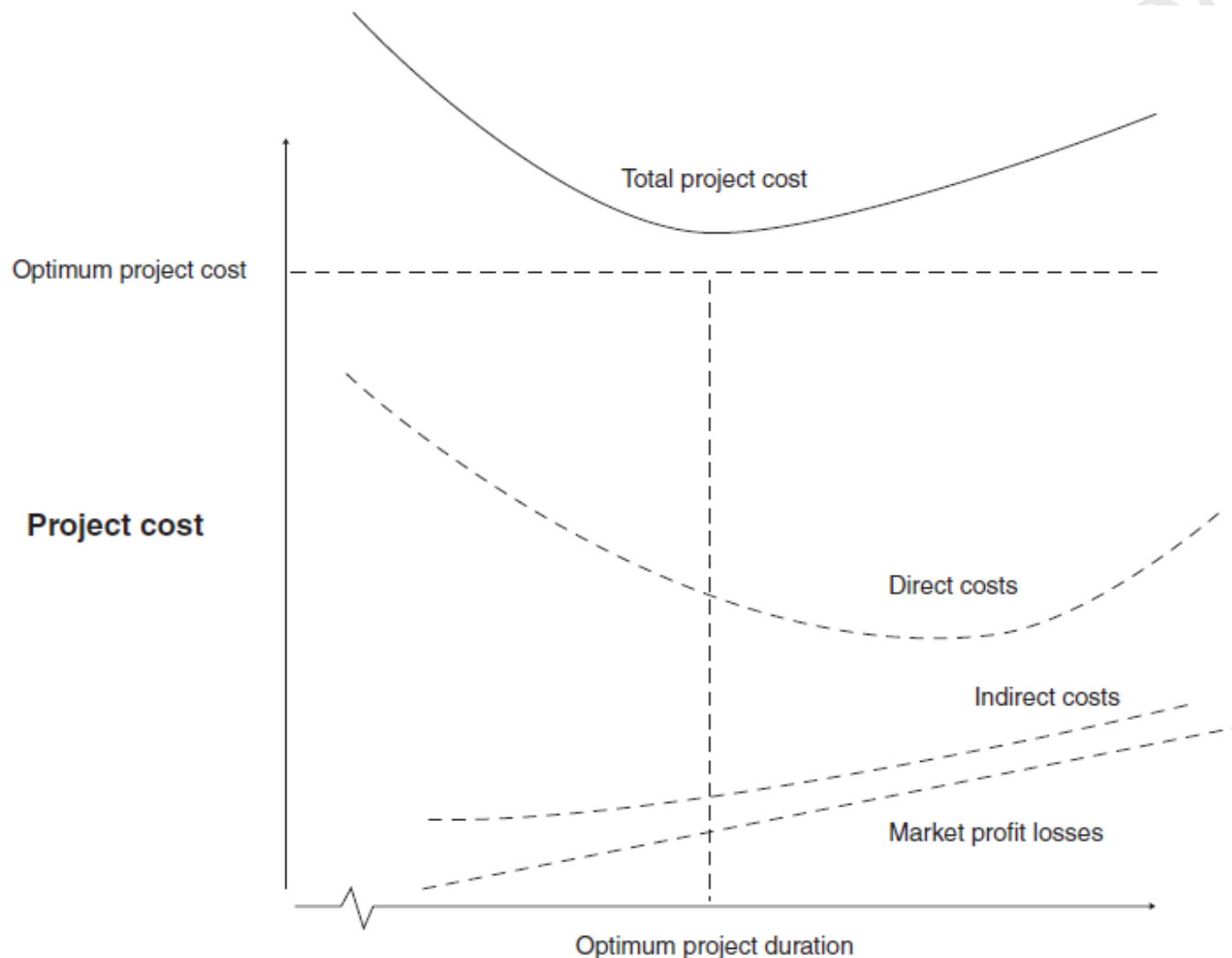
Activity #	Normal Duration	Crash Duration	Normal Cost	Crash Cost	Days to Shorten	Cost per Day
A	1	1	\$5,800	\$800	0	—
B	7	4	1,000	1,600	3	\$200
C	6	4	300	500	2	100
D	3	2	400	800	1	400
E	3	1	100	200	2	50
F	7	5	500	800	2	150
G	8	4	200	1,400	4	300
H	7	6	350	600	1	250
J	5	3	700	850	2	75
K	3	2	500	1,000	1	500
L	5	4	450	800	1	350
			5,300			

