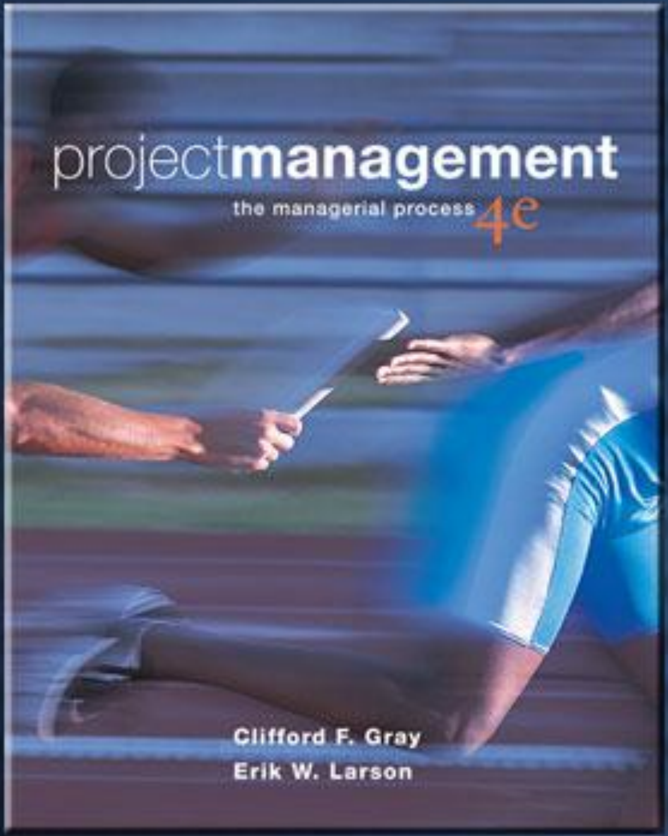
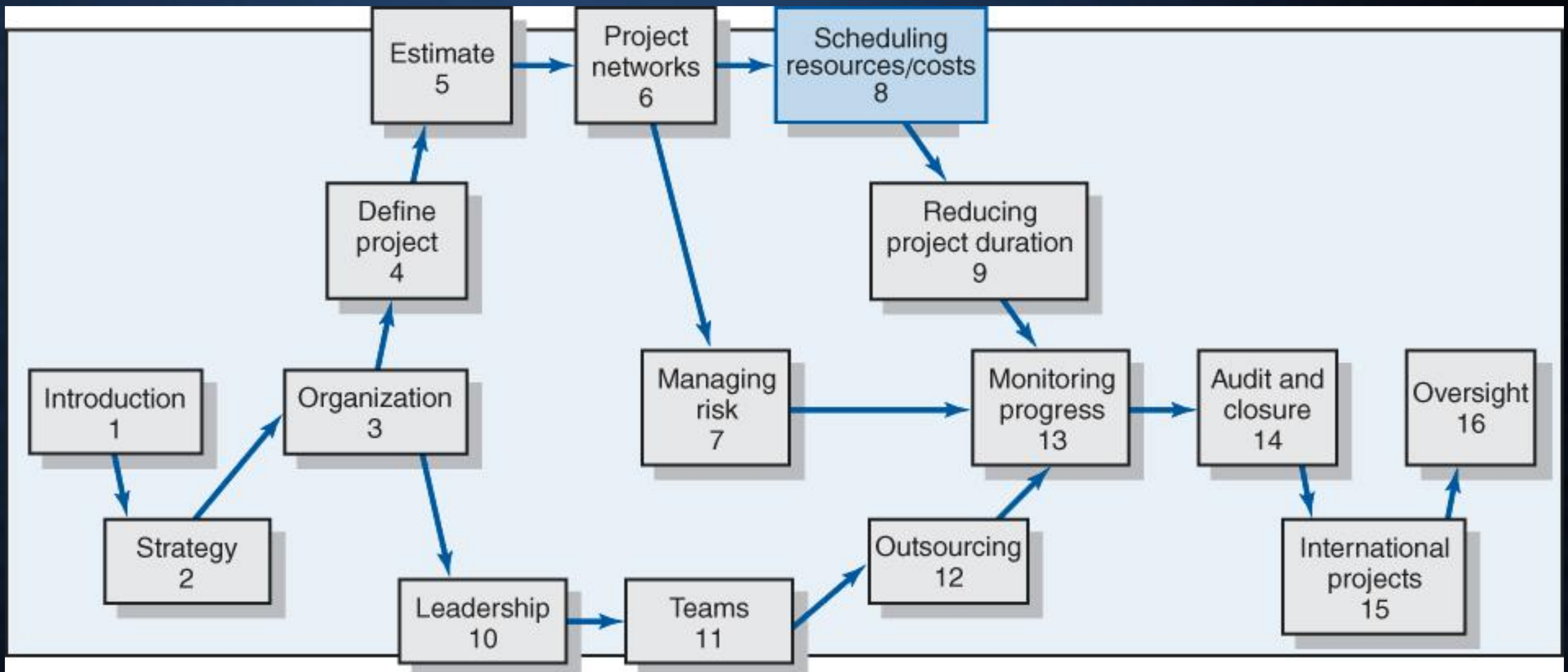


