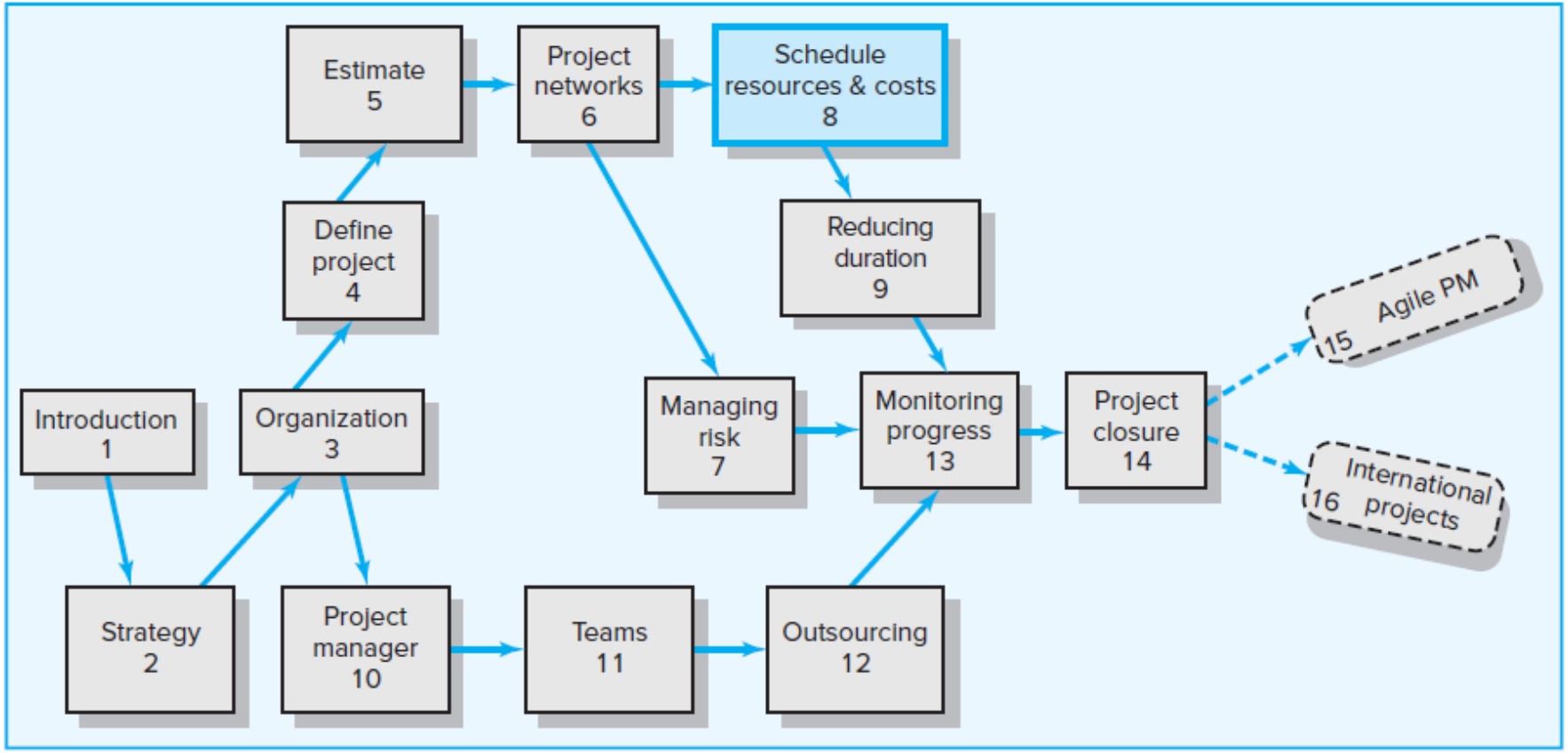
OntarioTech
Engineering
& Applied Science

Project Management for Engineers - ENGR 5410G
Fall 2024

Unit 5:
Resources & Reducing Duration (ch 8 & 9)

Where We Are Now



Learning Objectives

08-01 Understand the differences between time-constrained and resource-constrained schedules.
08-02 Identify different types of resource constraints.
08-03 Describe how the smoothing approach is used on time-constrained projects.
08-04 Describe how the leveling approach is used for resource-constrained projects.
08-05 Understand how project management software creates resource-constrained schedules.
08-06 Understand when and why splitting tasks should be avoided.
08-07 Identify general guidelines for assigning people to specific tasks.
08-08 Identify common problems with multiproject resource scheduling.
08-09 Explain why a time-phased budget baseline is needed.
08-10 Create a time-phased project budget baseline.

Chapter Outline

8.1 Overview of the Resource Scheduling Problem

8.2 Types of Resource Constraints

8.3 Classification of a Scheduling Problem

8.4 Resource Allocation Methods

8.5 Computer Demonstration of Resource-Constrained Scheduling

8.6 Splitting Activities

8.7 Benefits of Scheduling Resources

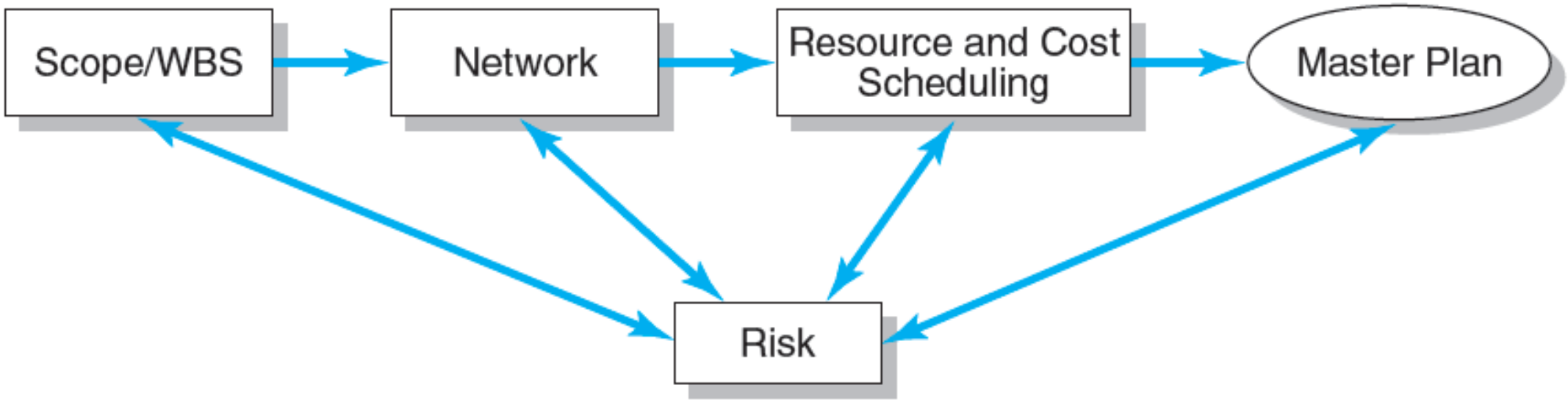
8.8 Assigning Project Work

8.9 Multiproject Resource Schedules

8.10 Using the Resource Schedule to Develop a Project Cost Baseline

Project Planning Process

- **FIGURE 8.1**



8.1 Overview of the Resource Scheduling Problem

- **Resources and Priorities**

- Project network times are not a schedule until resources have been assigned.
  - There are always more project proposals than there are available resources.
  - The project priority team will add a new project only if resources are available.
- Cost estimates are not a budget until they have been time-phased.
  - Once resource assignments have been finalized, you are able to develop a baseline budget schedule for the project.

The Resource Scheduling Problem

- **Resource Smoothing**

- Involves attempting to even out varying demands on resources by delaying non-critical activities (using slack) to lower peak resource demand and, thus, increase resource utilization when resources are adequate over the life of the project.

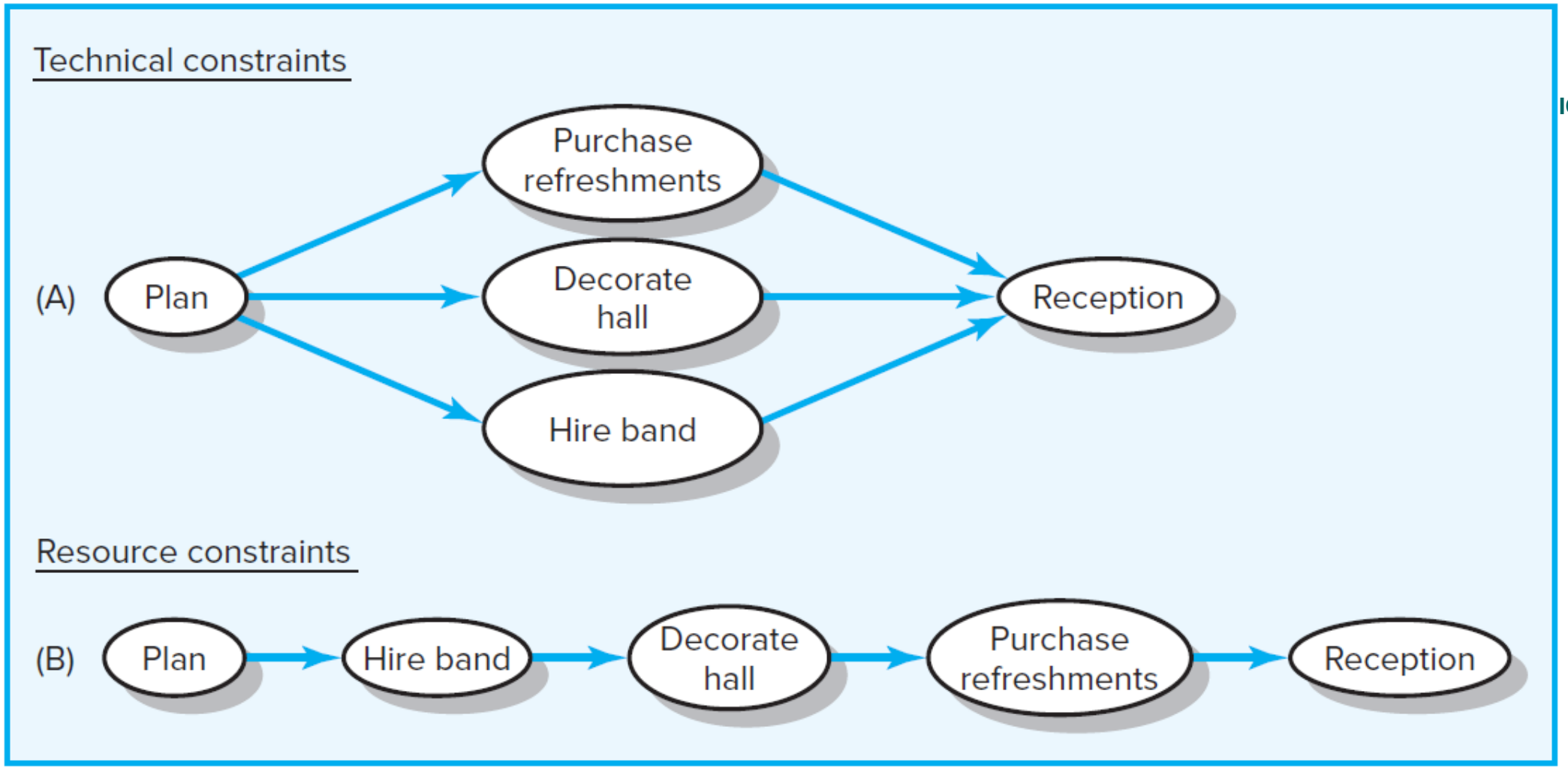
- **Resource-Constrained Scheduling**

- Occurs when resources are not adequate to meet peak demands. The late start of some activities must be delayed, and the duration of the project may be increased.

