Remember:

- Quiz 3 next week (Ch 6, 7, 8 and 9)
- Assignment 2 is on Canvas

Scheduling

So far, we have:

- learned how to **select a project** from a pool of projects
- derived **project activities**
- assigned **durations** to these activities

But, is that enough to start a project??

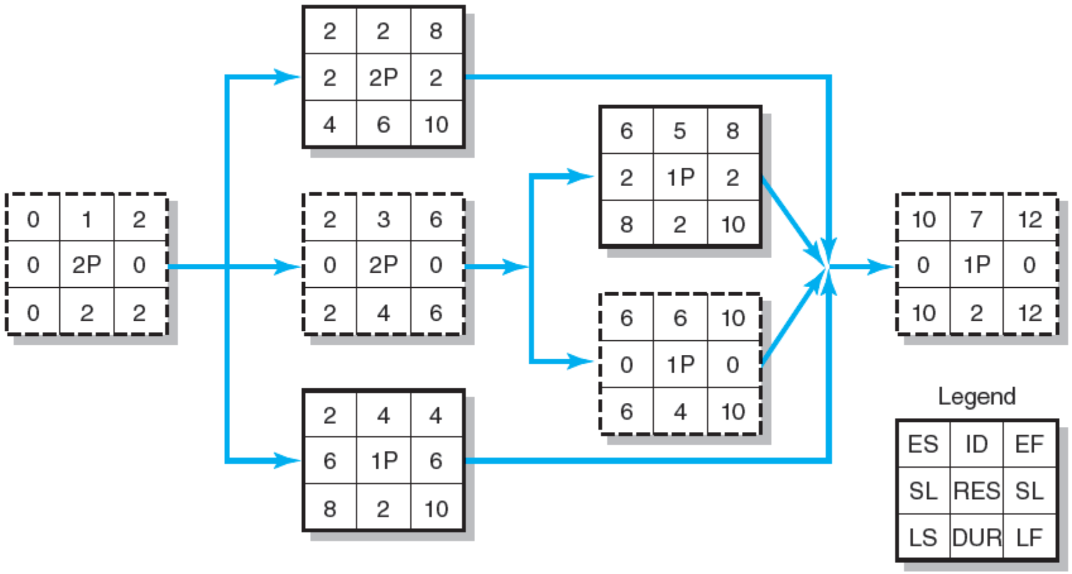
The resource problem

- BIG assumption:
  - Work package (WP) time estimates and project duration estimates are made with the assumption that resources will be available when needed!
  - **But would they???**

Scenario 1: What if there are enough resources but demand for them varies?

Scenario 2: What if there are not enough resources?

Resource-Constrained Schedule

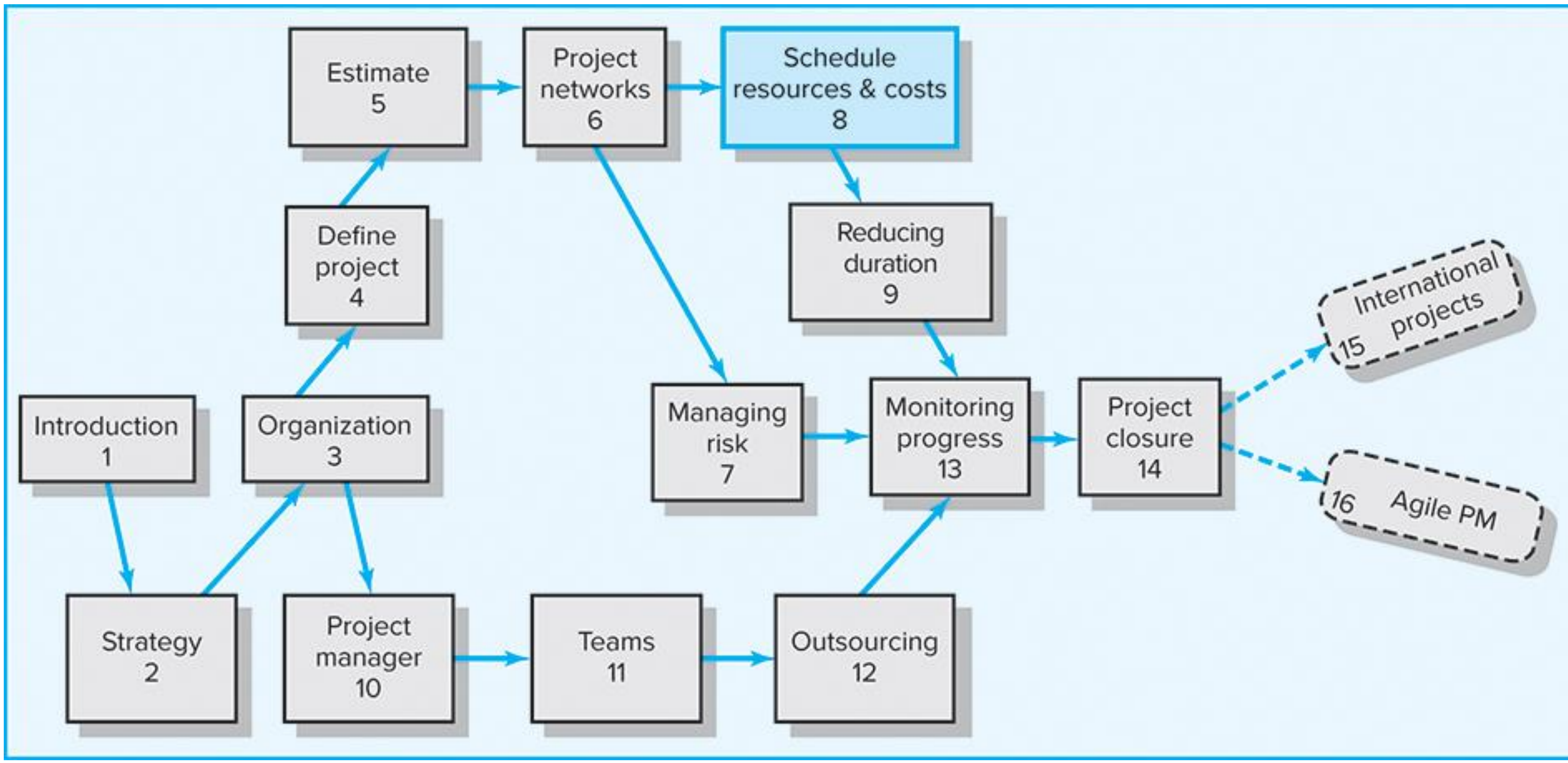


ES resource load chart

ID	RES	DUR	ES	LF	SL	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14
1	2P	2	0	2	0	2	2												
2	2P	6	2	10	2			2	2	2	2	2	2						
3	2P	4	2	6	0			2	2	2	2								
4	1P	2	2	10	6			1	1										
5	1P	2	6	10	2							1	1						
6	1P	4	6	10	0							1	1	1	1				
7	1P	2	10	12	0											1	1		
Total resource load						2P	2P	5P	5P	4P	4P	4P	4P	1P	1P	1P	1P		

Chapter Eight

Scheduling Resources and Costs



Learning Objectives

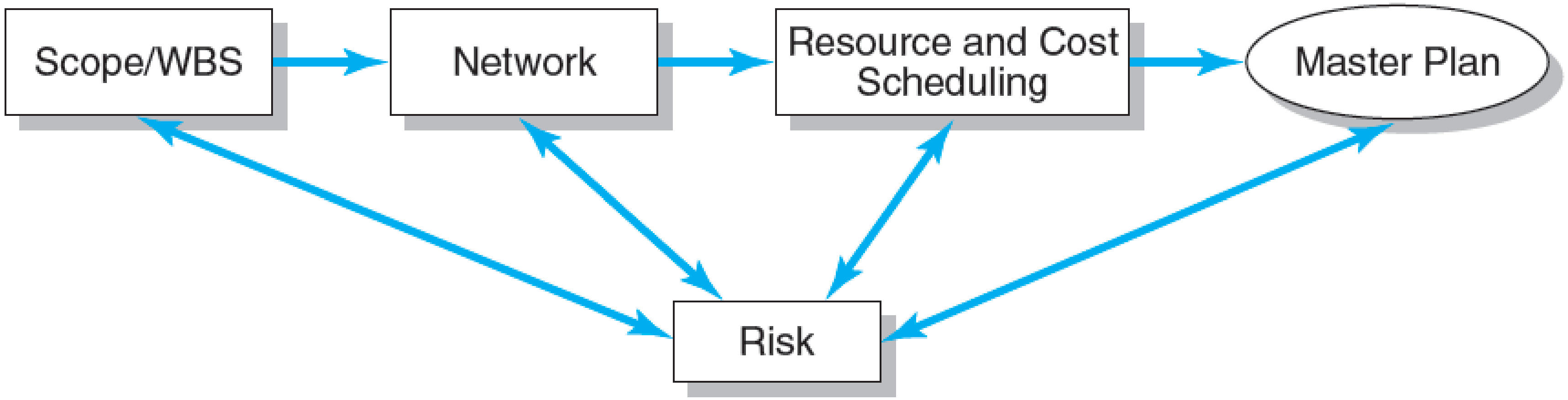
1. Understand the differences between time-constrained and resource-constrained schedules
2. Understand when and why splitting tasks should be avoided
3. Identify common problems with multiproject resource scheduling

The Resource Scheduling Problem

- Resources and Priorities
  - Project network times are not a **schedule** until resources have been assigned.
    - The implicit assumption is that resources will be available in the required amounts when needed.
    - Adding new projects requires making realistic judgments of resource availability and project durations.
  - Cost estimates are not a **budget** until they have been *time-phased*.