Project schedule data and activity acceleration method inputs

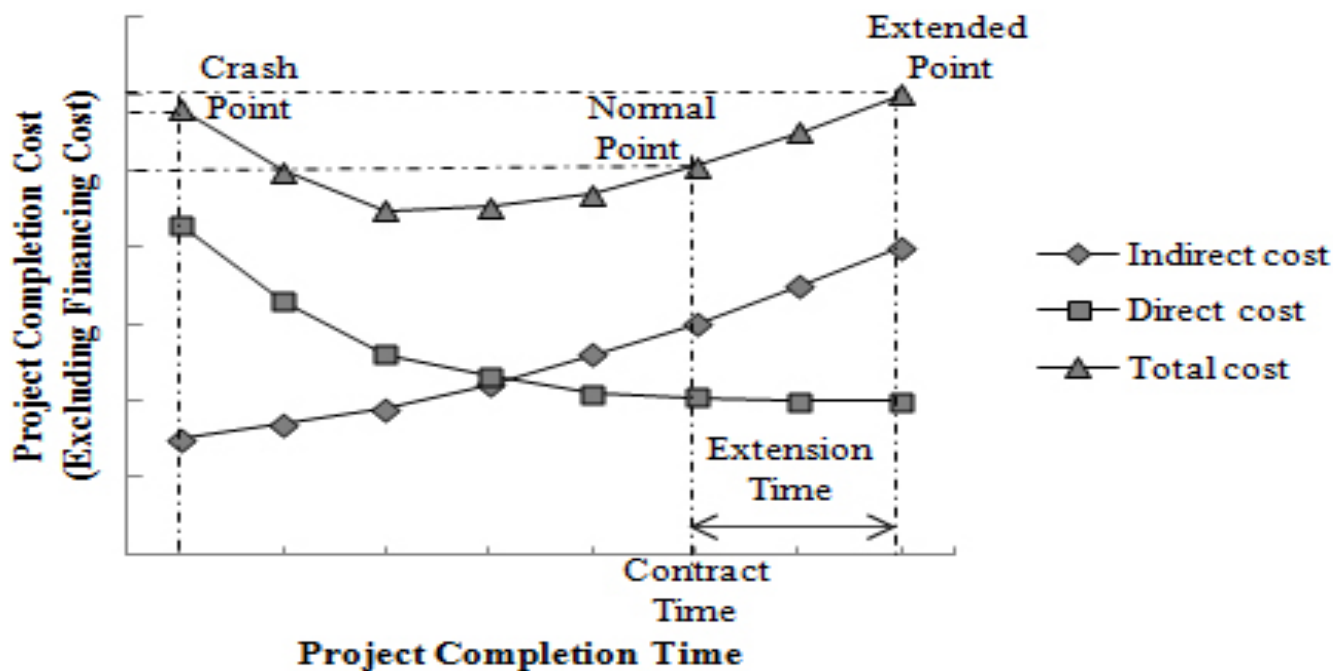
Project Schedule Data and Activity Acceleration Method Inputs

Activity ID	Activity name	Predecessors			Duration (weeks)			Direct cost (\$/week)		
		Predecessor 1	Predecessor 2	Predecessor 3	Acceleration Method 1	Acceleration Method 2	Acceleration Method 3	Acceleration Method 1	Acceleration Method 2	Acceleration Method 3
1	Start	-	-	-	-	-	-	-	-	-
2	A	1	-	-	11	10	9	70,000	90,000	110,000
3	B	1	-	-	4	3	-	40,000	60,000	-
4	C	1	-	-	8	5	4	45,000	70,000	85,000
5	D	3	-	-	3	2	-	50,000	85,000	-
6	E	2	-	-	9	8	-	70,000	90,000	-
7	F	5	-	-	8	7	-	60,000	70,000	-
8	G	4	5	-	10	7	6	55,000	75,000	90,000
9	H	6	-	-	9	8	-	70,000	80,000	-
10	I	7	8	-	11	8	7	60,000	80,000	90,000
11	J	7	-	-	12	11	10	85,000	100,000	115,000
12	K	10	-	-	11	8	7	80,000	110,000	130,000
13	L	9	-	-	9	8	-	60,000	80,000	-
14	M	11	-	-	10	9	8	100,000	115,000	130,000