Types of Project Constraints

- **Technical or Logical Constraints**
  - Are related to the networked sequence in which project activities must occur.
- **Resource Constraints**
  - Occur when the absence, shortage, or unique interrelationship and interaction characteristics of resources require a particular sequencing of project activities.
  - Note that the resource dependency takes priority over the technological dependency but does not violate the technological dependency.
- **Types of Resources Constraints**
  - People
  - Materials
  - Equipment

Constraint Examples



IGURE 8.2

8.3 Classification of a Scheduling Problem

- **Time-Constrained Project**
  - Must be completed by an imposed date.
  - Time (project duration) is fixed and resources are flexible. If required, resources can be added to ensure the project is completed by a specific date.
- **Resource-Constrained Project**
  - Assumes the level of resources available cannot be exceeded.
  - Resources are fixed and time is flexible. If the resources are inadequate, it will be acceptable to delay the project.

- Consult a project priority matrix to determine if the project is time- or resource- constrained.

8.4 Resource Allocation Methods

- **Limiting Assumptions**
  - Splitting activities will not be allowed.
    - **Splitting** refers to interrupting work on one task and assigning the resources to work on a different task for a period of time, then reassigning them to work on the original task.
  - Level of resources used for an activity cannot be changed.
- **Risk Assumptions**
  - Activities with the most slack pose the least risk.
  - Reduction of flexibility does not increase risk.
  - The nature of an activity (easy, complex) doesn't increase risk.

Time-Constrained Projects

- Must be completed by an imposed date.
- Focus on resource utilization.
- Require use of resource smoothing techniques that balance demand for a resource.

• **Leveling (Smoothing) Techniques**

- Delay noncritical activities by using positive slack to reduce peak demand and fill in the valleys for the resources without delaying the entire project.

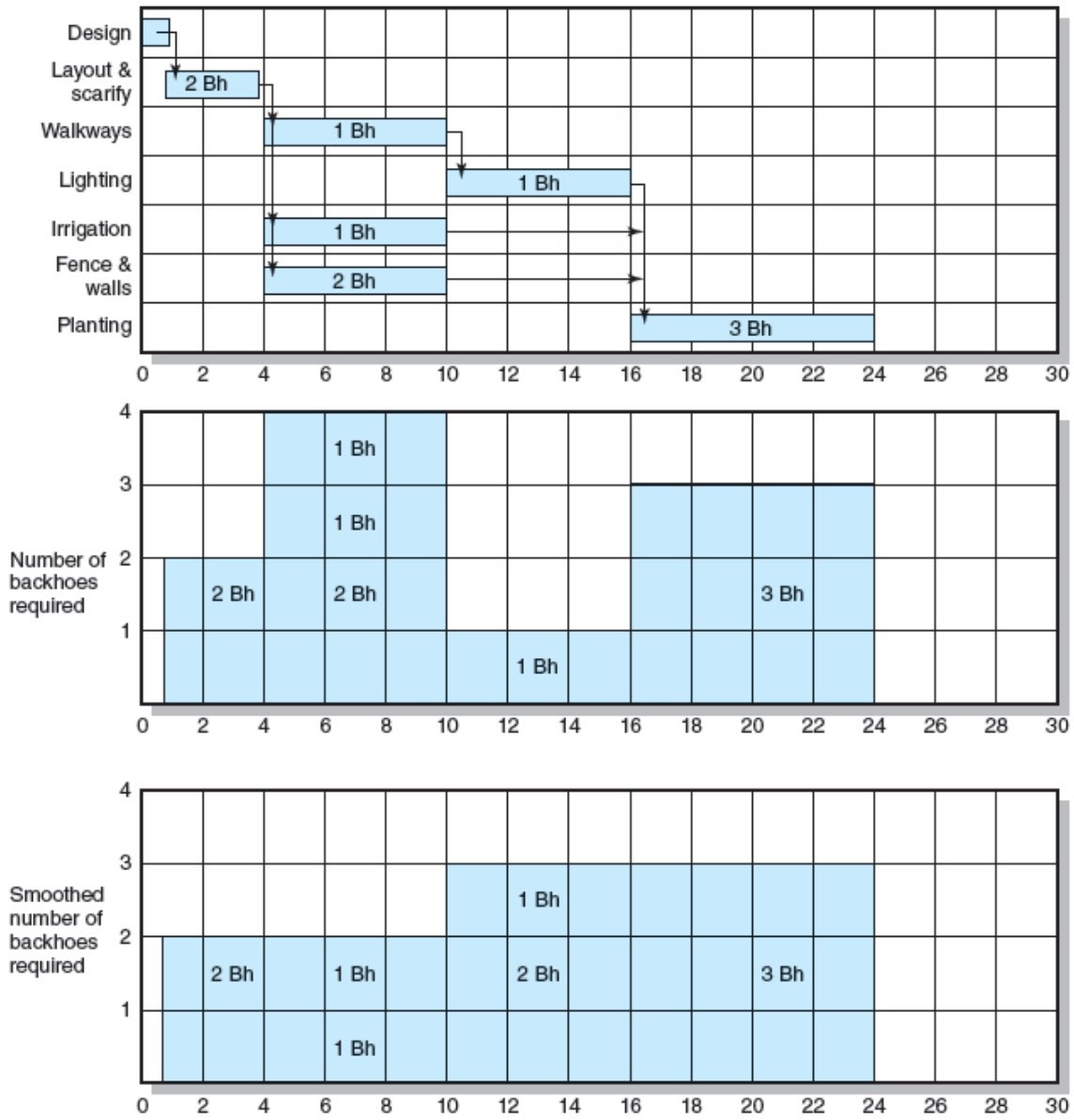
• **Goals of Smoothing Resource Demand**

- Reduce the peak of demand for the resource
- Reduce the number of resources over the life of the project
- Minimize the fluctuation in resource demand

• **Downside of Smoothing Resource Demand**

- Loss of flexibility that occurs from reducing slack
- Creates more critical activities and/or near-critical activities because of slack reduction

Botanical Garden

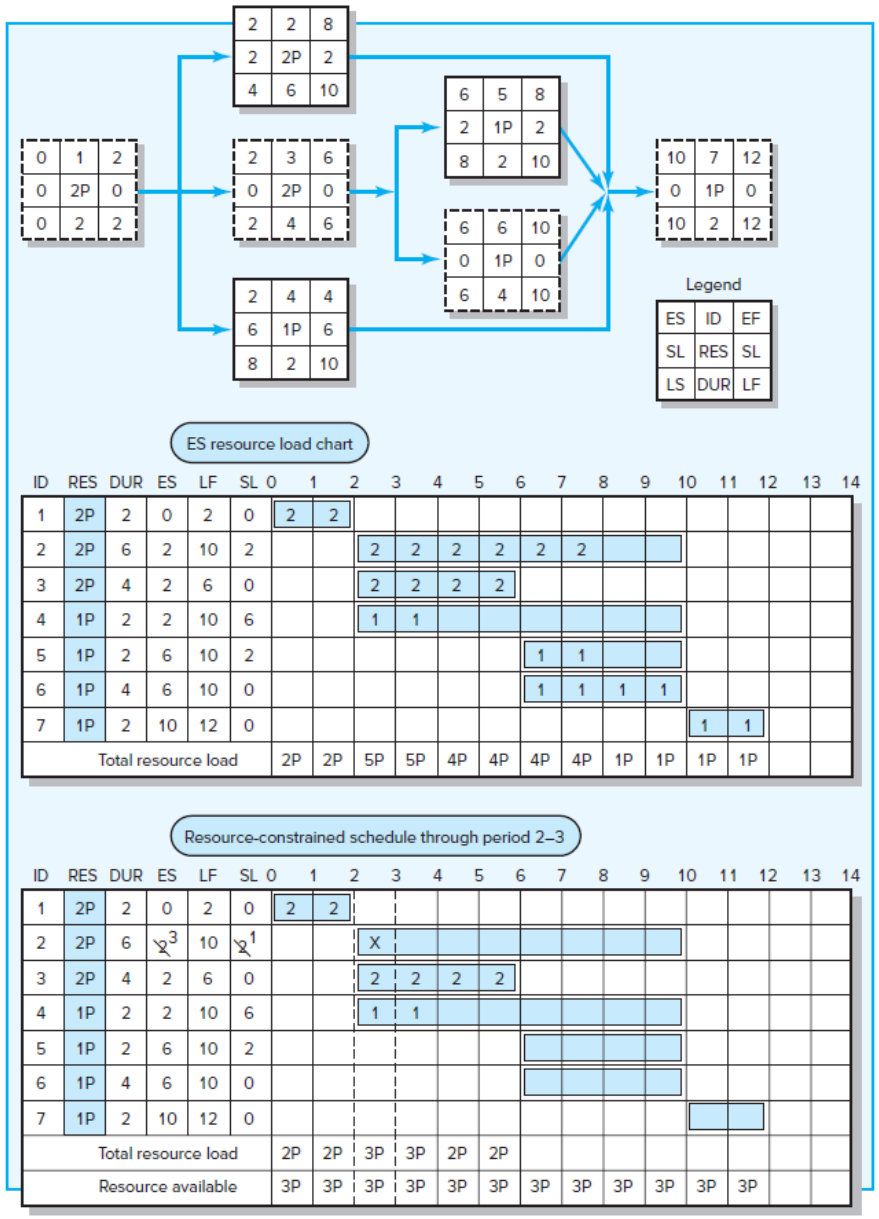


- **FIGURE 8.3**

Resource-Constrained Projects

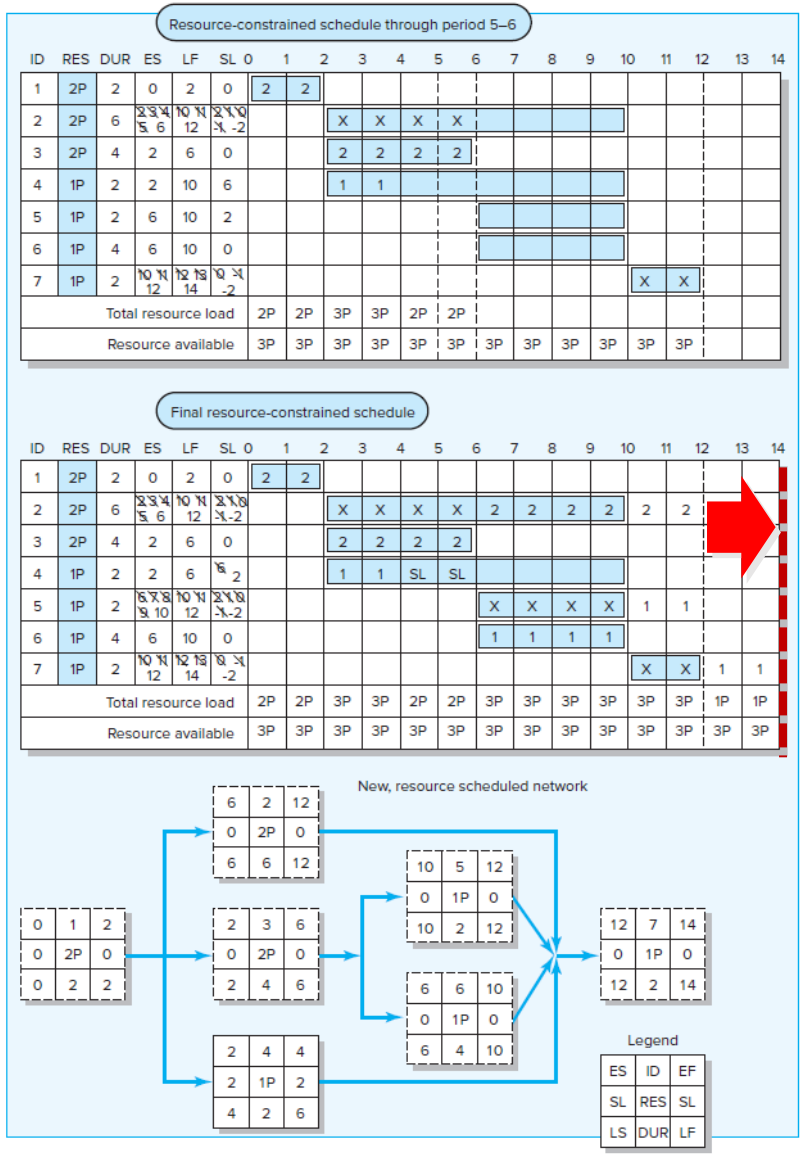
- Resources are limited in quantity or availability.
- Activities are scheduled using **heuristics** (rules of thumb) by following the priority rules:
  1. Minimum slack
  2. Smallest (least) duration
  3. Lowest activity identification number
- The parallel method is used to apply heuristics.
  - The parallel method is an iterative process that starts from the beginning of project time and, when the resources needed exceed the resources available, retains activities first by the priority rules.