Scheduling Resources and Costs


Estimate 5
Project networks 6
Scheduling resources/costs 8
Define project 4
Reducing project duration 9
Introduction 1
Organization 3
Managing risk 7
Monitoring progress 13
Audit and closure 14
Oversight 16
Strategy 2
Leadership 10
Teams 11
Outsourcing 12
International projects 15

The Resource 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.
- Resource-Constrained Scheduling
  - Resource leveling (or smoothing) involves attempting to even out demands on resources by using slack (delaying noncritical activities) to manage resource utilization.

Types of Project Constraints

- Technical or Logic Constraints
  - Constraints related to the networked sequence in which project activities must occur
- Resource Constraints
  - The absence, shortage, or unique interrelationship and interaction characteristics of resources that require a particular sequencing of project activities

Constraint Examples

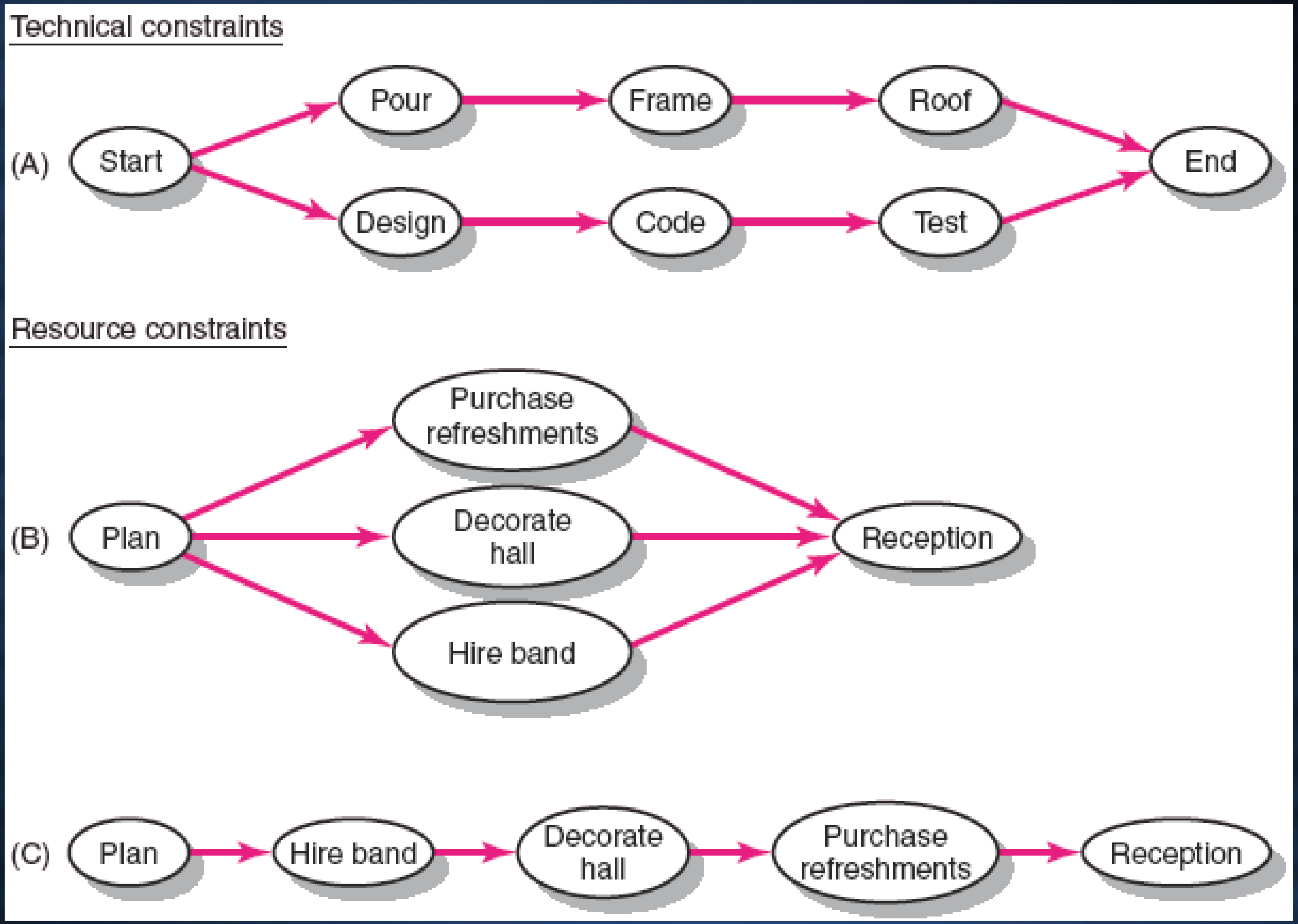


FIGURE 8.2

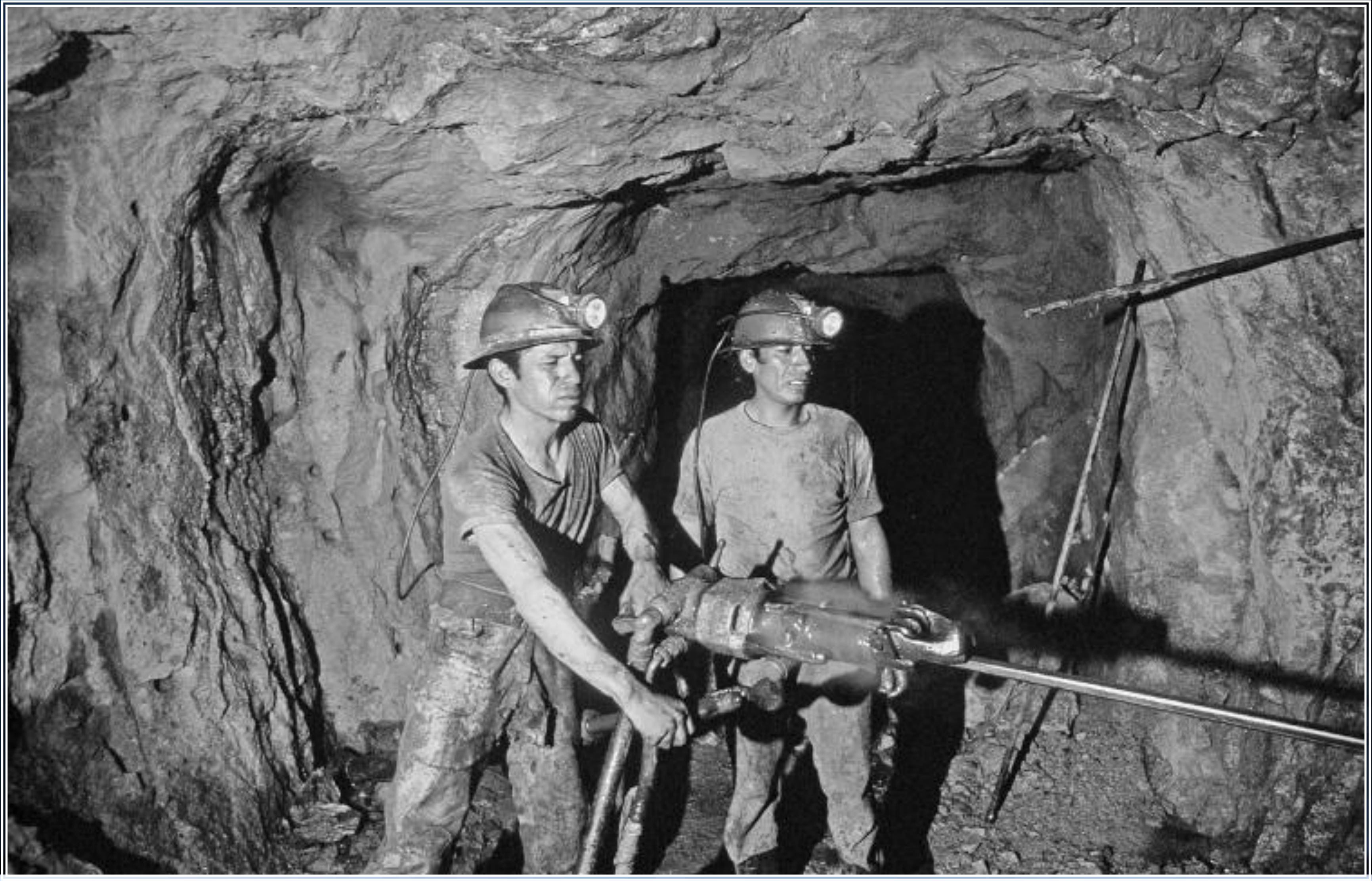
Kinds of Resource Constraints

- **People**
- **Materials**
- **Equipment**
- **Working Capital**

Classification of a Scheduling Problem

- Classification of Problem
  - Using a priority matrix will help determine if the project is time or resource constrained
- Time Constrained Project
  - A project that must be completed by an imposed date
    - Time is fixed, resources are flexible: additional resources are required to ensure project meets schedule.
- Resource Constrained Project
  - A project in which the level of resources available cannot be exceeded