Project Planning Process

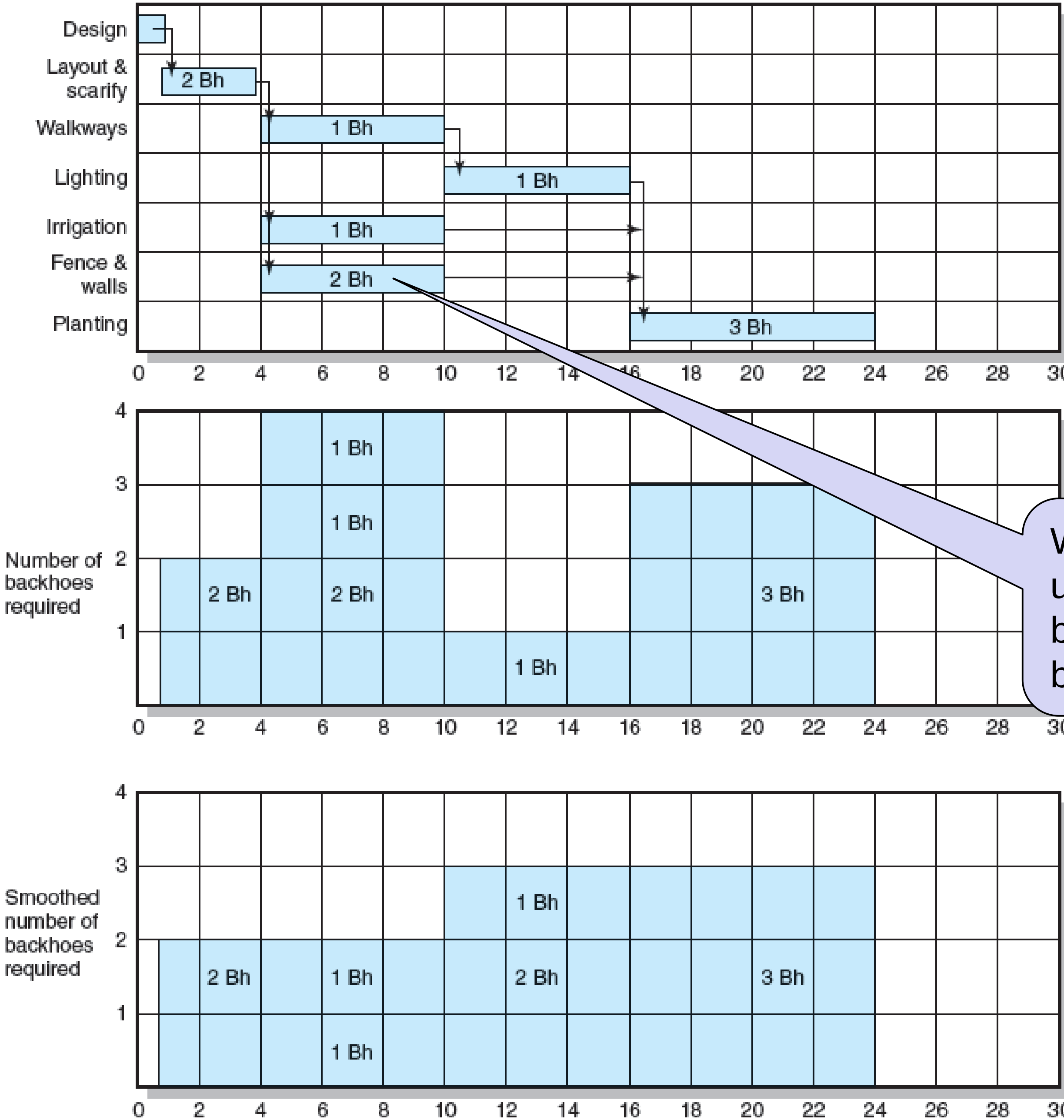
FIGURE 8.1



The Resource Scheduling Problem (cont'd)

- Resource **Smoothing** (or **Leveling**)
  - Involves attempting to even out varying demands on resources by using slack (delaying noncritical activities) to manage resource utilization when resources are adequate over the life of the project.

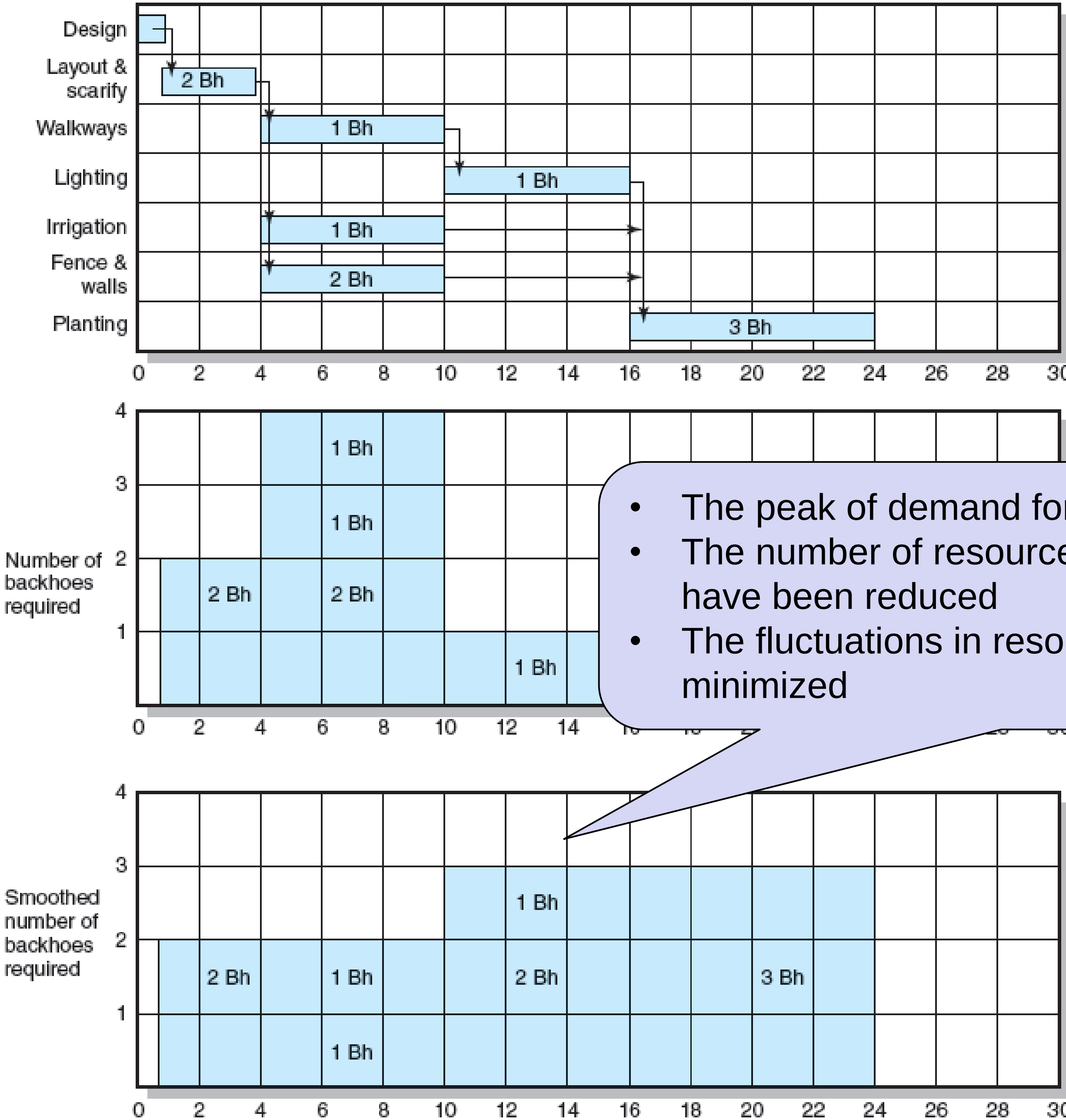
Botanical Garden



We delay Fence & walls to utilise resources better (see below - now we only require 2 backhoes instead of 4)

FIGURE 8.3

Botanical Garden



- The peak of demand for the resource was reduced
- The number of resources over the life of the project have been reduced
- The fluctuations in resource demand were minimized

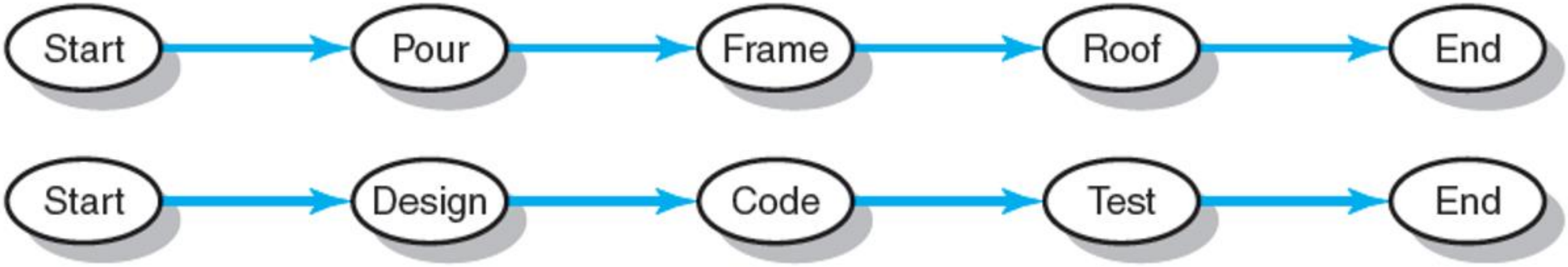
FIGURE 8.3

The Resource Scheduling Problem (cont'd)

- Resource **Smoothing** (or **Leveling**)
  - Involves attempting to even out varying demands on resources by using slack (delaying noncritical activities) to manage resource utilization when resources are adequate over the life of the project.
- **Resource-Constrained** Scheduling
  - The duration of a project may be increased by delaying the late start of some of its activities if resources are not adequate to meet peak demands.

Resource-Constrained Scheduling

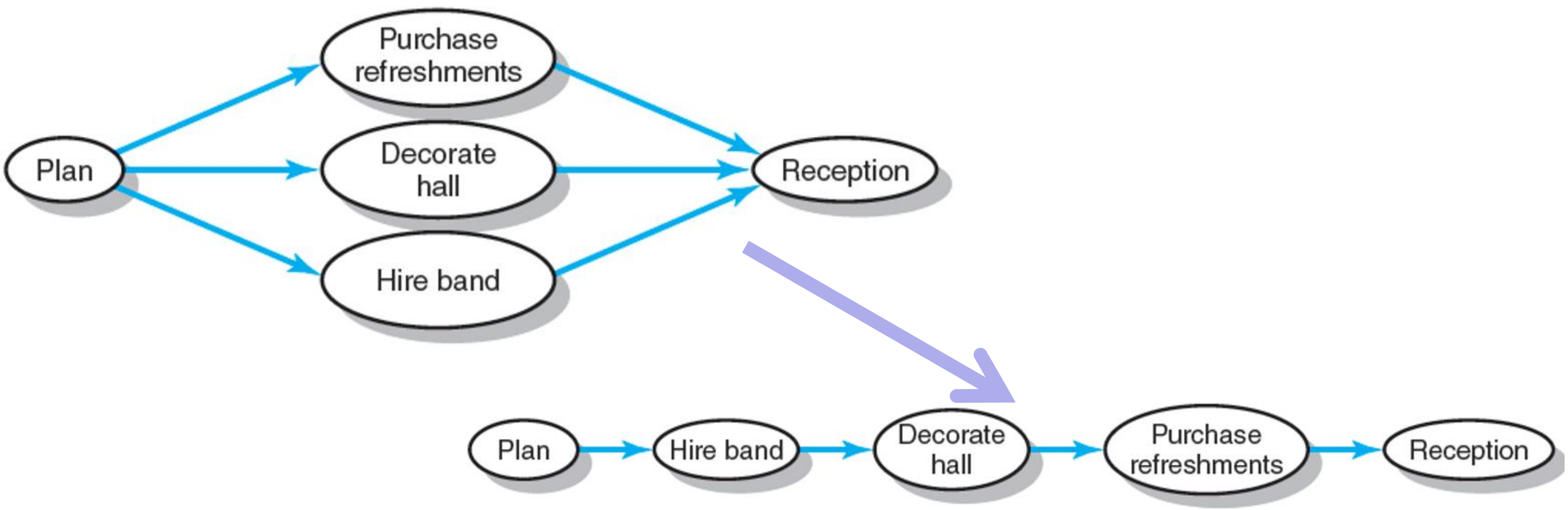
- Technical or Logic Constraints
  - Constraints related to the networked sequence in which project activities must occur