Resource-Constrained Schedule through Period 2-3



- **FIGURE 8.4**

Resource-Constrained Schedule through Period 5-6



- **FIGURE 8.5**

8.5 Computer Demonstration of Resource-Constrained Scheduling

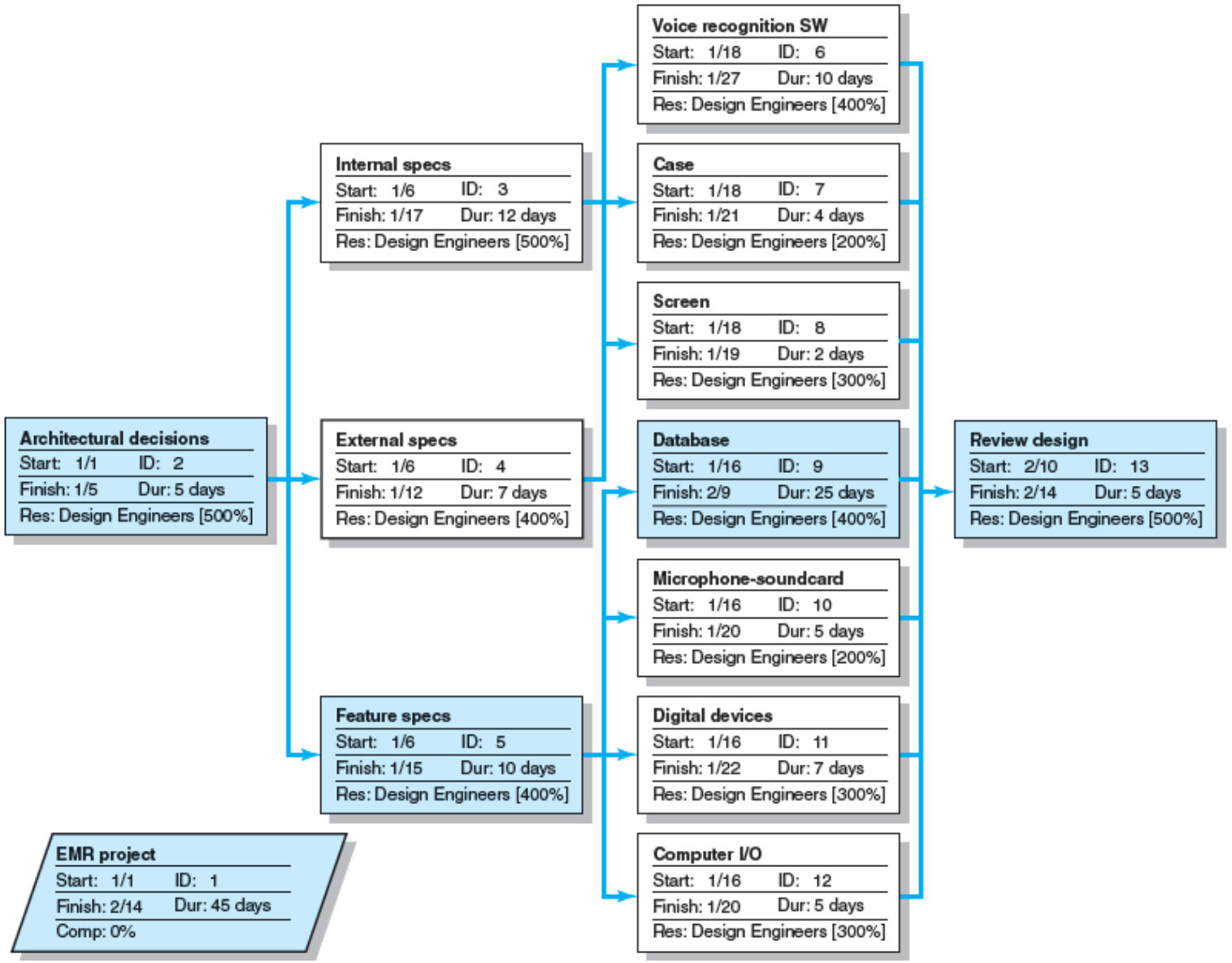
- **EMR Project**

- The development of a hand-held electronic medical reference guide to be used by emergency medical technicians and paramedics

- **Resource Problem**

- Only eight design engineers can be assigned to the project due to the shortage of design engineers and commitments to other projects.
- The peak demand is 21 design engineers.

EMR Project Network View Schedule before Resources Leveled

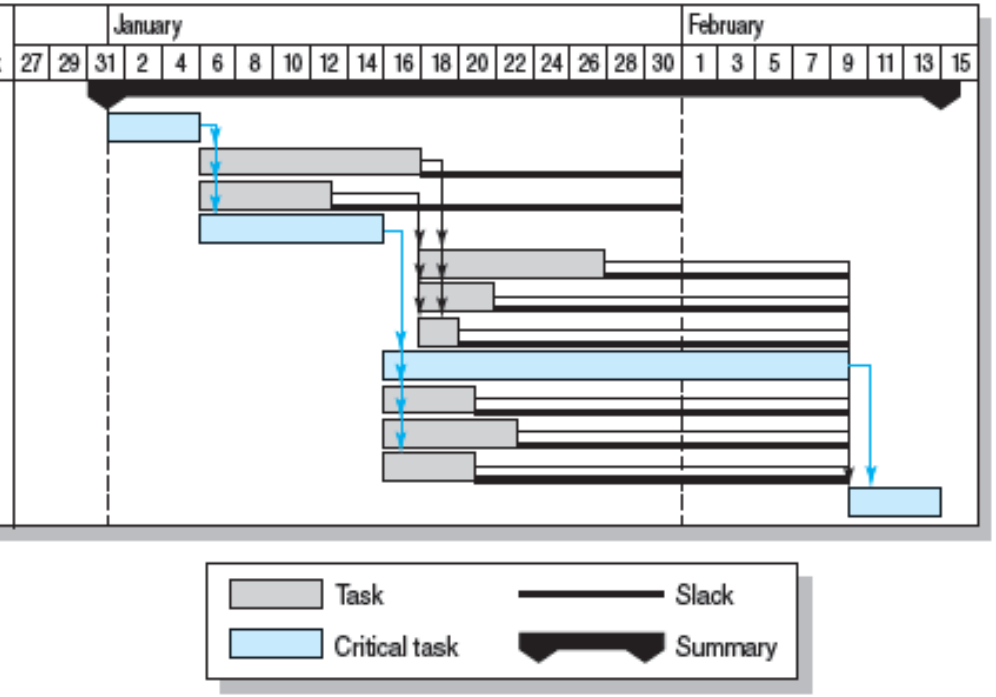


- **FIGURE 8.6**

EMR Project before Resources Added

- FIGURE 8.7

ID	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	EMR project	Tue 1/1	Thu 2/14	Tue 1/1	Thu 2/14	0 days	0 days
2	Architectural decisions	Tue 1/1	Sat 1/5	Tue 1/1	Sat 1/5	0 days	0 days
3	Internal specs	Sun 1/6	Thu 1/17	Sat 1/19	Wed 1/30	0 days	13 days
4	External specs	Sun 1/6	Sat 1/12	Thu 1/24	Wed 1/30	5 days	18 days
5	Feature specs	Sun 1/6	Tue 1/15	Sun 1/6	Tue 1/15	0 days	0 days
6	Voice recognition SW	Fri 1/18	Sun 1/27	Thu 1/31	Sat 2/9	13 days	13 days
7	Case	Fri 1/18	Mon 1/21	Wed 2/6	Sat 2/9	19 days	19 days
8	Screen	Fri 1/18	Sat 1/19	Fri 2/8	Sat 2/9	21 days	21 days
9	Database	Wed 1/16	Sat 2/9	Wed 1/16	Sat 2/9	0 days	0 days
10	Microphone-soundcard	Wed 1/16	Sun 1/20	Tue 2/5	Sat 2/9	20 days	20 days
11	Digital devices	Wed 1/16	Tue 1/22	Sun 2/3	Sat 2/9	18 days	18 days
12	Computer I/O	Wed 1/16	Sun 1/20	Tue 2/5	Sat 2/9	20 days	20 days
13	Review design	Sun 2/10	Thu 2/14	Sun 2/10	Thu 2/14	0 days	0 days



EMR Project—Time-Constrained Resource Usage View, January 15-23

Resource Name	Work	Jan 15						Jan 21		
		T	W	T	F	S	S	M	T	W
Design engineers	**3,024 hrs**	72h	136h	136h	168h	168h	144h	104h	88h	64h
Architectural decisions	200 hrs									
Internal specs	480 hrs	40h	40h	40h						
External specs	224 hrs									
Feature specs	320 hrs	32h								
Voice recognition SW	320 hrs				32h	32h	32h	32h	32h	32h
Case	64 hrs				16h	16h	16h	16h		
Screen	48 hrs				24h	24h				
Database	800 hrs		32h	32h	32h	32h	32h	32h	32h	32h
Microphone-soundcard	80 hrs		16h	16h	16h	16h	16h			
Digital devices	168 hrs		24h	24h	24h	24h	24h	24h	24h	
Computer I/O	120 hrs		24h	24h	24h	24h	24h			
Review design	200 hrs									