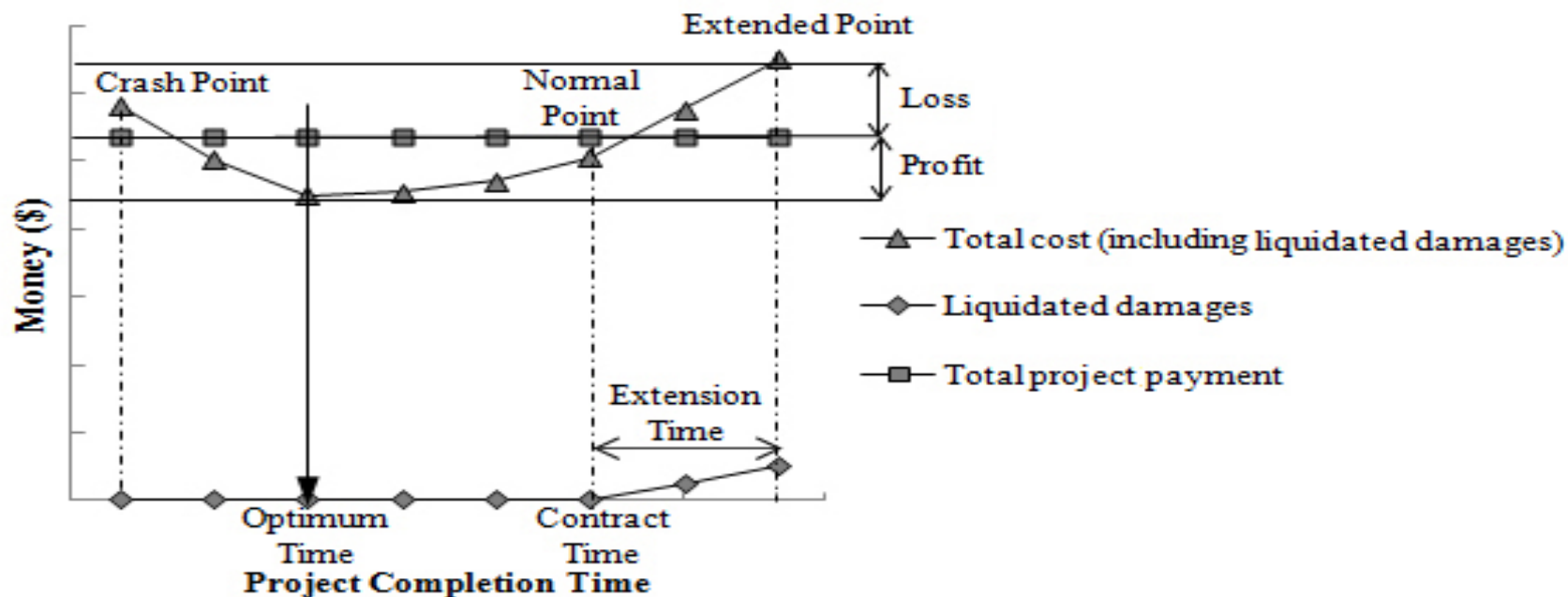
General relationship of project cost to project duration



General relationship of project cost to project duration



General relationship of project profit to project duration



**Checklist For a Scheduler For
Determining and Assigning Durations
To Activities**

- ☐ Activity durations directly related to the resources and estimated work required.
- ☐ In general, estimated detailed activity durations are shorter than the reporting period management requires.
- ☐ Durations are as short as possible, to a point, to facilitate the objective measurement of accomplished effort.
- ☐ Long durations should be broken into shorter activities if logical breaks can be identified.
- ☐ If it is not practical, justification for long durations is provided in the document.
- ☐ Very short durations, such as 1 day or less, may imply a schedule that is too detailed and require more-frequent updates to schedule duration and logic than is otherwise necessary.

- ☐ LOE activities are clearly marked in the schedule and derive their durations from other discrete activities.
- ☐ All activity durations within the schedule are defined by the same time unit (hours, days, weeks). Days are preferred.
- ☐ Planning packages representing summarized or less-defined future work should be integrated into network logic.
- ☐ Activity durations are estimated under most likely conditions, not optimal or “success-oriented” conditions.
- ☐ “Most likely” for estimated durations implies that duration estimates do not contain padding or margin for risk.
- ☐ They should also not be unrealistically short or arbitrarily reduced by management to meet a program challenge.

- ☐ All assumptions related to activity duration estimates are documented in appropriate detail, such as describing the methodology used to create the estimate.
- ☐ Activity duration estimates for a WBS element in a schedule should clearly map to and correspond with the basis of the cost estimate for the same WBS element.
- ☐ Calendars are used to specify valid working times for activities and, when feasible, resources.

**An Auditor's Key Questions and
Documents for Determining and
Assigning Durations To Activities**

Key questions

1. Were durations determined from work to be done and realistic assumptions about available resources, productivity, normal interferences and distractions, and reliance on others?
2. For a detailed schedule, are durations short enough to be consistent with the needs of effective planning and program execution?
3. Are activities long in duration because of LOE or rolling wave planning?
4. Are LOE activity durations determined by the activities they support?
5. Did the person responsible for the activities estimate their durations?

Key questions

6. Was the project duration determined by some target or mandated date?
7. Are durations based on appropriate calendars?
8. Do any specific conditions necessitate special calendars, and are they addressed (for example, religious holidays, nonwork periods for climate, shift work, unavailability of resources)?
9. Are activity durations assigned inconsistent time units?

Key Documents

1. How durations of work activities were estimated is documented at the appropriate level of detail. For instance, the basis of estimate includes the assumptions made to justify the durations assumed for the cost. These should be consistent with the durations at the same level of detail.
2. Documentation justifies nonstandard working calendars.
3. Documentation justifies excessively long durations, including the identification of LOE activities and how they were scheduled.

موسسه مهندسی و مدیریت ساخت علوی پور (ACEMI)

دفتر آموزش

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