  - The network assumes the personnel and equipment are available but this is often not the case.
- Resource Constraints

Resource-Constrained Scheduling

- Technical or Logic Constraints
- Resource Constraints
  - The absence, shortage, or unique interrelationship and interaction characteristics of resources that require a particular sequencing of project activities

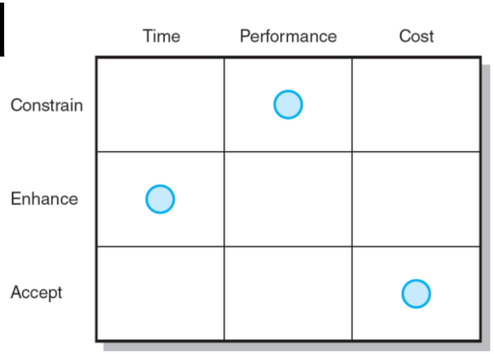


Types of Resource

1. People
   – Programmer, mechanical engineer, welder, inspector, marketing director, supervisor
2. Materials
   – Chemicals for a scientific project, concrete for a road project, survey data for a marketing project
3. Equipment
   – Equipment is often overlooked as a constraint.
   – Recognition of equipment constraints before the project begins can avoid high crashing or delay costs.

Resource Allocation Methods

Using a priority matrix will help determine if the project is time or resource constrained



1. Time-Constrained Project
   - Must be completed by an imposed date.
     - **Time is fixed**, **resources are flexible**: additional resources are required to ensure project meets schedule.
2. Resource-Constrained Project
   - Is one in which the level of resources available cannot be exceeded.
     - **Resources are fixed**, **time is flexible**: inadequate resources will delay the project.

Resource Allocation Methods (cont'd)

- **Assumptions**
  - Splitting activities is **not allowed**—once an activity is started, it is carried to completion.
  - **Level of resources** used for an activity cannot be changed.

Resource Allocation Methods (cont'd)

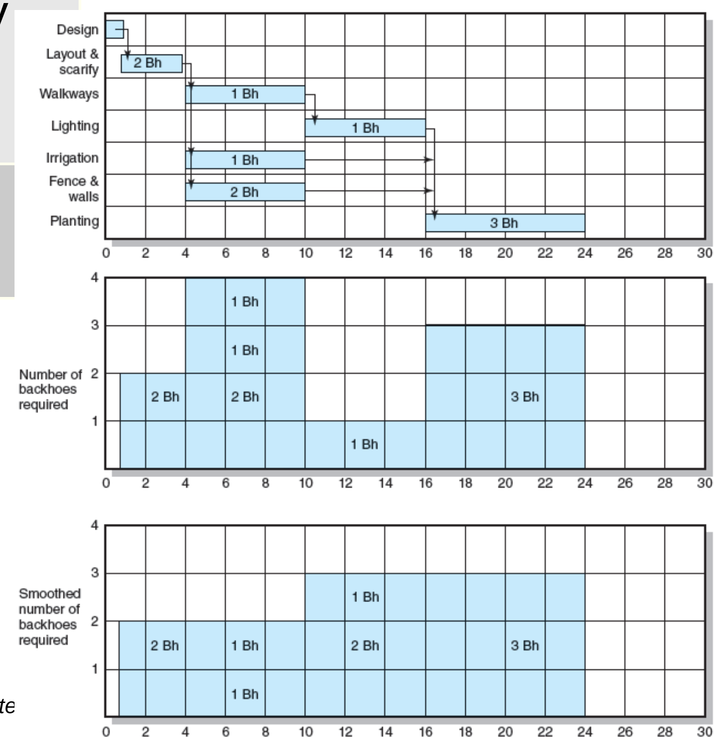
1. Time-Constrained Projects

- Must be completed by an **imposed date**.
- Require use of leveling techniques that focus on balancing or smoothing resource demands.
- Use positive slack (delaying noncritical activities) to manage resource utilization over the duration of the project.

Resource Allocation Methods (cont'd)

1. Time-Constrained Projects

Advantages	Disadvantages
Peak resource demands are reduced	Loss of flexibility that occurs from reducing slack
Resources over the life of the project are reduced	Increases the criticality of all activities
Fluctuation in resource demand is minimised	

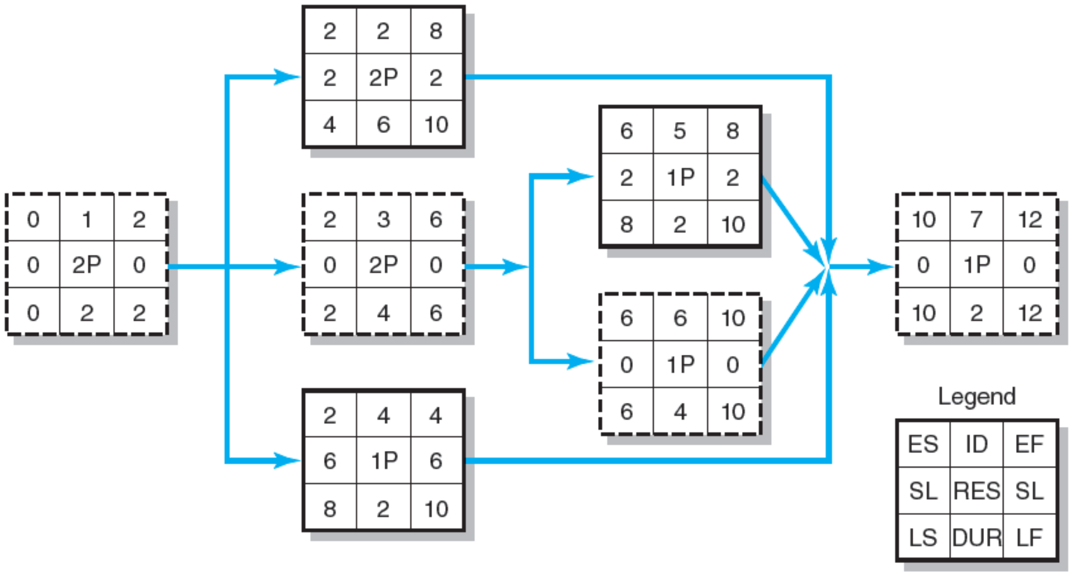


Resource Allocation Methods (cont'd)

2. Resource-Constrained Projects

- Resources are limited in quantity or availability.
- Activities are scheduled using *heuristics* (rules-of-thumb) that focus on:
  1. Minimum slack
  2. Smallest (least) duration
  3. Lowest activity identification number
- The ***parallel method*** is used to apply heuristics
  - An iterative process starting at the first time period of the project and scheduling **period-by-period** the start of any activities using the three priority rules.

Resource-Constrained Schedule



ES resource load chart

ID	RES	DUR	ES	LF	SL	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14
1	2P	2	0	2	0	2	2												
2	2P	6	2	10	2			2	2	2	2	2	2						
3	2P	4	2	6	0			2	2	2	2								
4	1P	2	2	10	6			1	1										
[illegible]	1P	2	6	10	2							1	1						
[illegible]	[illegible]	[illegible]	6	10	0							1	1	1	1				
7	1P	2	10	12	[illegible]											1	1		
Total resource load						2P	2P	5P	5P	4P	4P	4P	4P	1P	1P	1P	1P		

Assume that there are only ever 3 pilots available – we have a problem!!

Resource-Constrained Schedule through Period 2–3

Resource-constrained schedule through period 2–3

ID	RES	DUR	ES	LF	SL	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2P	2	0	2	0	2	2													
2	2P	6	~~2~~ 3	10	~~2~~ 1			X												
3	2P	4	2	6	0			2	2	2	2									
4	1P	2	2	10	6			1	1											
5	1P	2	6	10	2															
6	1P	4	6	10	0															
7	1P	2	10	12	0															
Total resource load						2P	2P	3P	3P	2P	2P									
Resource available						3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P			

FIGURE 8.4 (cont'd)

Resource-Constrained Schedule through Period 5–6

Resource-constrained schedule through period 5–6

ID	RES	DUR	ES	LF	SL	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14
1	2P	2	0	2	0	2	2												
2	2P	6	~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~10~~ ~~11~~ 12	~~2~~ ~~1~~ ~~0~~ ~~-1~~ -2			X	X	X	X								
3	2P	4	2	6	0			2	2	2	2								
4	1P	2	2	10	6			1	1										
5	1P	2	6	10	2														
6	1P	4	6	10	0														
7	1P	2	~~10~~ ~~11~~ 12	~~12~~ ~~13~~ 14	~~0~~ ~~-1~~ -2											X	X		
Total resource load						2P	2P	3P	3P	2P	2P								
Resource available						3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P		

FIGURE 8.5

Resource-Constrained Schedule through Period 5–6

Final resource-constrained schedule

ID	RES	DUR	ES	LF	SL	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2P	2	0	2	0	2	2													
2	2P	6	~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~10~~ ~~11~~ 12	~~2~~ ~~1~~ ~~0~~ ~~-1~~ -2			X	X	X	X	2	2	2	2	2	2			
3	2P	4	2	6	0			2	2	2	2									
4	1P	2	2	6	~~6~~ 2			1	1	SL	SL									
5	1P	2	~~6~~ ~~7~~ ~~8~~ ~~9~~ 10	~~10~~ ~~11~~ 12	~~2~~ ~~1~~ ~~0~~ ~~-1~~ -2							X	X	X	X	1	1			
6	1P	4	6	10	0							1	1	1	1					
7	1P	2	~~10~~ ~~11~~ 12	~~12~~ ~~13~~ 14	~~0~~ ~~-1~~ -2											X	X	1	1	
Total resource load						2P	2P	3P	3P	2P	2P	3P	3P	3P	3P	3P	3P	1P	1P	
Resource available						3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	3P	