FIGURE 8.8A

Resource Loading Chart for EMR Project, January 15-23

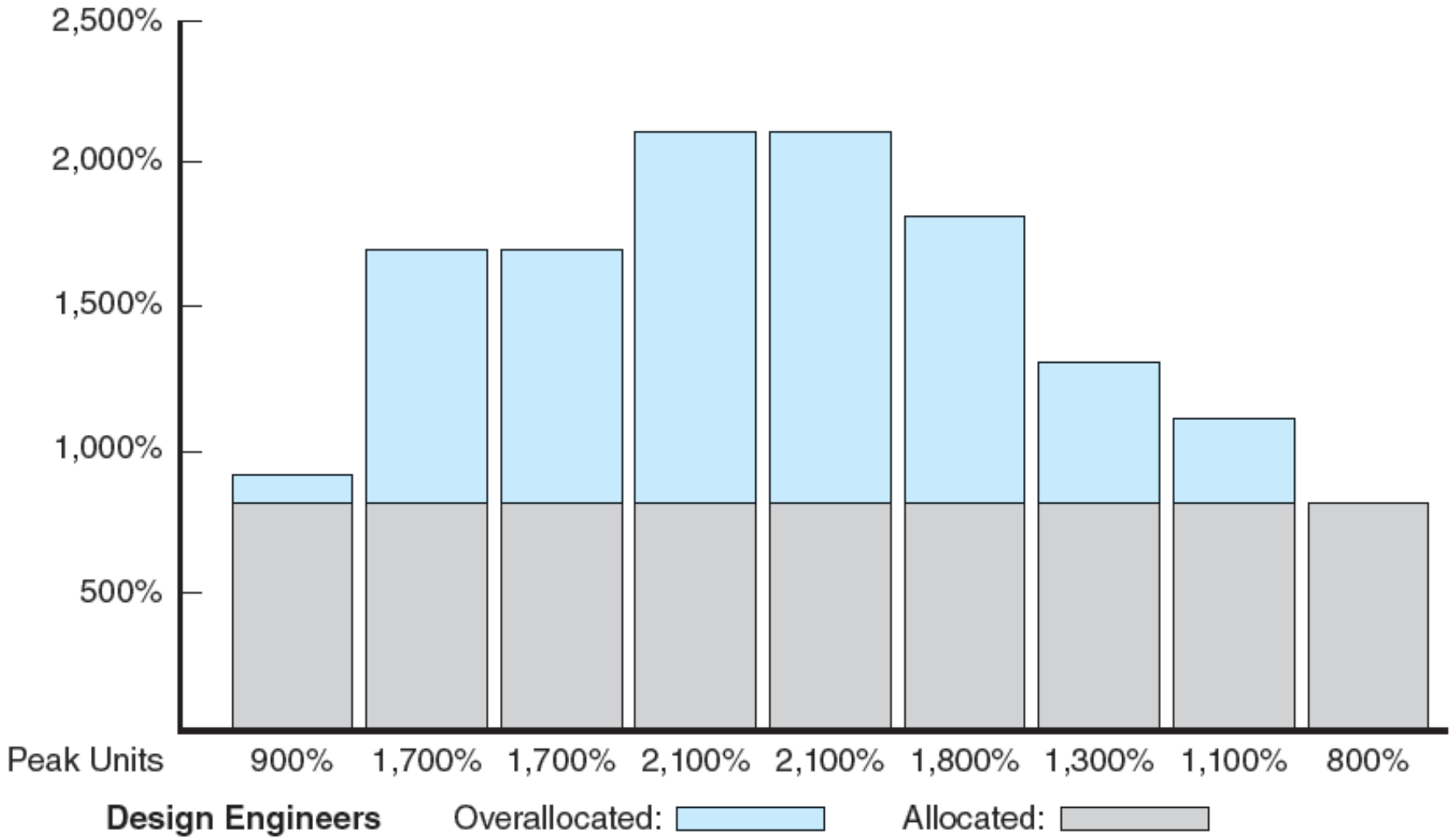
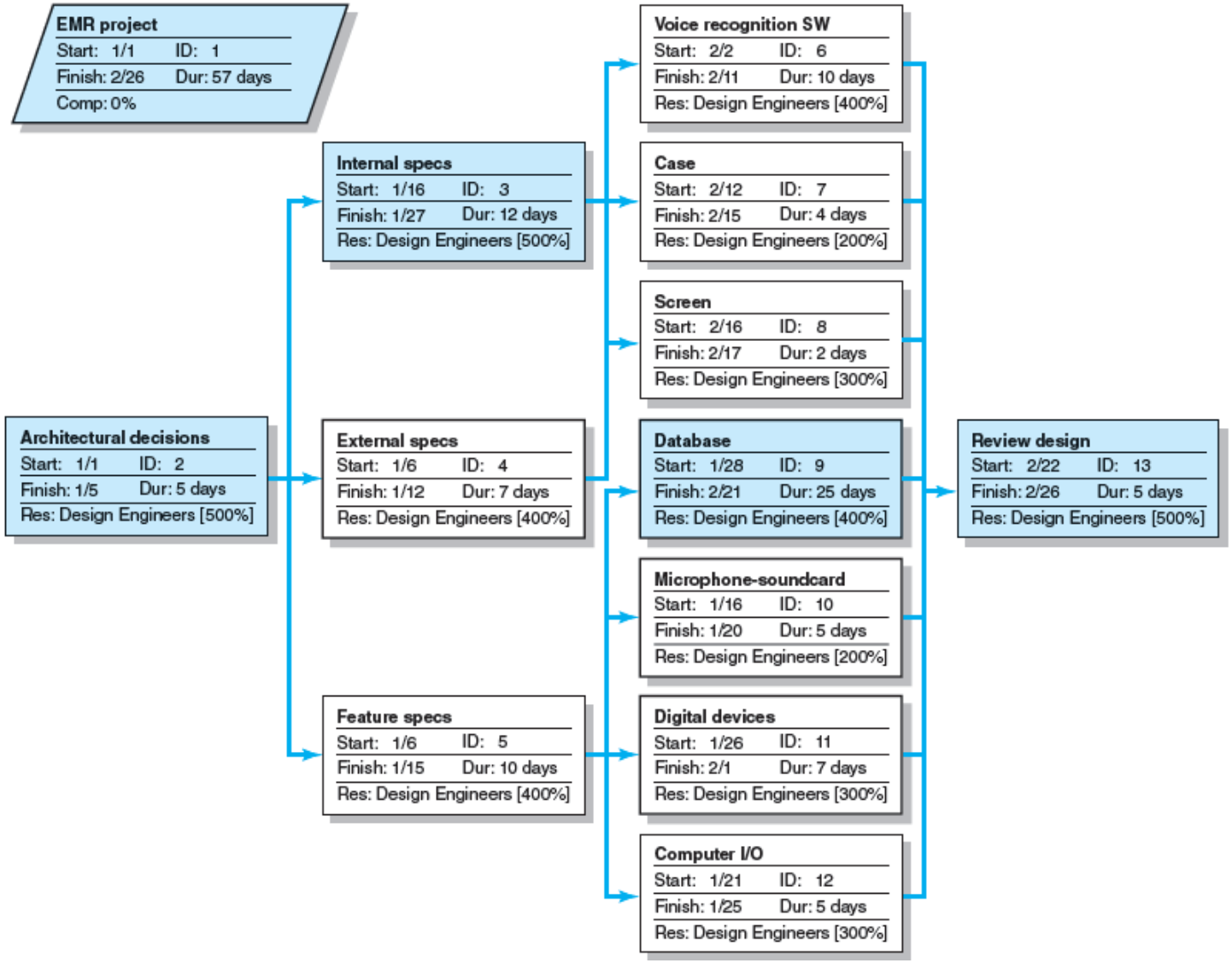


FIGURE 8.8B

EMR Project Network View Schedule after Resources Leveled



- **FIGURE 8.9**

EMR Project Resources Leveled

ID	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	**EMR project**	**Tue 1/1**	**Thu 2/26**	**Tue 1/1**	**Tue 2/26**	**0 days**	**0 days**
2	Architectural decisions	Tue 1/1	Sat 1/5	Tue 1/1	Sat 1/5	0 days	0 days
3	Internal specs	Wed 1/16	Sun 1/27	Sun 1/20	Thu 1/31	0 days	4 days
4	External specs	Sun 1/6	Sat 1/12	Fri 1/25	Thu 1/31	15 days	19 days
5	Feature specs	Sun 1/6	Tue 1/15	Sun 1/6	Tue 1/15	0 days	0 days
6	Voice recognition SW	Sat 2/2	Mon 2/11	Tue 2/12	Thu 2/21	10 days	10 days
7	Case	Tue 2/12	Fri 2/15	Mon 2/18	Thu 2/21	6 days	6 days
8	Screen	Sat 2/16	Sun 2/17	Wed 2/20	Thu 2/21	4 days	4 days
9	Database	Mon 1/28	Thu 2/21	Mon 1/28	Thu 2/21	0 days	0 days
10	Microphone-soundcard	Wed 1/16	Sun 1/20	Sun 2/17	Thu 2/21	32 days	32 days
11	Digital devices	Sat 1/26	Fri 2/1	Fri 2/15	Thu 2/21	20 days	20 days
12	Computer I/O	Mon 1/21	Fri 1/25	Sun 2/17	Thu 2/21	27 days	27 days
13	Review design	Fri 2/22	Tue 2/26	Fri 2/22	Tue 2/26	0 days	0 days