    - Resources are fixed, time is flexible: inadequate resources will delay the project.

A Third Constraint: Physical



Resource Allocation Methods

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

Resource Allocation Methods (cont’d)

- Time-Constrained Projects
  - Projects that must be completed by an imposed date
  - Require the use of leveling techniques that focus on balancing or smoothing resource demands by using positive slack (delaying noncritical activities) to manage resource utilization over the duration of the project
    - Peak resource demands are reduced.
    - Resources over the life of the project are reduced.
    - Fluctuation in resource demand is minimized.

Botanical Garden

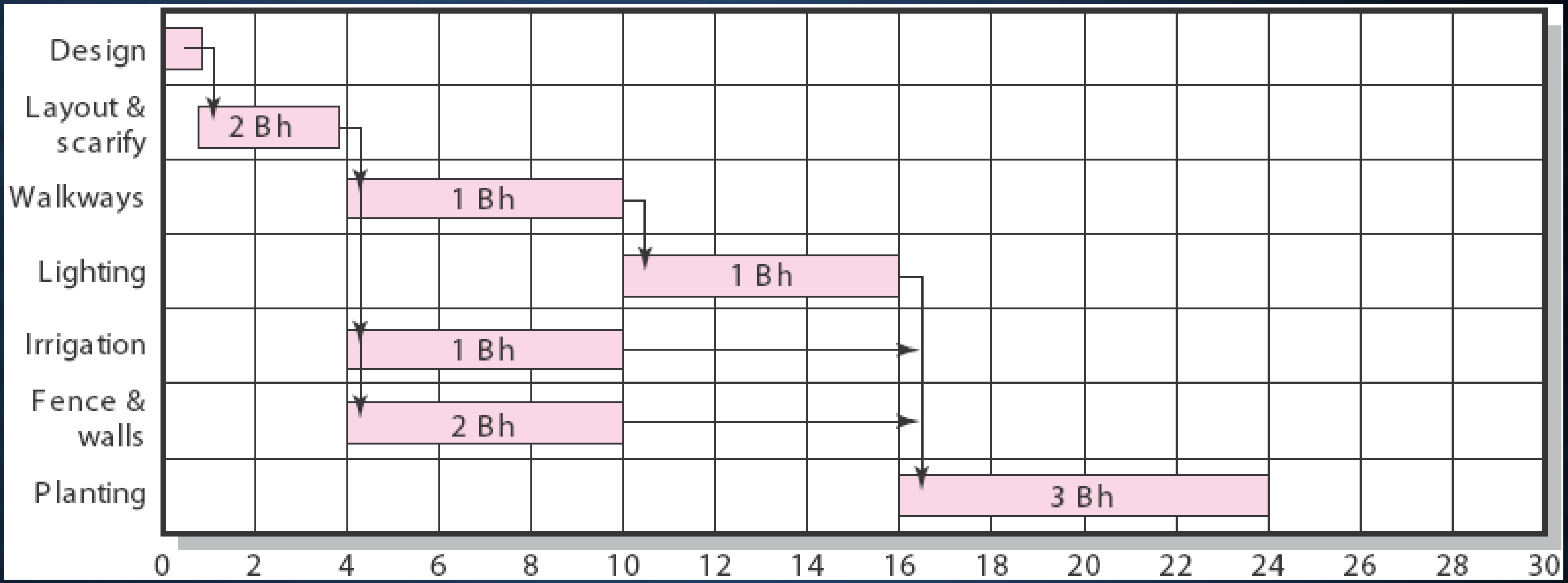


FIGURE 8.3

Botanical Garden (cont'd)