FIGURE 8.5 (cont'd)

Resource-Constrained Schedule through Period 5–6

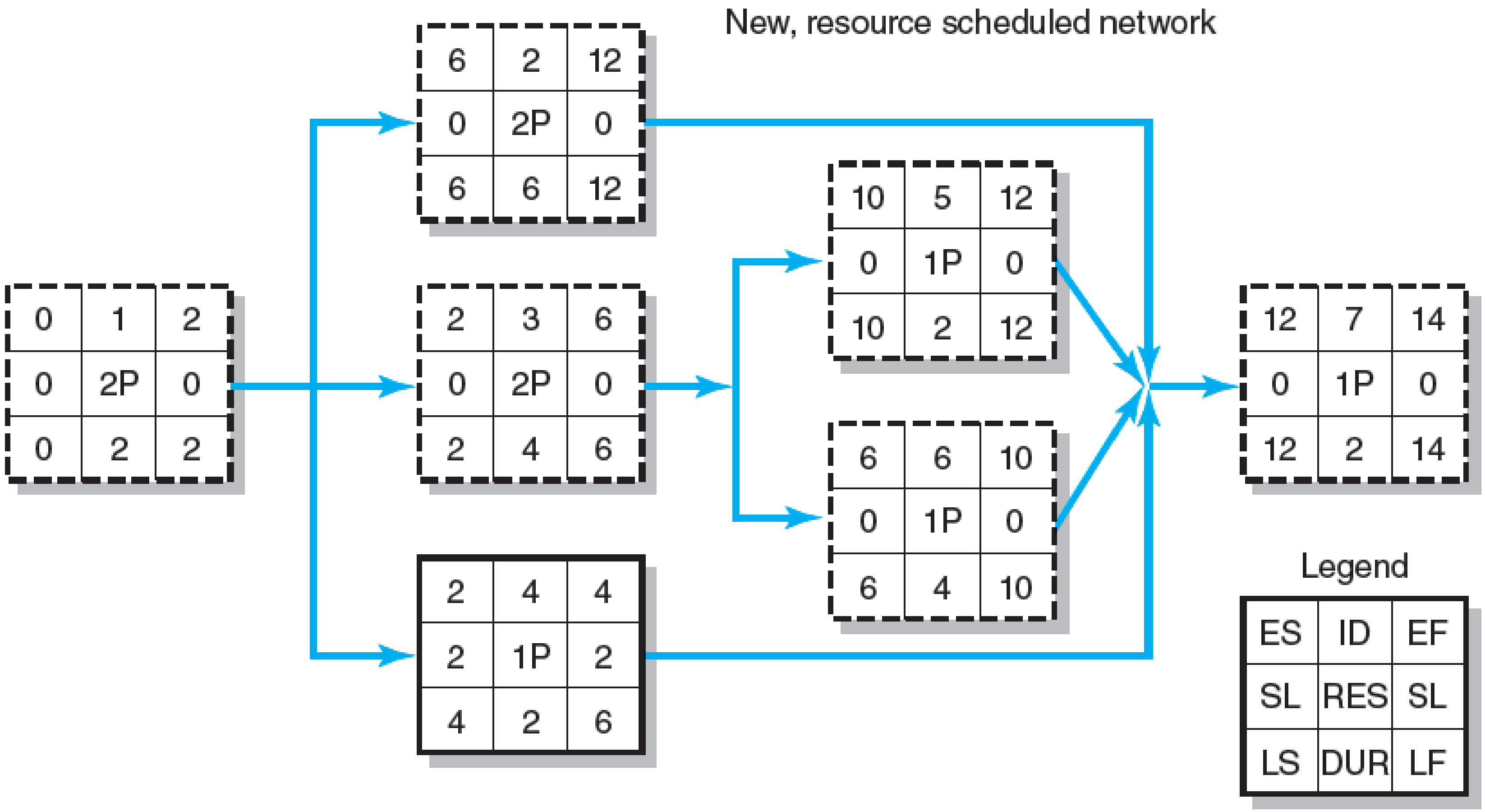


FIGURE 8.5 (cont'd)

The Impacts of Resource-Constrained Scheduling

- Reduces slack; reduces flexibility
  - By using slack to ensure delay is minimised
- Increases criticality of events
- Increases scheduling complexity
  - Because resource constraints are added to technical constraints
- May make the traditional critical path no longer meaningful
- Can break sequence of events
- May cause parallel activities to become sequential
- Activities with slack may become critical

Splitting Activities

- Splitting
  - A scheduling technique for creating a better project schedule and/or increase resource utilisation
    - Involves interrupting work on an activity to employ the resource on another activity, then returning the resource to finish the interrupted work.
    - Is feasible when startup and shutdown costs are low.
    - Dealing with resource shortages by splitting is a major reason why projects fail to meet schedule – Planners should avoid the use of splitting as much as possible.

Splitting Activities

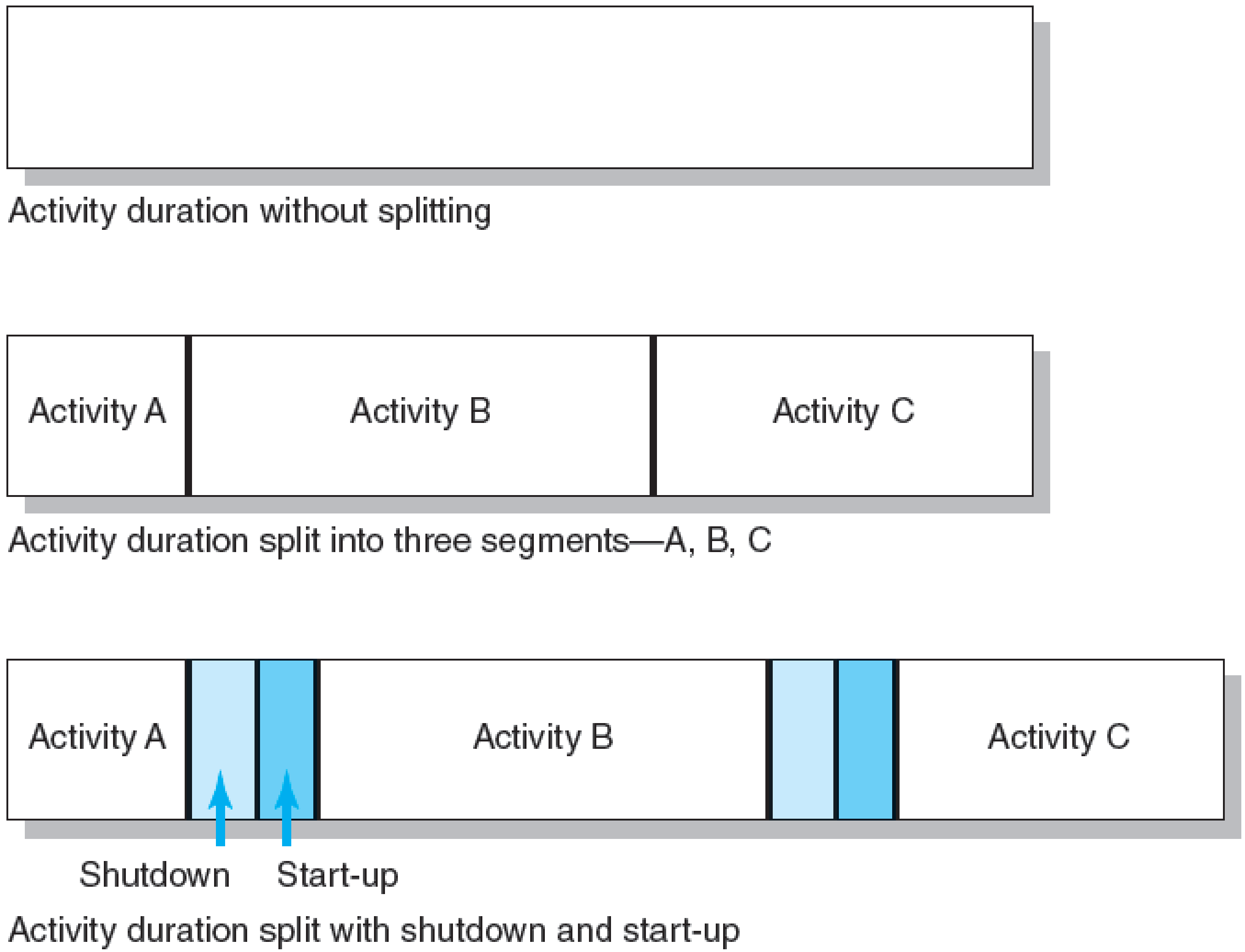


FIGURE 8.11

Assigning Project Work

- Reasons why we should not always assign the best people the most difficult tasks
  - Best people: resent to the fact that they are always given the toughest assignments
  - Less experienced participants: resent to the fact that they are never given the opportunity to expand their skill/knowledge base
- Factors to be considered in deciding who should work together
  - Minimize unnecessary tension; complement each other
  - Experience: veterans team up with new hires

Multiproject Resource Schedules

- Multiproject Scheduling Problems

  1. Overall project slippage
     - Delay on one project create delays for other projects.
  2. Inefficient resource application
     - The peaks and valleys of resource demands create scheduling problems and delays for projects.
  3. Resource bottlenecks
     - Shortages of critical resources required for multiple projects cause delays and schedule extensions.

Multiproject Resource Schedules (cont'd)

- Managing Multiproject Scheduling:
  - Create project offices or departments to oversee the scheduling of resources across projects
  - Use a project priority queuing system: first come, first served for resources
  - Centralize project management: treat all projects as a part of a "megaproject"
  - Outsource projects to reduce the number of projects handled internally

Using the Resource Schedule to Develop a Project Cost Baseline

Why do we need a Time-Phased Budget Baseline?