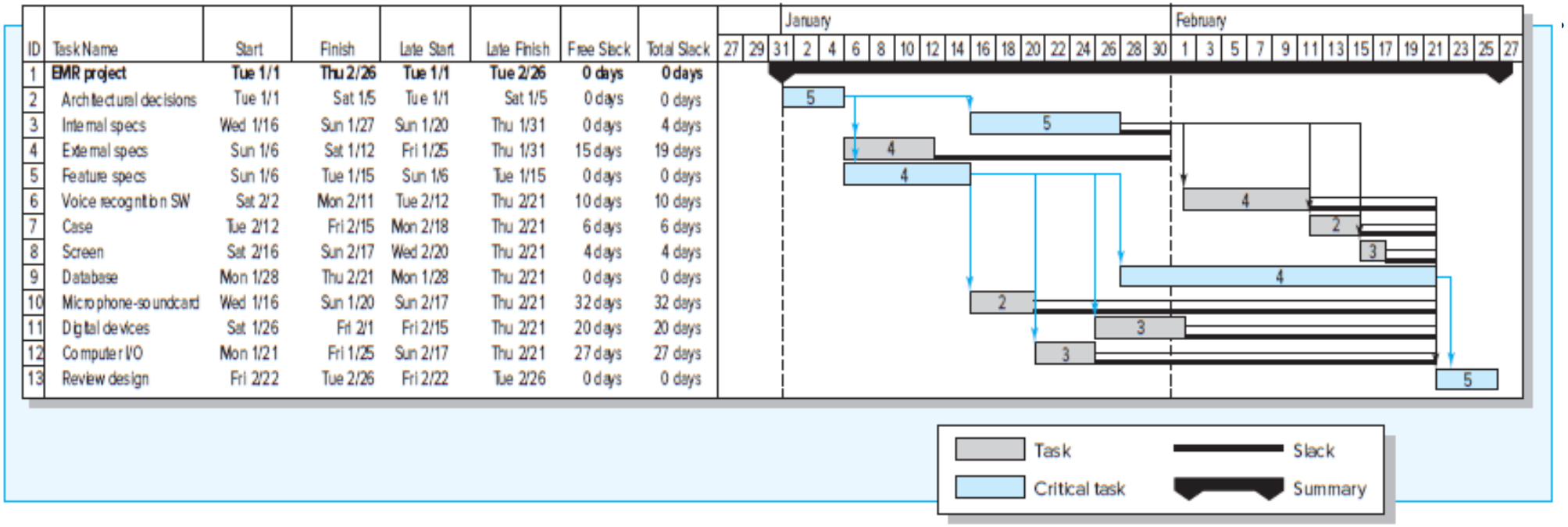


FIGURE 8.10

The Impacts of Resource-Constrained Scheduling

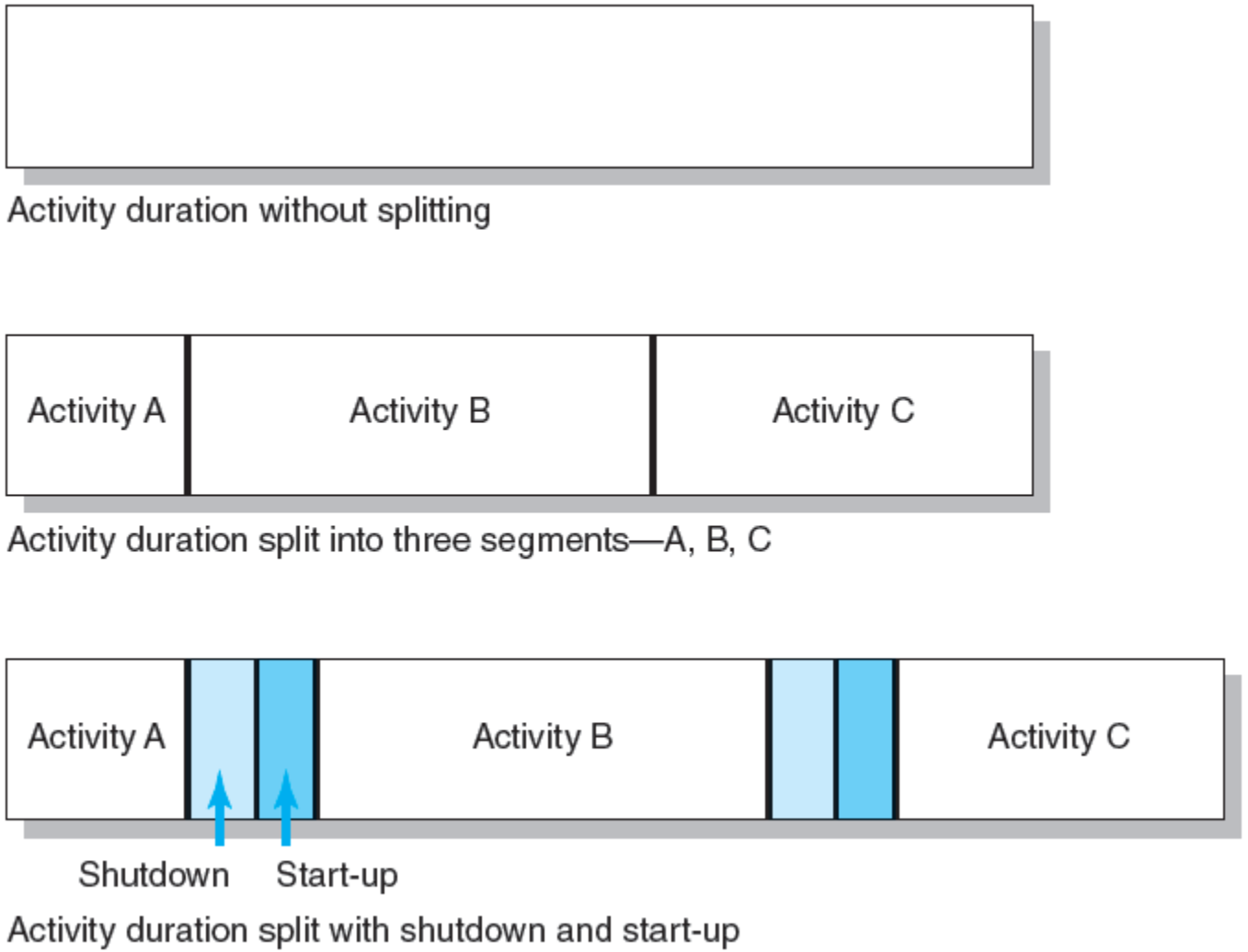
- Reduces slack; reduce flexibility
- Increases the number of critical and near-critical activities
- Increases scheduling complexity because resource constraints are added to technical constraints
- May make the traditional critical path no longer meaningful
- Can break the sequence and leave the network with a set of disjointed critical activities
- May cause parallel activities to become sequential
- Can change activities from critical to noncritical

8.6 Splitting Activities

- **Splitting Tasks**

- Is a scheduling technique used to get a better project schedule and/or to increase resource utilization.
- Involves interrupting the work and sending the resource to another activity for a period of time and then having the resource resume work on the original activity.
- Can be useful if the work involved does not include large start-up or shut-down costs.
- Is considered a major reason why projects fail to meet schedule.

Splitting Activities



- **FIGURE 8.11**

8.7 Benefits of Scheduling Resources

- Leaves time for considering reasonable alternatives
  - Cost-time tradeoffs
  - Changes in priorities
- Provides the information needed to prepare time-phased work package budgets with dates
  - To gauge the impact of unforeseen events
  - To assess how much flexibility over certain resources

8.8 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
  - Future needs: have people work together early on so that they can become familiar with each other

8.9 Multiproject Resource Schedules

- Problems in a multiproject environment

1. Overall schedule slippage
   - Shared resources causes a ripple effect—delays in one project create delays for other projects.
2. Inefficient resource utilization
   - Different schedules and requirements by multiple projects create the peaks and valleys in overall resource demands.
3. Resource bottlenecks
   - Shortages of critical resources required by multiple projects cause delays and schedule extensions.

Managing Multiproject Scheduling

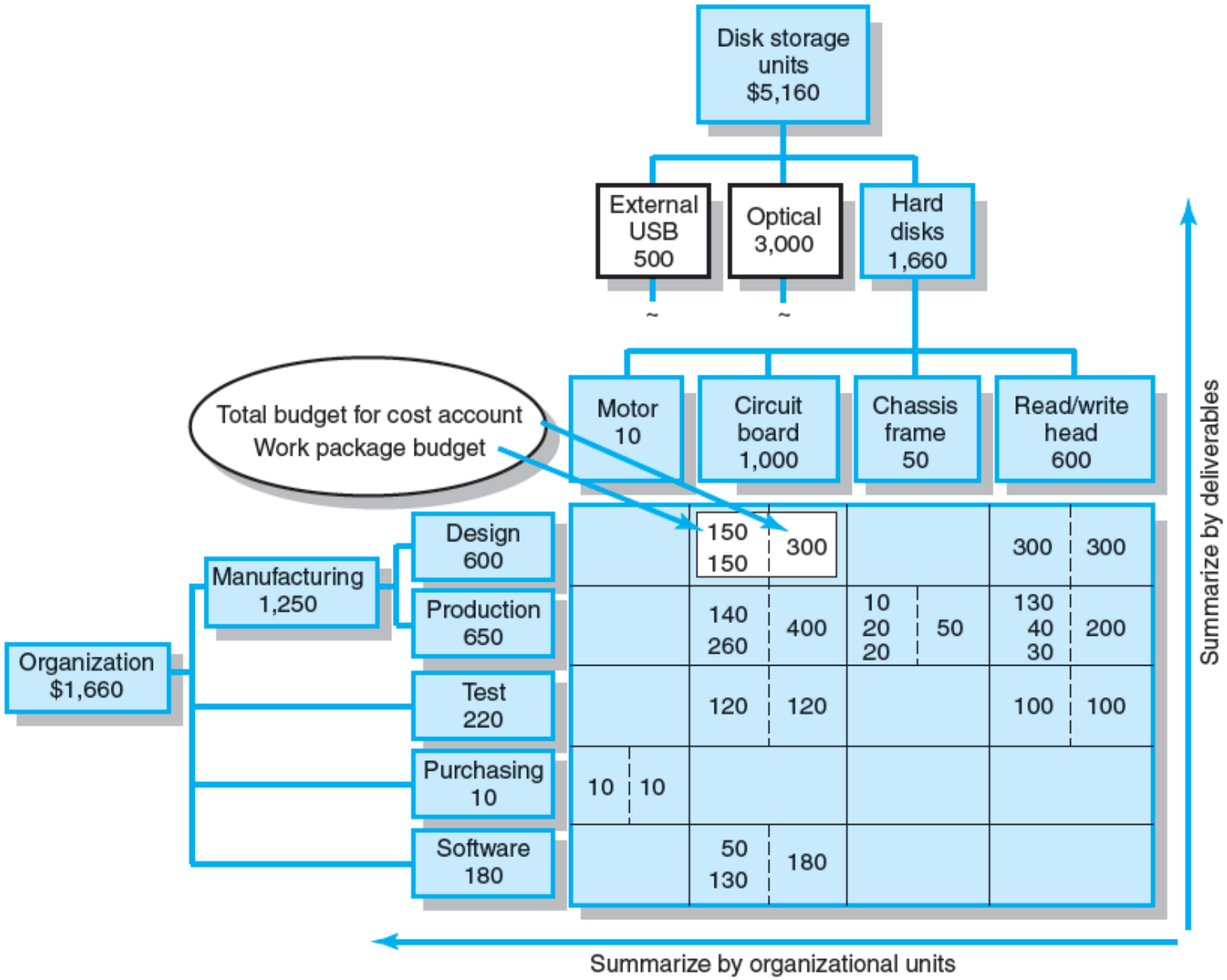
- Create project offices or departments to oversee the scheduling of resources across multiple projects
- Use a project priority queuing system—first come, first served for resources
- Treat individual projects as part of one big project and adapt the scheduling heuristics to this “mega project”
- Utilize project management software to prioritize resource allocation
- Outsource projects to reduce the number of projects managing internally
- Hire temporary workers to expedite certain activities that are falling behind schedule
- Contract project work during peak periods when there are insufficient internal resources to meet the demands of all project

8.10 Using the Resource Schedule to Develop a Project Cost Baseline

- Why a Time-Phased Budget Baseline Is Needed
  - To determine if the project is on, ahead, or behind schedule and over or under its budgeted costs
  - To assess how much work has been accomplished for the allocated money spent—the project cost baseline (planned value, PV)
- Creating a Time-Phased Budget
  - Assign each work package to one responsible person or department and deliverable
  - Compare planned schedule and costs using an integrative system called earned value
  - Generate cash flow statements and resource usage schedules

Direct Labor Budget Rollup ($000)

- FIGURE 8.12



Time-Phased Work Package Budget (labor cost only)

Time-Phased Work Package Budget
Labor cost only

FIGURE 8.13

Work Package Description *Test*

Work Package ID ***1.1.3.2.3***

Deliverable *Circuit board*

Responsible organization unit *Test*

Work Package Duration *3* weeks

Page *1* of *1*

Project *PC Prototype*

Date *3/24/xx*

Estimator *CEG*

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

Two Time-Phased Work Packages (labor cost only)