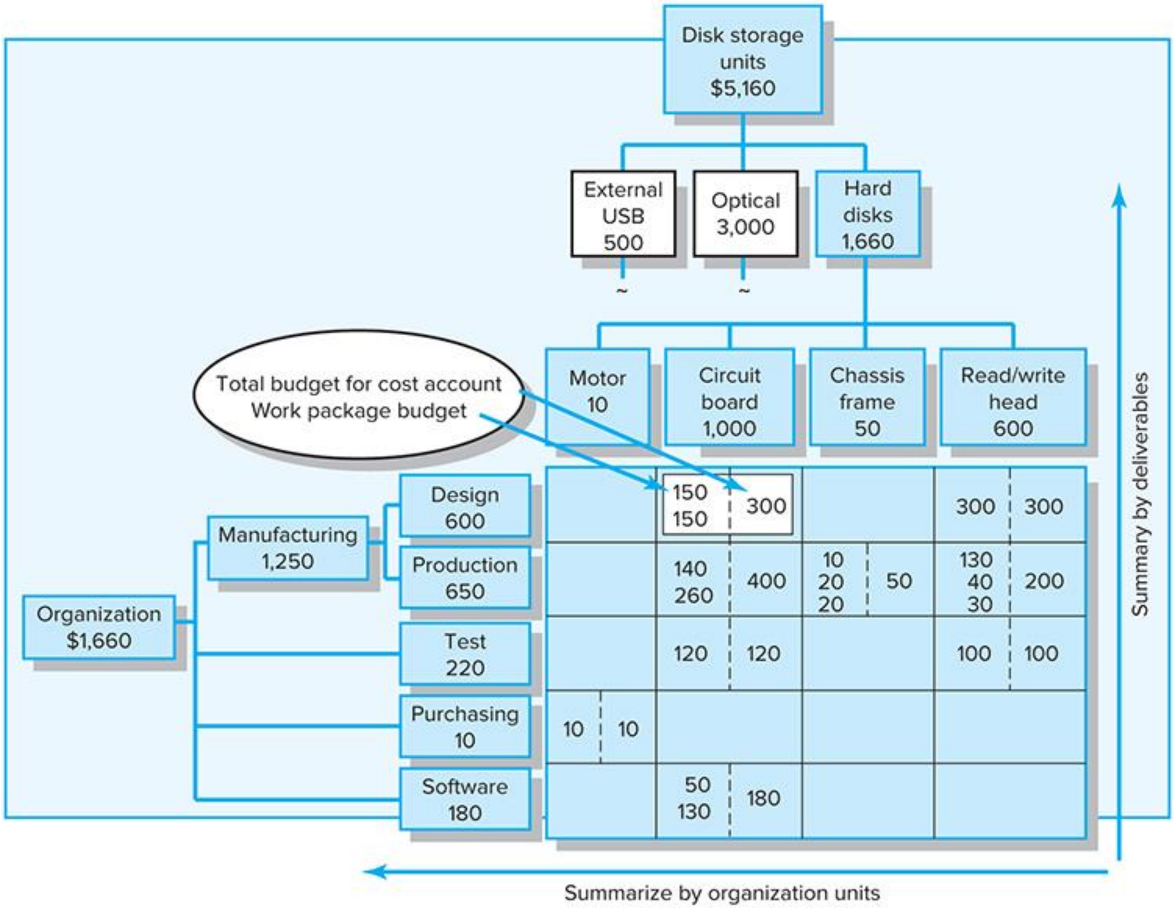
- Scenario: A new product is to be completed in 10 weeks at an estimated cost of $400,000 per week (Total: $4 Million).
- Management needs a status report at the end of 5 weeks, in which you can present the following information:
  - Planned costs for the first 5 weeks are $2,000,000
  - Actual costs for the first 5 weeks are $2,400,000
- Assume another 5 weeks have passed:
  - Planned costs for the fi weeks are $1,700,000

Why do we need a Time-Phased Budget Baseline?

- Scenario: A new product is to be completed in 10 weeks at an estimated cost of $400,000 per week (Total: $4 Million).
- Management needs a status report at the end of 5 weeks, in which you can present the following information:
  - Planned costs for the first 5 weeks are $2,000,000
  - Actual costs for the first 5 weeks are $2,400,000
- Assume another 5 weeks have passed:
  - Planned costs for the first 5 weeks are $2,000,000
  - Actual costs for the first 5 weeks are $1,700,000

Creating a Time-Phased Budget Baseline

- Using information in your Work Breakdown Structure and resource schedule, you can create a time-phased cost baseline



Creating a Time-Phased Budget Baseline

- A work package is the lowest level of the WBS.
  - It is output-oriented in that it:
    1. Defines work (what).
    2. Identifies time to complete a work package (how long).
    3. Identifies a time-phased budget to complete a work package (cost).
    4. Identifies resources needed to complete a work package (how much).
    5. Identifies a person responsible for units of work (who).
    6. Identifies monitoring points for measuring success (how well).

Creating a Time-Phased Budget Baseline

- A work package is the lowest level of the WBS.
  - It is output-oriented in that it:

1. Defines work (what).
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3. Identifies a time-phased budget to complete a work package (cost).
4. Identifies resources needed to complete a work package (how much).
5. Identifies a person responsible for units of work (who).
6. Identifies monitoring points for measuring success (how well).

Creating a Time-Phased Budget Baseline

Time-Phased Work Package Budget
Labor cost only

Work Package Description *Test*

Page *1* of *1*

Work Package ID ***1.1.3.2.3***

Project *PC Prototype*

Deliverable *Circuit board*

Date *3/24/xx*

Responsible organization unit *Test*

Estimator *CEG*

Work Package Duration *3* weeks

Total labor cost *$120,000*

Time-Phased Labor Budget ($000)

Work Package	Resource	Labor rate	Work Periods--Weeks					
			1	2	3	4	5	Total
Code ***1.1.3.2.3***	Quality testers	$xxxx/ week	$40	$30	$50			$120

Creating a Time-Phased Budget Baseline

Time-Phased Work Package Budget
Labor cost only

Work Package Description *Software*

Page *1* of *1*

Work Package ID ***1.1.3.2.4.1 and 1.1.3.2.4.2***

Project *PC Prototype*

Deliverable *Circuit board*

Date *3/24/xx*

Responsible organization unit *Software*

Estimator *LGG*

Work Package Duration *4* weeks

Total labor cost *$180,000*

Time-Phased Labor Budget ($000)

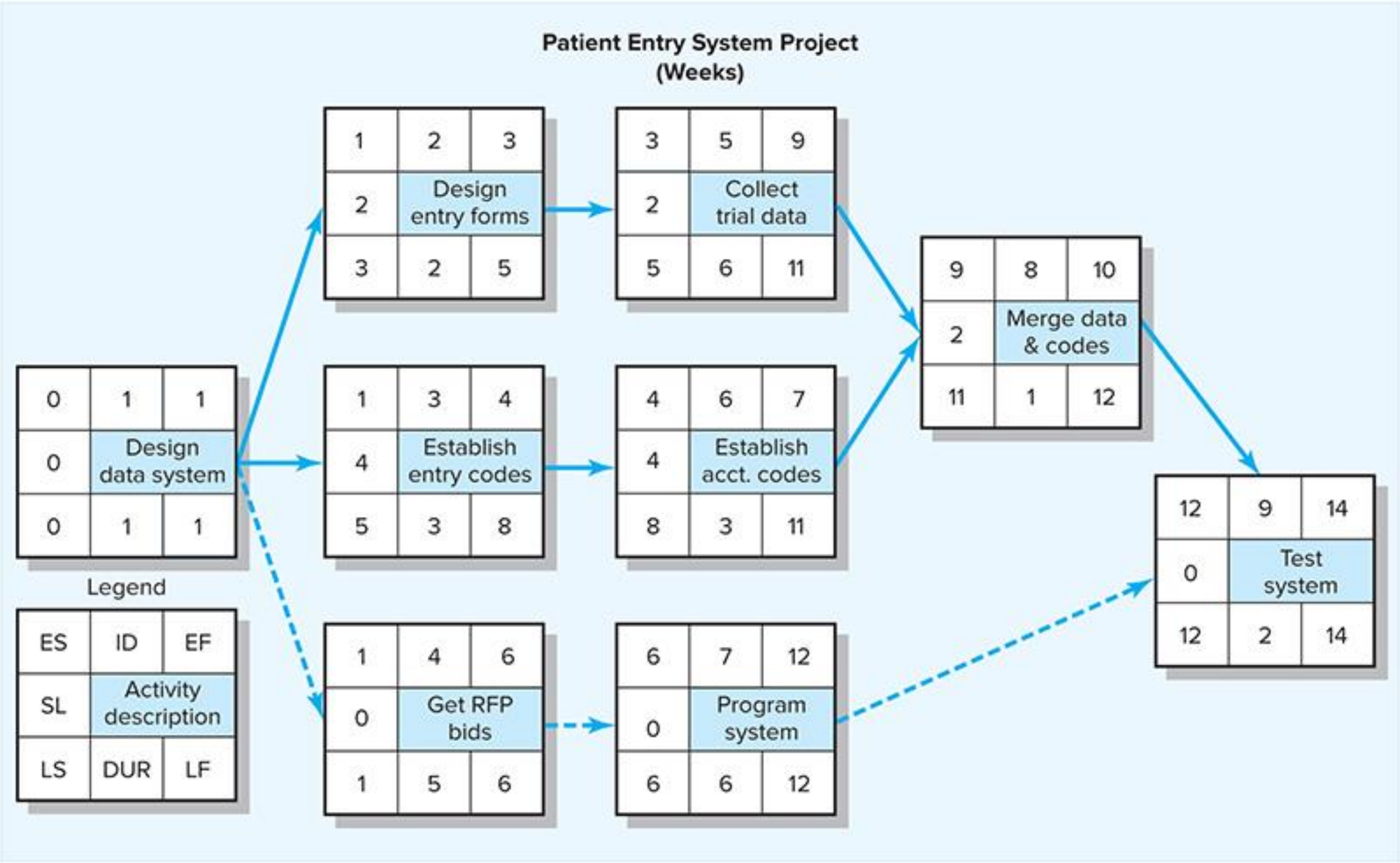
Work Package	Resource	Labor rate	Work Periods--Weeks					
			1	2	3	4	5	Total
Code ***1.1.3.2.4.1***	Program'rs	$2,000/ week	$20	$15	$15			$50
Integration ***1.1.3.2.4.2***	System/ program'rs	$2,500/ week			$60	$70		$130
Total			$20	$15	$75	$70		$180

Creating a Time-Phased Budget Baseline

- These time-phased budgets for work packages are taken from your Work Breakdown Structure (WBS) and are placed in your project schedule as they are expected to occur over the life cycle of your project

- The outcome of these budget allocations is the project *cost* baseline (**planned value, PV**) which is used to determine cost and schedule variances as the project is implemented

Creating a Time-Phased Budget Baseline

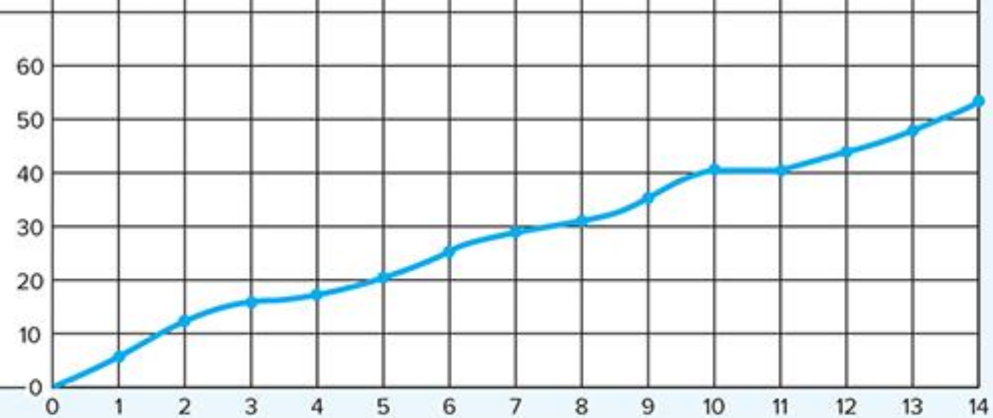


Creating a Time-Phased Budget Baseline

($000) Week

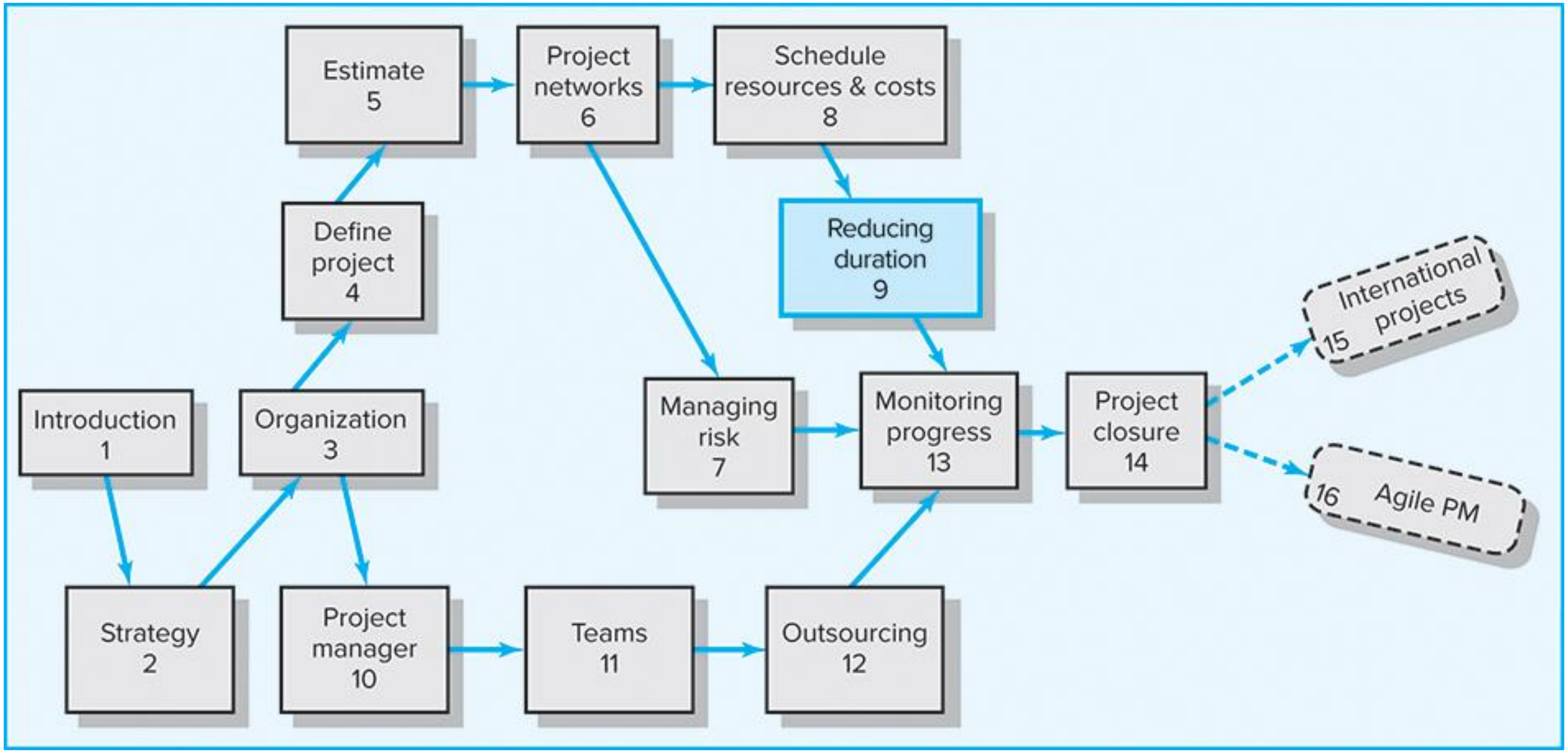
ID	Dur.	Task	Budget	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	Design data system	5	5													
2	2	Design entry forms	4		2	2											
3	3	Establish entry codes	6		2	2	2										
4	5	Get RFP bids	3		2				1								
5	6	Collect trial data	6				1	1	1	1	1	1					
6	3	Establish account codes	5					2	2	1							
7	6	Program system	12							2		4	2		4		
8	1	Merge data & codes	4										4				
9	2	Test system	7													4	3
		Week total	52	5	6	4	3	3	4	4	1	5	6	0	4	4	3
		Cumulative		5	11	15	18	21	25	29	30	35	41	41	45	49	52

Cumulative Baseline Budget (PV)



Chapter Nine (10 mins break)

Reducing Project Duration



Learning Objectives

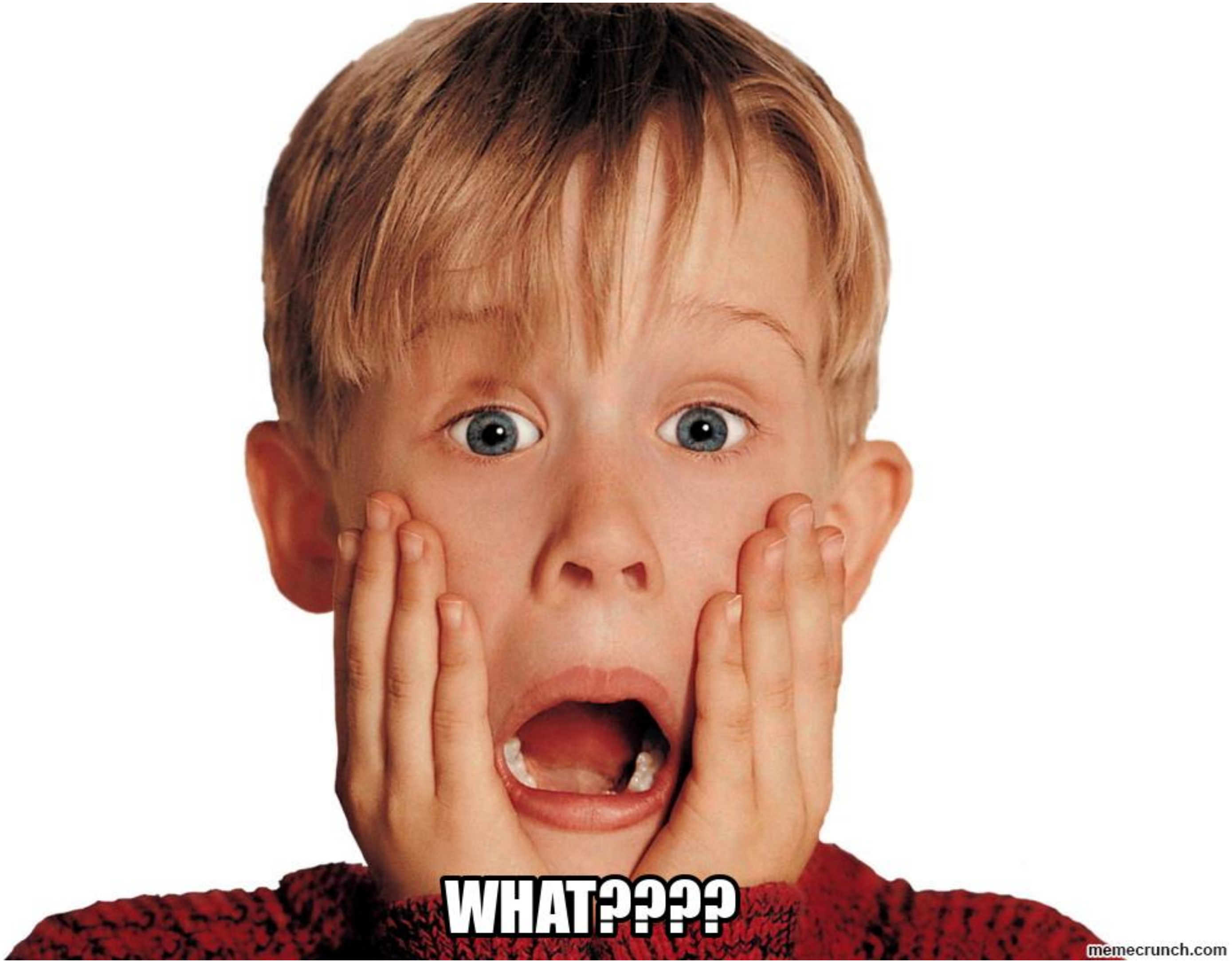
1. Understand the different reasons for crashing a project
2. Identify the different options for crashing an activity when resources are not constrained
3. Identify the different options for crashing an activity when resources are constrained
4. Determine the optimum cost-time point in a project network
5. Understand the risks associated with compressing or crashing a project
6. Identify different options for reducing the costs of a project

Imagine This

- After finalising your project schedule, you realise the estimated completion date is 2 months beyond what your company promised to the customers.

- 4 months into the project, senior management says they need to take back all allocated funds and ask you to finish the project ASAP.