Time-Phased Work Package Budget
Labor cost only

Work Package Description *Software*

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

Deliverable *Circuit board*

Responsible organization unit *Software*

Work Package Duration *4* weeks

Page *1* of *1*

Project *PC Prototype*

Date *3/24/xx*

Estimator *LGG*

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

• FIGURE 8.14

Patient Entry Project Network

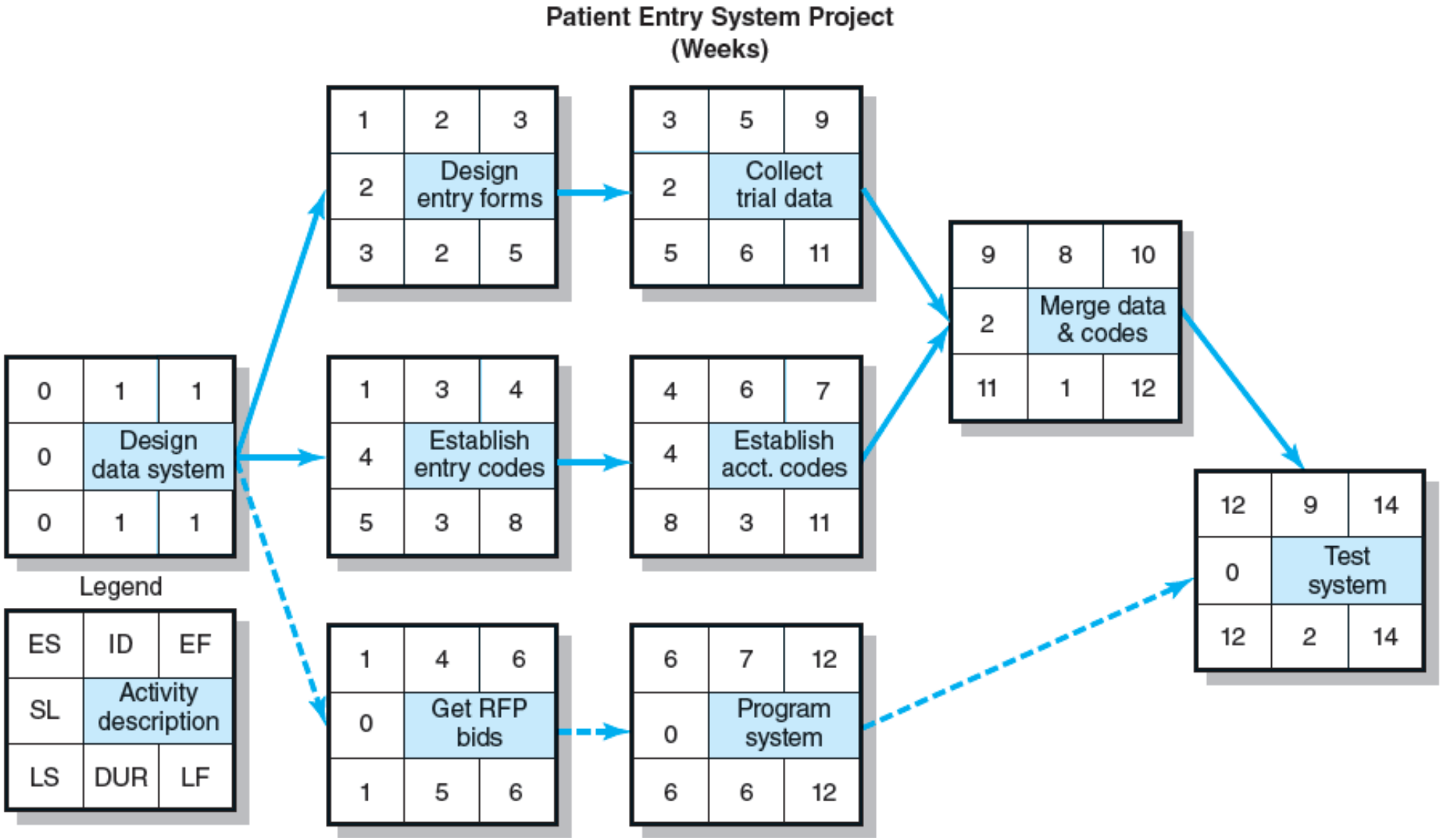
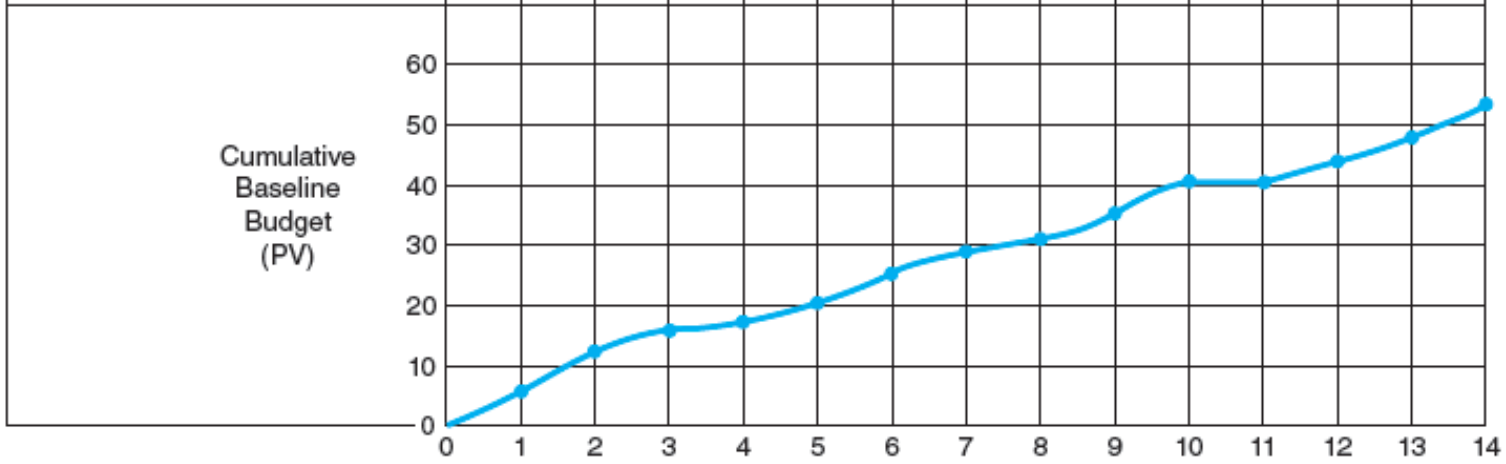


FIGURE 8.15

Patient Entry Time-Phased Work Packages Assigned

($000) Week

ID	Dur.	Task	Budget	0	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	



- **FIGURE 8.16**

Project Monthly Cash Flow Statement

	January	February	March	April	May	June	July
Project							
Hardware							
Hardware specifications	$11,480.00	$24,840.00	$3,360.00				
Hardware design			$23,120.00	$29,920.00	$14,960.00		
Hardware documentation					$14,080.00	$24,320.00	
Prototypes							
Order GXs							
Assemble preproduction models							
Operating system							
Kernel specifications	$5,320.00	$9,880.00					
Drivers							
OC drivers				$3,360.00	$12,320.00	$11,760.00	$12,880.00
Serial VO drivers							
Memory management							
Operating system documentation		$10,240.00	$21,760.00				
Network interface							
Utilities							
Utilities specifications				$8,400.00			
Routine utilities				$5,760.00	$21,120.00	$20,160.00	$10,560.00
Complex utilities							
Utilities documentation				$7,680.00	$17,920.00		
Shell							
System integration							
Architectural decisions	$20,400.00						
Integration first phase							
System H/S test							
Project documentation							
Integration acceptance test							
Total	$37,200.00	$44,960.00	$48,240.00	$55,120.00	$80,400.00	$56,240.00	$23,440.00

- **FIGURE 8.17**

Project Weekly Resource Usage Schedule

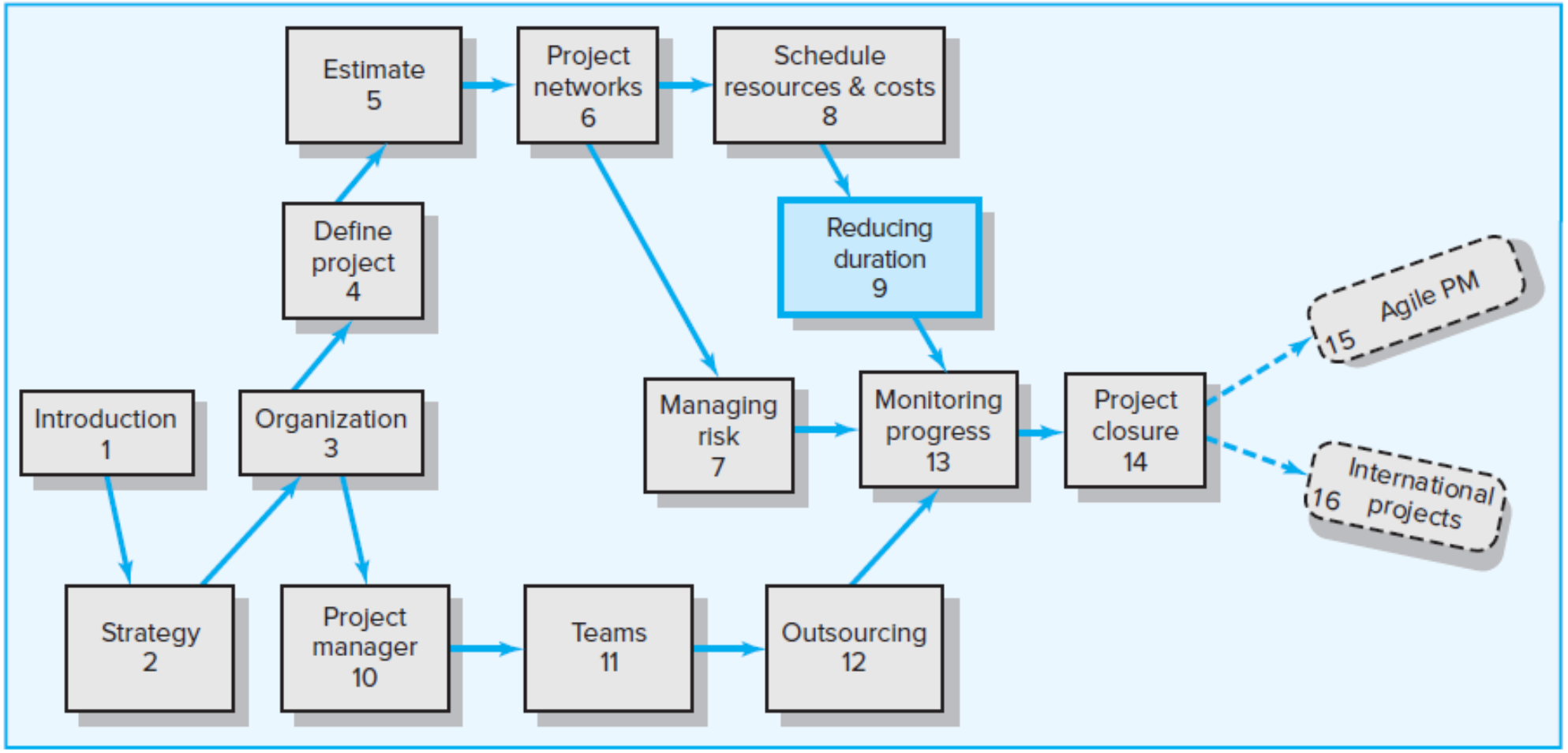
	12/30	1/6	1/13	1/20	1/27	2/03
I. Suzuki	24 hrs	40 hrs	40 hrs	40 hrs	40 hrs	40 hrs
Hardware specifications				24 hrs	40 hrs	40 hrs
Hardware design						
Hardware documentation						
Operating system documentation						
Utilities documentation						
Architectural decisions	24 hrs	40 hrs	40 hrs	16 hrs		
J. Lopez	24 hrs	40 hrs	40 hrs	40 hrs	40 hrs	40 hrs
Hardware specifications				12 hrs	20 hrs	20 hrs
Hardware design						
Prototypes						
Kernel specifications				12 hrs	20 hrs	20 hrs
Utilities specifications						
Architectural decisions	24 hrs	40 hrs	40 hrs	16 hrs		
Integration first phase						
J.J. Putz				24 hrs	40 hrs	40 hrs
Hardware documentation						
Kernel specifications				24 hrs	40 hrs	40 hrs
Operating system documentation						
Utilities documentetion						
Project documentation						
R. Sexon				24 hrs	40 hrs	40 hrs
Hardware specifications				24 hrs	40 hrs	40 hrs
Prototypes						
Assemble preproduction models						
OC drivers						
Complex utilities						
Integration first phase						
System H/S test						
Integration acceptance test						

- FIGURE 8.18

Key Terms

- Heuristics
- Leveling
- Planned value (PV)
- Resource-constrained project
- Resource-constrained scheduling
- Resource smoothing
- Splitting
- Time-constrained project
- Time-phased budget baseline

Where We Are Now



Learning Objectives

09-01 Understand the different reasons for crashing a project.