Reducing duration



Rationale for Reducing Project Duration

- Time Is Money: Cost-Time Tradeoffs
  - **Reducing the time** of a critical activity usually incurs additional direct costs.
    - Cost-time solutions focus on reducing (crashing) activities on the critical path to **shorten overall duration** of the project.
  - Reasons for imposed project duration dates:
    - Time-to-market pressures: six months delay / 35% loss
    - Unforeseen delays: adverse weather, design flaws
    - Incentive contracts: bonuses for early completion
    - Very high overhead costs: $80,000 per day
    - Pressure to move resources to other projects

Options for Accelerating Project Completion

When resources are not constrained	**When resources are constrained**
Adding resources	Fast-tracking Rearrange the logic of the project, finish-to-start to start-to-start
Outsourcing project work Contract for a backhoe, a consulting firm	Reducing project scope
Scheduling overtime Works 50 hours a week instead of 40, it might accomplish 20%	Compromise quality
Establishing a core project team Assigning professionals full time to a project	Reduce duration
Do it twice—fast and then correctly Rose Garden stadium: set up temporary bleachers	Critical chain project management (CCPM) Emphasize the resource

Explanation of Project Costs

- Project Indirect Costs
  - Costs that cannot be associated with any particular work package or project activity
    - Supervision, administration, consultants, and interest
  - Costs that vary (increase) with time
    - **Reducing project time directly reduces indirect costs**
- Project Direct Costs
  - Normal costs that can be assigned directly to a specific work package or project activity
    - Labor, materials, equipment, and subcontractors
  - **Crashing activities increases direct costs.**

Reducing Project Duration to Reduce Project Cost

Identifying direct costs to reduce project time

- Gather information about direct and indirect costs of specific project durations
- Search critical activities for lowest direct-cost activities to shorten project duration
- Compute total costs for specific durations and compare to benefits of reducing project time

Project Cost–Duration Graph

Total costs = direct costs + indirect costs
Reducing project time directly <u>reduces</u> indirect costs
Crashing activities <u>increases</u> direct costs.

Figure 9.1 PROJECT COST–DURATION GRAPH

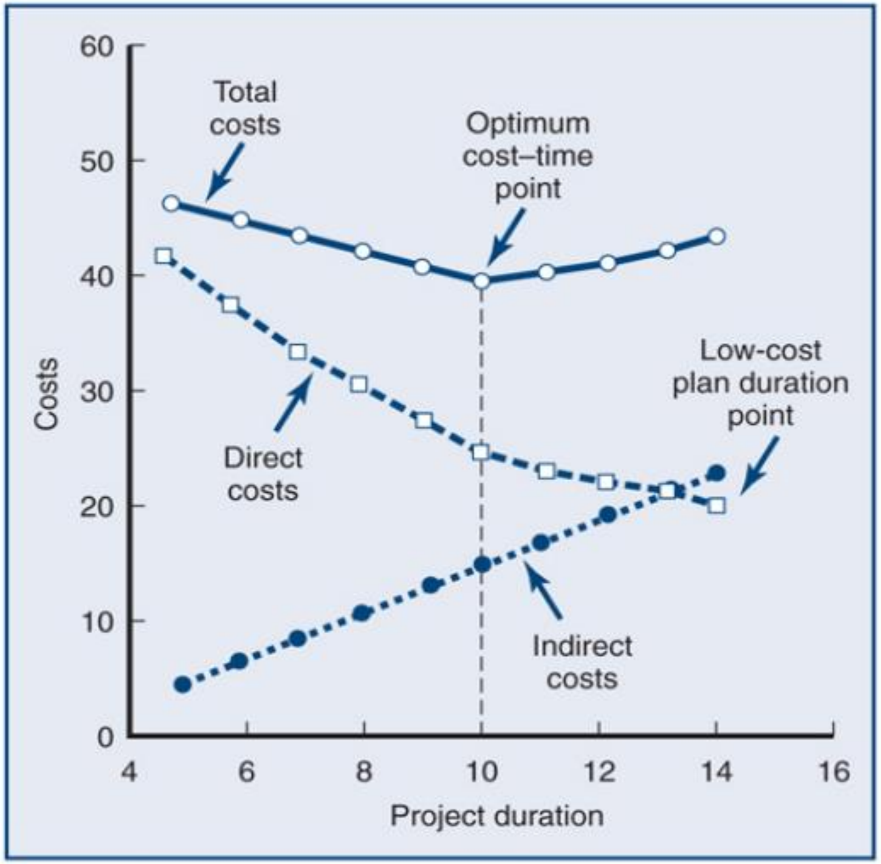


FIGURE 9.1

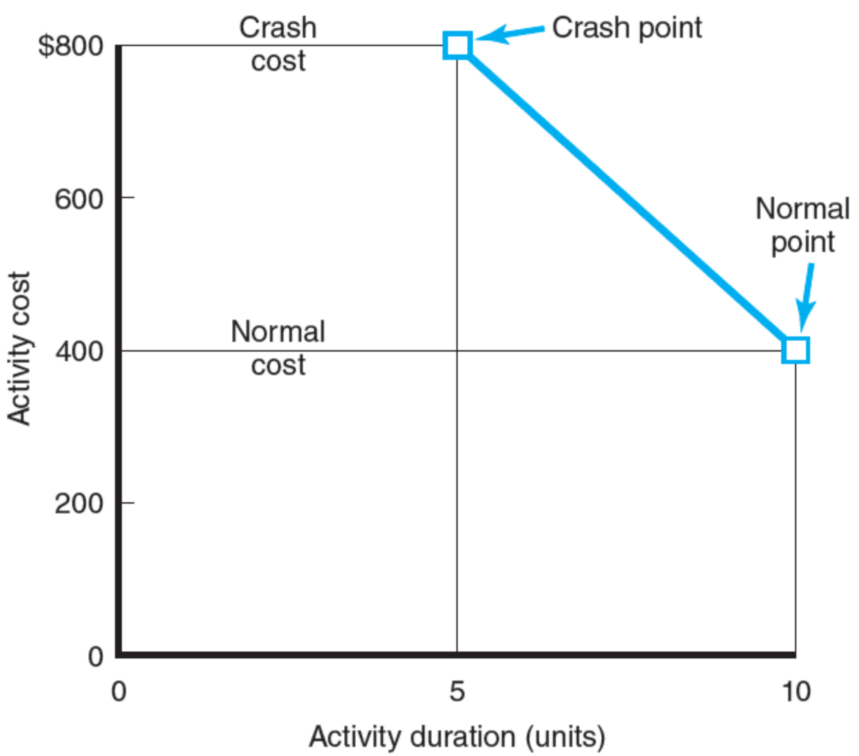
Constructing a Project Cost–Duration Graph

- Three major steps
  - Find total **direct costs** for selected project durations
  - Find total **indirect costs** for selected project durations
  - **Sum** direct and indirect costs for these selected project durations
- The graph is then used to compare additional cost alternatives for benefits

Constructing a Project Cost–Duration Graph

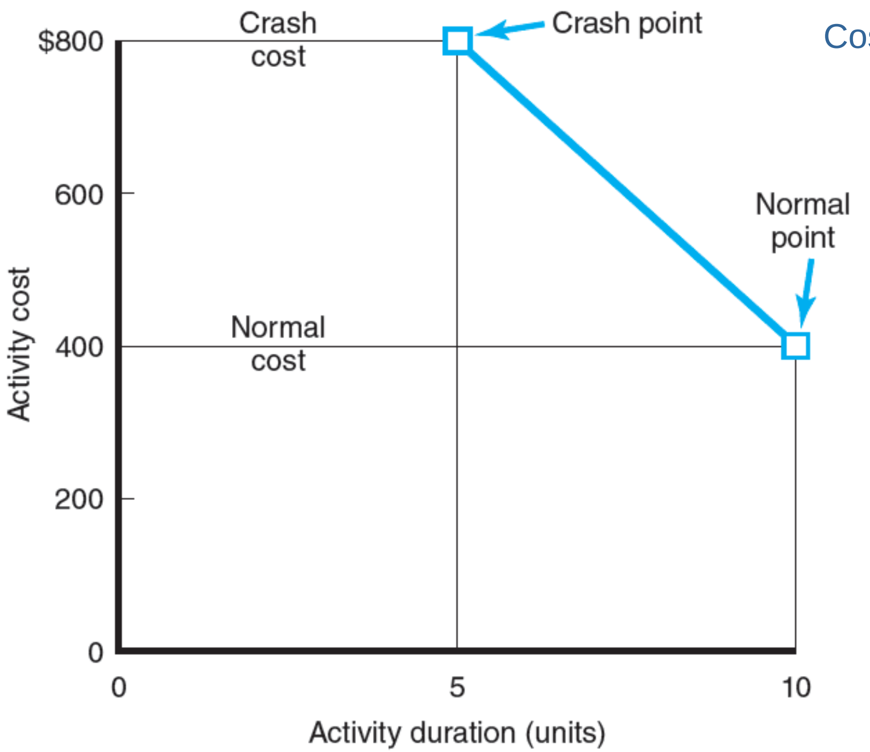
- How do we determining the activities to shorten?
  - Shorten the activities with the *smallest increase in cost per unit of time*
  - How do we compute *cost per unit of time* of an activity???
    - Crashing: shortening an activity
    - Crash time: the shortest time in which an activity can be completed
    - The cost-time relationship is linear.
    - Normal time assumes low-cost, efficient methods to complete the activity.
    - Crash time represents a limit—the greatest time reduction possible under realistic conditions.
    - Slope represents a constant cost per unit of time.
    - All accelerations must occur within the normal and crash times.

Constructing a Project Cost–Duration Graph



- How do we determining the activities to shorten?
  - Shorten the activities with the *smallest increase in cost per unit of time*
  - How do we compute *cost per unit of time* of an activity???
    - **Crashing**: shortening an activity
    - **Crash time**: the shortest time in which an activity can be completed
    - **Crash point**: the maximum time an activity can be compressed

Constructing a Project Cost–Duration Graph



- It is important to compute the Cost Slope

$$\text{Cost Slope} = \frac{(\text{Crash Cost} - \text{Normal Cost})}{(\text{Normal time} - \text{Crash Time})} = \frac{\$800 - \$400}{10 - 5}$$

$$= \$80 \text{ per unit of time}$$

  - The steeper the slope the greater the cost to shorten an activity – this helps managers decide which activities to shorten and how far to carry the shortening period.
  - For this example the cost per unit of time to shorten the activity is $400/5 = $80 per unit of time
  - This technique allows manager to compare which critical activities to shorten

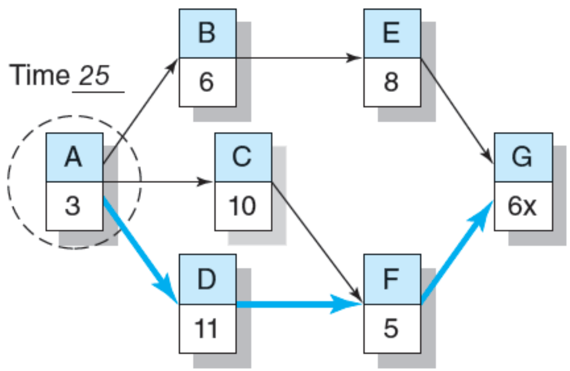
Cost–Duration Trade-off Example

Activity ID	Slope	Maximum crash time	Direct costs			
			Normal		Crash	
			Time	Cost	Time	Cost
A	*$20*	*1*	3	$50	2	$70
B	*40*	*2*	6	80	4	160
C	*30*	*1*	10	60	9	90
D	*25*	*4*	11	50	7	150
E	*30*	*2*	8	100	6	160
F	*30*	*1*	5	40	4	70
G	*0*	*0*	6	70	6	70

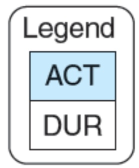
FIGURE 9.3

Cost–Duration Trade-off Example (cont'd)

Total direct cost $450

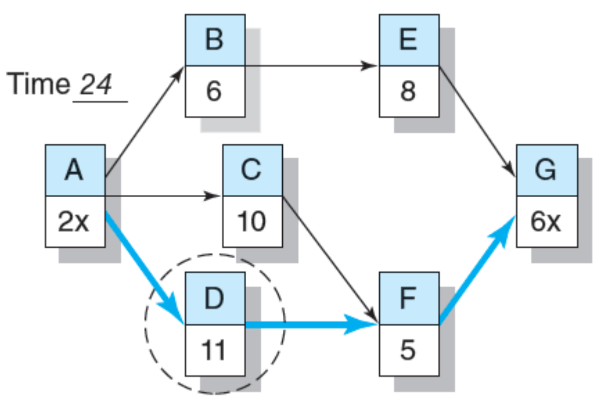


(A)



Initial total direct cost $ 450

Activity ID	Slope	Maximum crash time	Direct costs			
			Normal		Crash	
			Time	Cost	Time	Cost
A	*$20*	*1*	3	$50	2	$70
B	*40*	*2*	6	80	4	160
C	*30*	*1*	10	60	9	90
D	*25*	*4*	11	50	7	150
E	*30*	*2*	8	100	6	160
F	*30*	*1*	5	40	4	70
G	*0*	*0*	6	70	6	70



(B)

Total direct cost $ 470

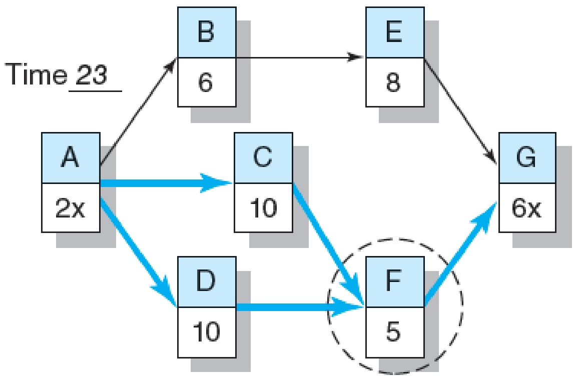
Activities changed

A ____ ____

$20

FIGURE 9.3 (cont'd)

Cost–Duration Trade-off Example (cont'd)

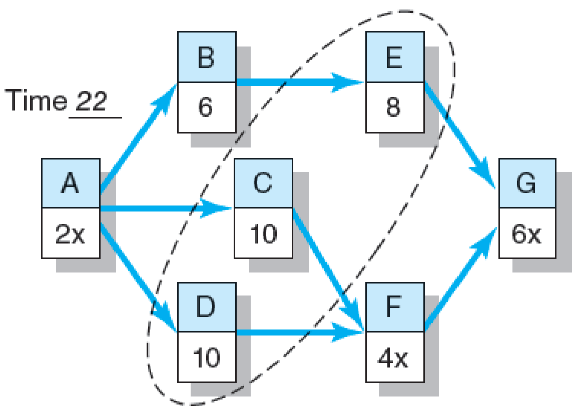


(A)

Total direct cost $ 495

Activities changed

D
$25



(B)

Total direct cost $ 525

Activities changed

F
$30

Activity ID	Slope	Maximum crash time	Direct costs			
			Normal		Crash	
			Time	Cost	Time	Cost
A	$20	1	3	$50	2	$70
B	40	2	6	80	4	160
C	30	1	10	60	9	90
D	25	4	11	50	7	150
E	30	2	8	100	6	160
F	30	1	5	40	4	70
G	0	0	6	70	6	70

FIGURE 9.4

Cost–Duration Trade-off Example (cont'd)

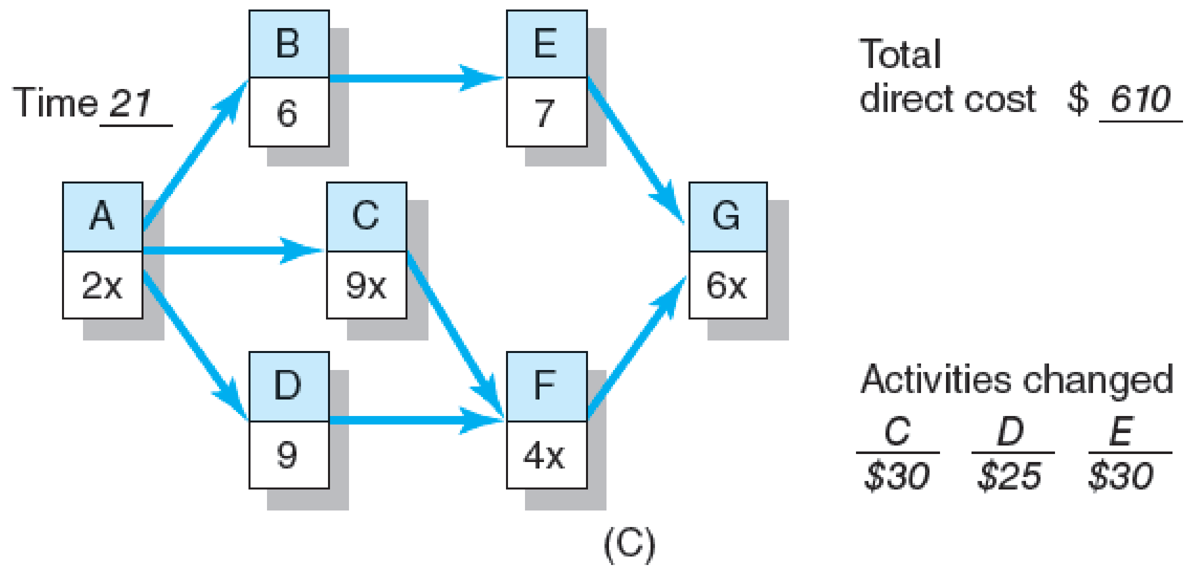


FIGURE 9.4 (cont'd)

Summary Costs by Duration

Project duration	Direct costs	+	Indirect costs	=	Total costs
25	*450*		400		*$850*
24	*470*		350		*820*
23	*495*		300		*795*
22	*525*		250		*775*
21	*610*		200		*810*

FIGURE 9.5

Project Cost–Duration Graph

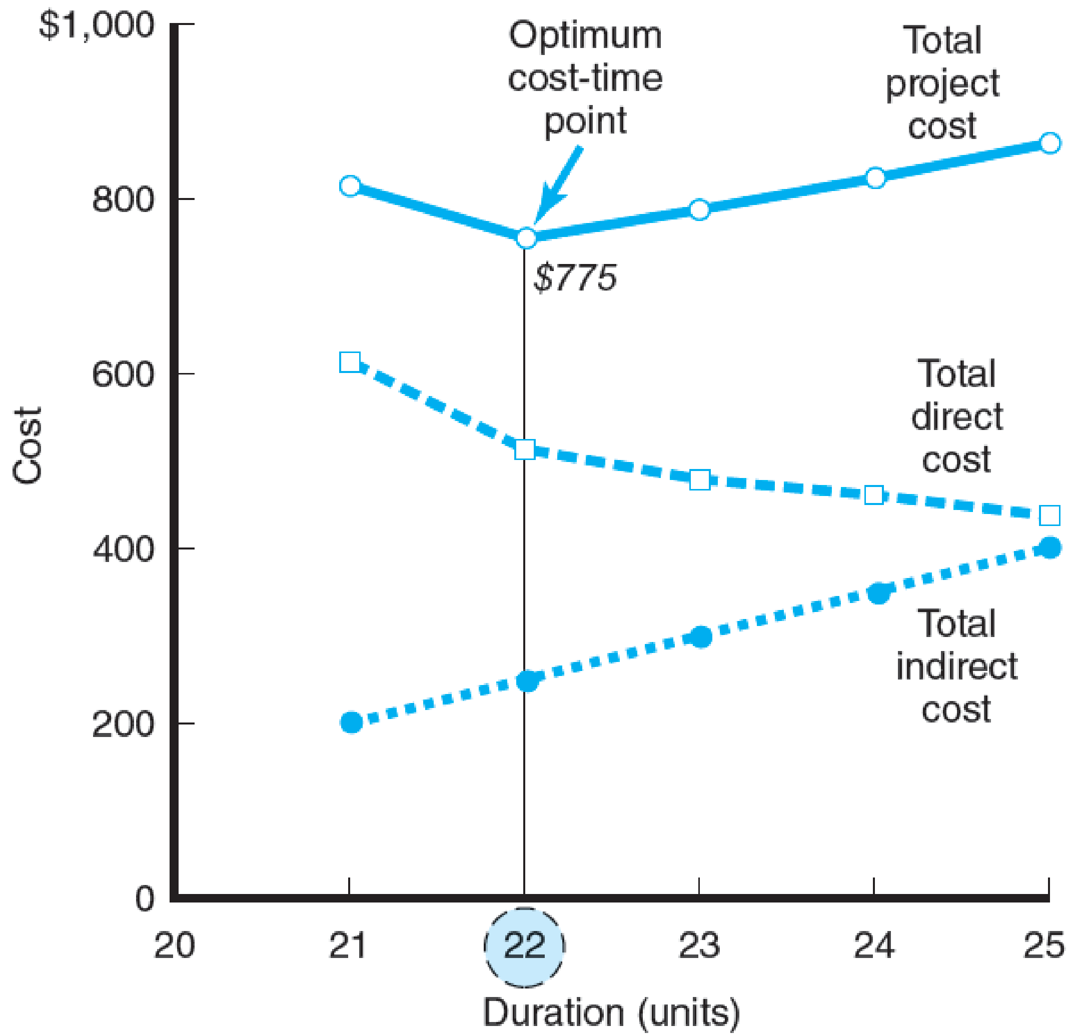


FIGURE 9.6

What if Cost, Not Time Is the Issue?

- Commonly Used Options for Cutting Costs
  - Reducing project scope
  - Having owner take on more responsibility
  - Outsourcing project activities or even the entire project
  - Brainstorming cost savings options

Next week

- Quiz 3
- Skim Chapter 10 and 11
  - Chapter 10 Leadership
  - Chapter 11 Managing Teams