09-02 Identify the different options for crashing an activity when resources are not constrained.

09-03 Identify the different options for crashing an activity when resources are constrained.

09-04 Determine the optimum cost-time point in a project network.

09-05 Understand the risks associated with compressing or crashing a project.

09-06 Identify different options for reducing the costs of a project.

Chapter Outline

9.1 Rationale for Reducing Project Duration

Crash is a term that has emerged in the project management lexicon for shortening the duration of an activity or a project beyond when it normally can be done.

Reasons for attempting to reduce the duration of a project are:

- Time-to-market pressures
- Unforeseen delays
- Incentive contracts (bonuses for early completion)
- Imposed deadlines and contract commitments
- Overhead costs
- Pressure to reassign resources to other projects

9.2 Options for Accelerating Project Completion

Resources Are Not Constrained

- Add resources
- Outsource project work
- Schedule overtime
- Establish a core project team
- Do it twice—fast and correctly

Resources Are Constrained

- Improve project team efficiency
- Fast tracking
- Use critical-chain management
- Reduce project scope
- Compromise quality

9.3 Project Cost-Duration Graph

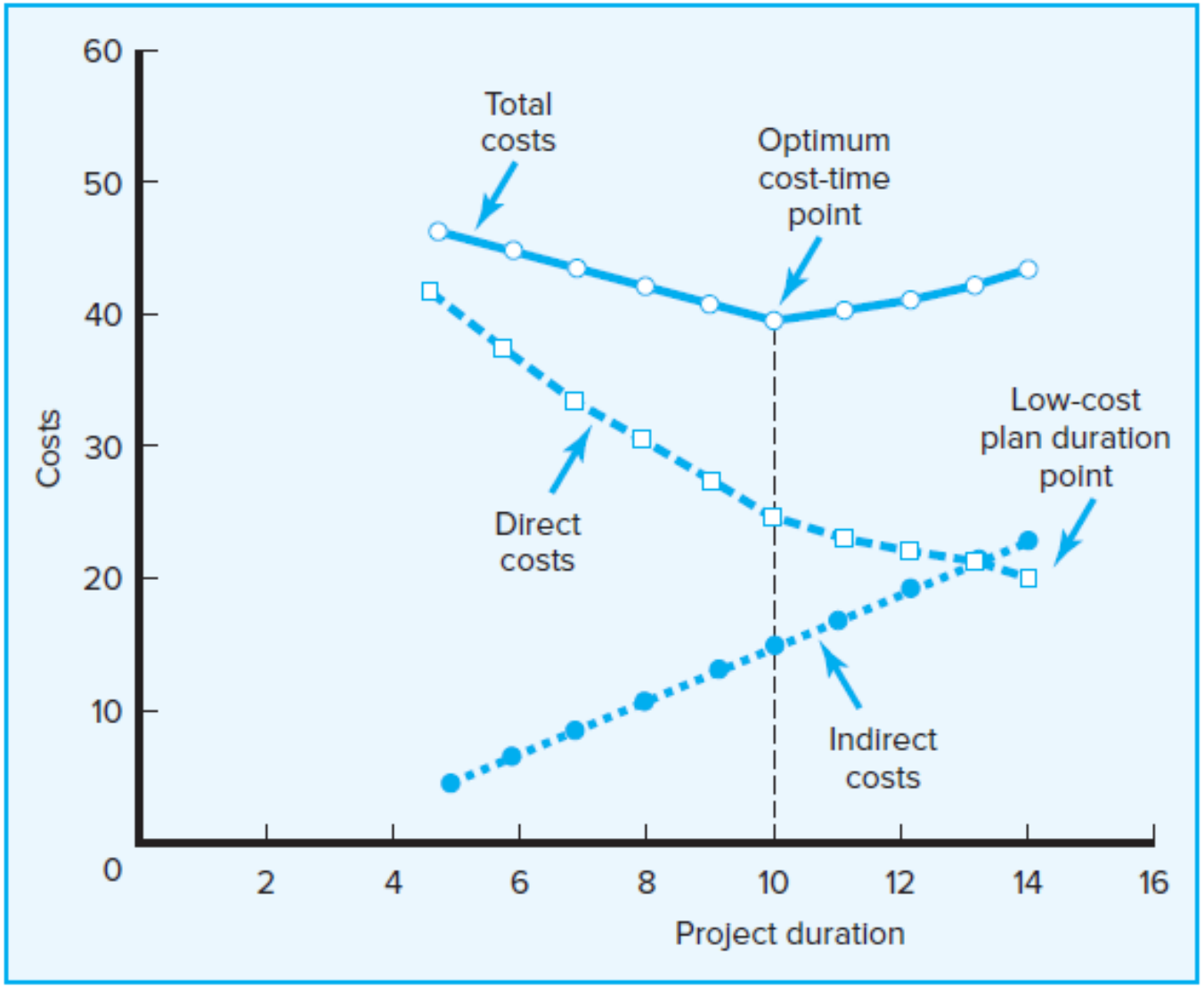


FIGURE 9.1

Explanation of Project Costs

Project Indirect Costs

- Are costs that cannot be associated with any particular work package or activity.
  - Examples are overhead costs such as supervision, administration, consultants, and interest.
- Are costs that vary directly with time.

Project Direct Costs

- Are costs that assigned directly to a work package and activity.
  - Examples are labor, materials, equipment, subcontractors.
- Represent normal costs (low-cost, efficient methods for a normal time).

9.4 Constructing a Project Cost-Duration Graph

The project cost-duration graph is used to compare additional cost alternatives for benefits.

Three major steps are required to construct a project cost-duration graph:

1. Find total direct costs for selected project durations.
2. Find total indirect costs for selected project durations.
3. Sum direct and indirect costs for these selected durations.

Determining the Activities to Shorten

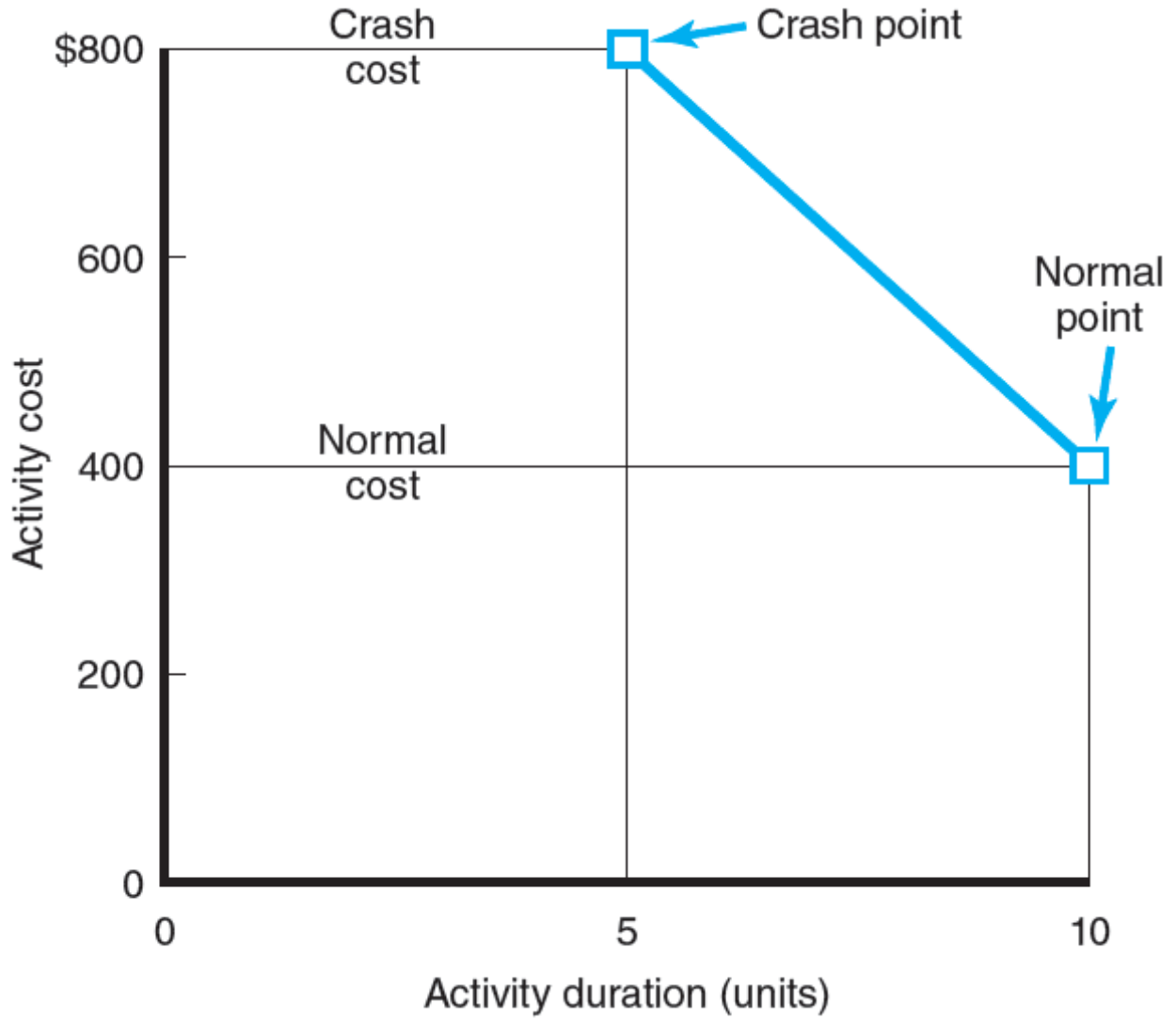
Which activities to shorten?

Look for critical activities that can be shortened with the smallest increase in cost per unit of time.

Assumptions:

1. The cost-time relationship is linear.
2. Normal time assumes low-cost, efficient methods to complete the activity.
3. Crash time represents a limit—the greatest time reduction possible under realistic conditions.
4. Slope represents cost per unit of time.
5. All accelerations must occur within the normal and crash times.

Activity Graph



$$\text{Cost slope} = \frac{\text{Rise}}{\text{Run}} = \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}} = \frac{\$800 - \$400}{10 - 5} = \$80 \text{ per unit of time}$$

FIGURE 9.2

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 (Continued)

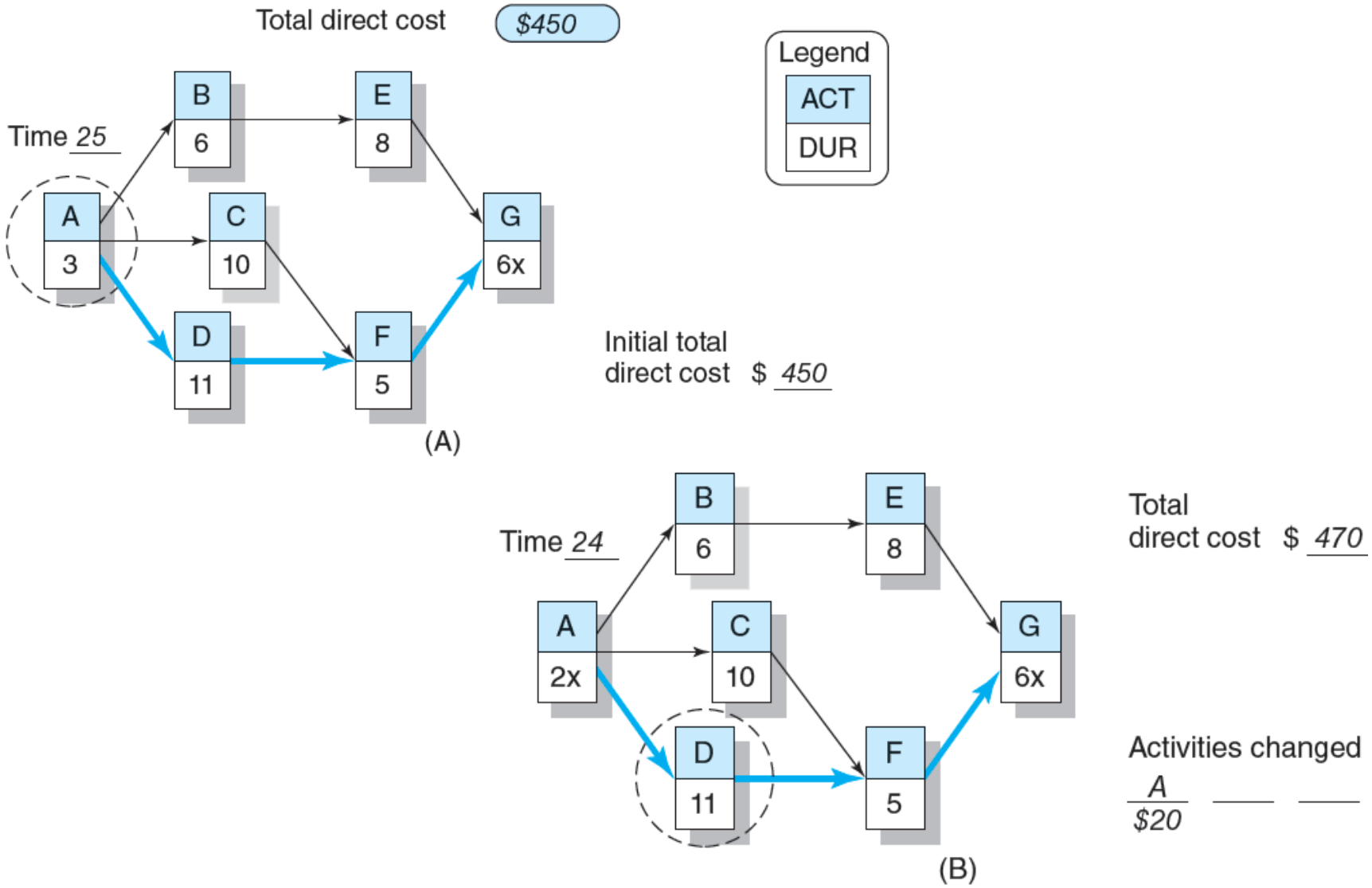
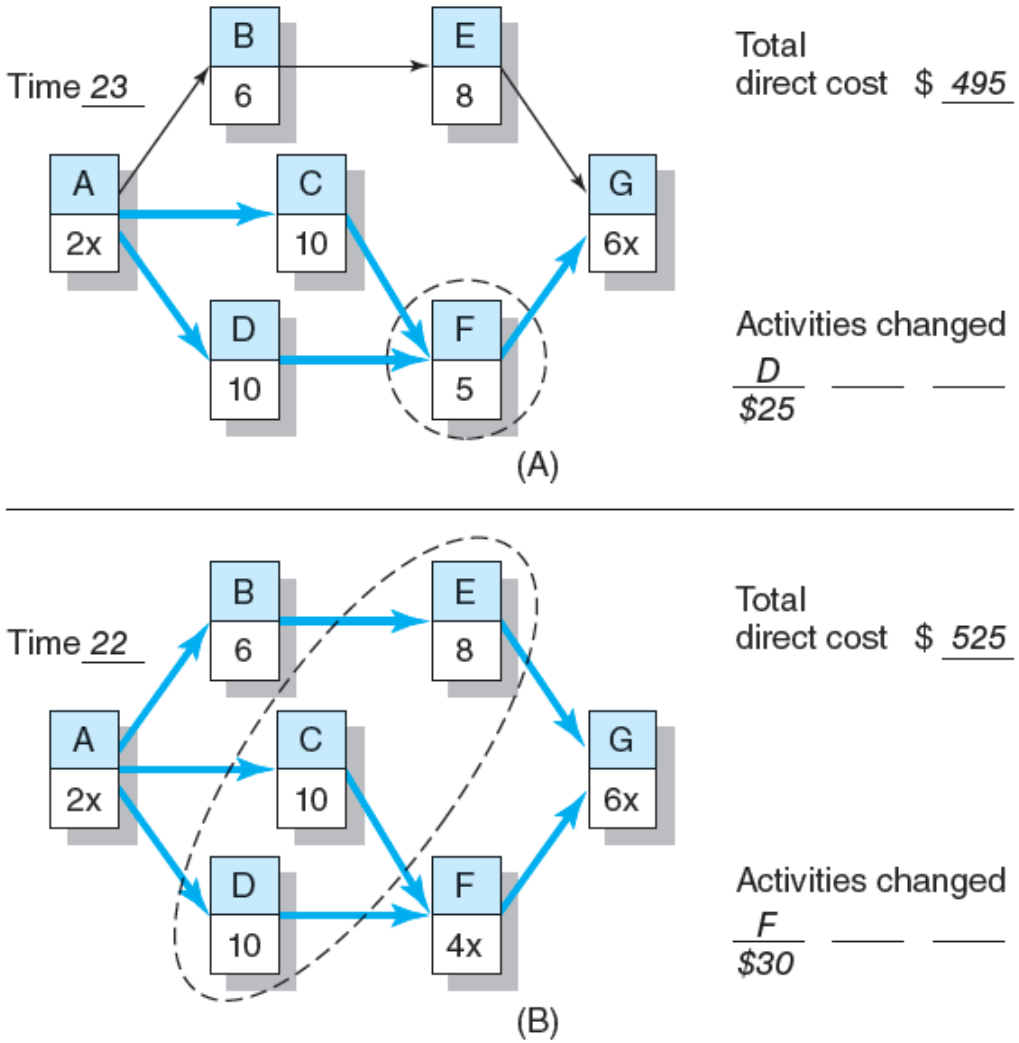


FIGURE 9.3 (Continued)

Cost-Duration Trade-off Example (Continued)



FIG

Cost-Duration Trade-off Example (Continued)

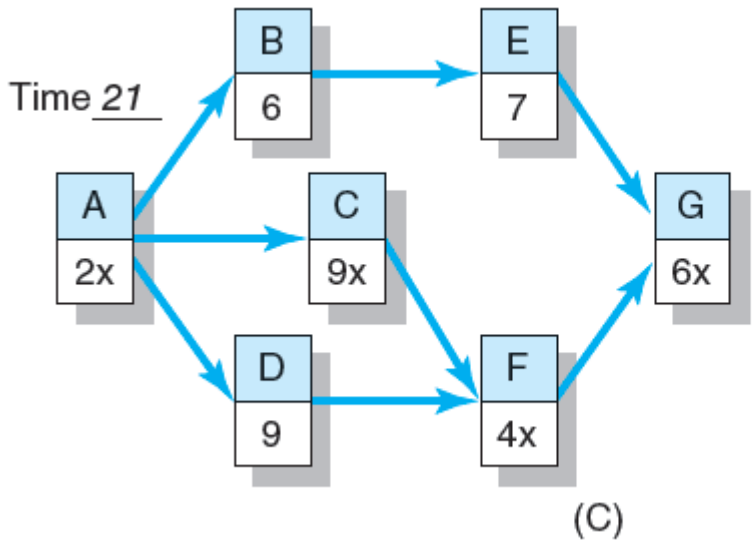


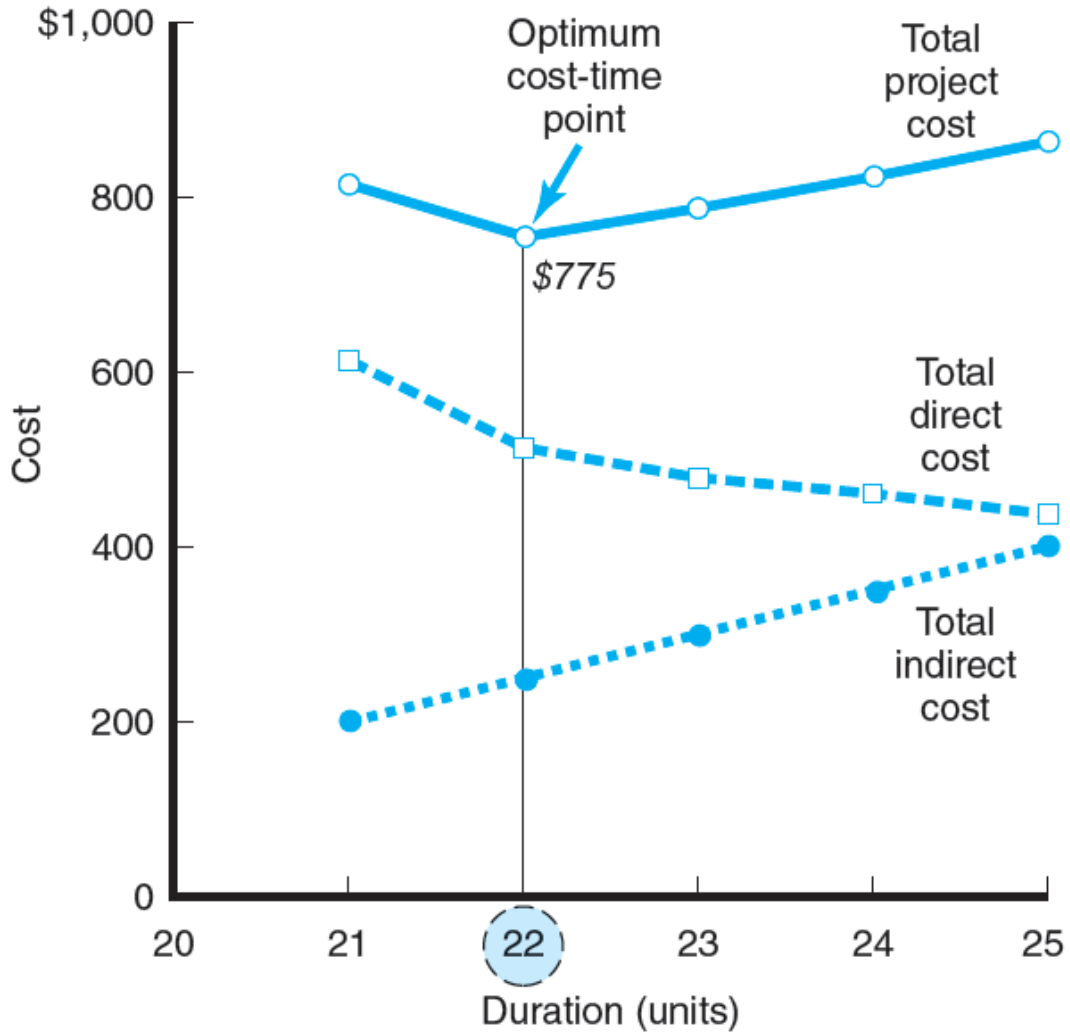
FIGURE 9.4 (Continued)

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*

FIG

Project Cost-Duration Graph



FIG

9.5 Practical Considerations

- Using the project cost-duration graph
- Crash times
- Linearity assumption
- Choice of activities to crash revisited
- Time reduction decisions and sensitivity

9.6 What If Cost, Not Time, Is the Issue?

Commonly used options for cutting costs are:

- Reduce project scope
- Have owner take on more responsibility
- Outsource project activities or even the entire project
- Brainstorm cost savings options

Key Terms

Crash

Crash point

Crash time

Direct costs

Fast tracking

Indirect costs

Project cost-duration graph

Any Questions!