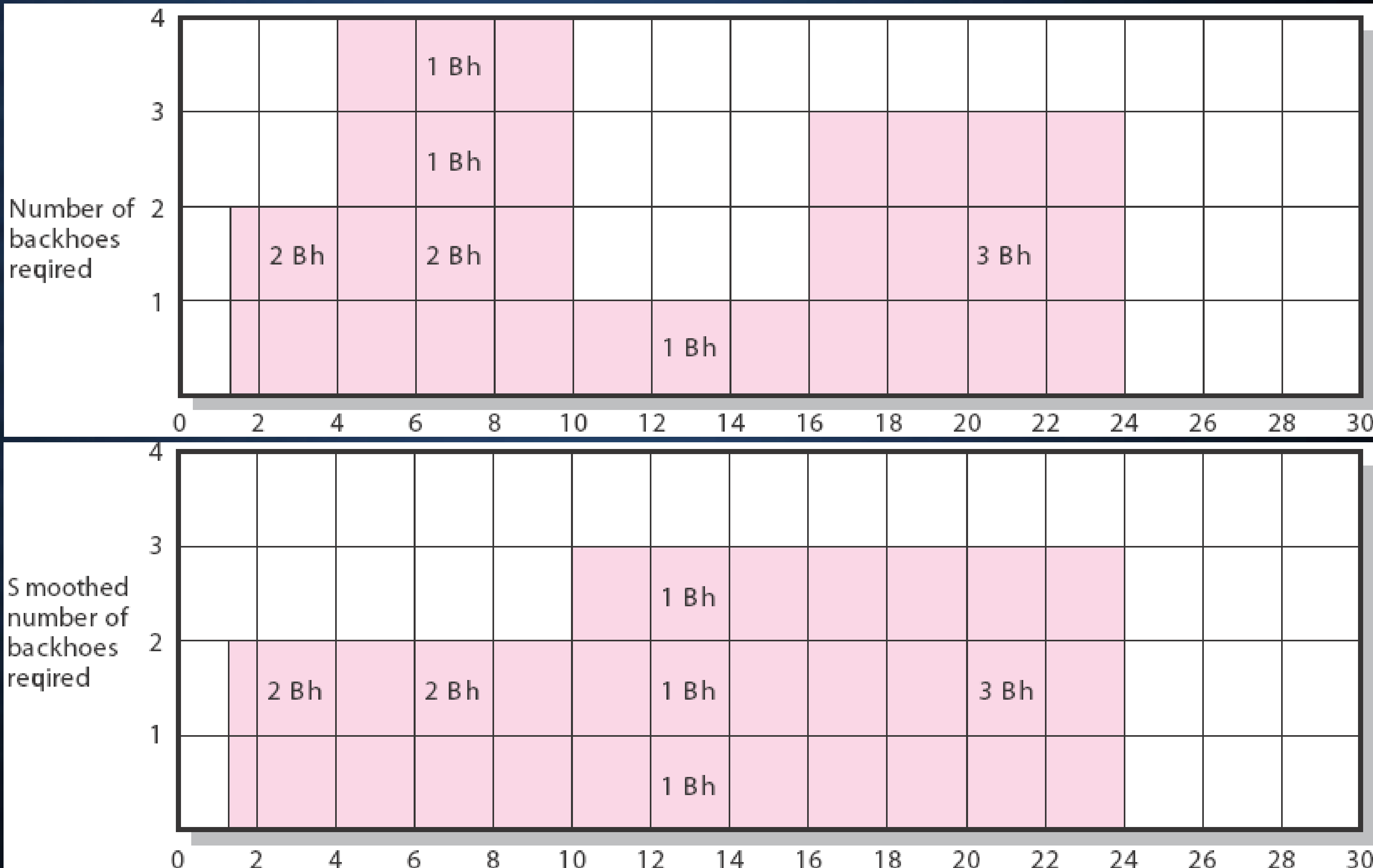


FIGURE 8.3 (cont'd)

Resource Allocation Methods (cont'd)

- Resource Demand Leveling Techniques for Time-Constrained Projects
  - Advantages
    - Peak resource demands are reduced.
    - Resources over the life of the project are reduced.
    - Fluctuation in resource demand is minimized.
  - Disadvantages
    - Loss of flexibility that occurs from reducing slack
    - Increases in the criticality of all activities

Resource Allocation Methods (cont'd)

- Resource-Constrained Projects
  - Projects that involve resources that are limited in quantity or by their availability
  - Scheduling of activities requires the use of 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 that starts at the first time period of the project and schedules period-by-period any activities scheduled to start using the three priority rules

Resource-Constrained Schedule through Period 2–3

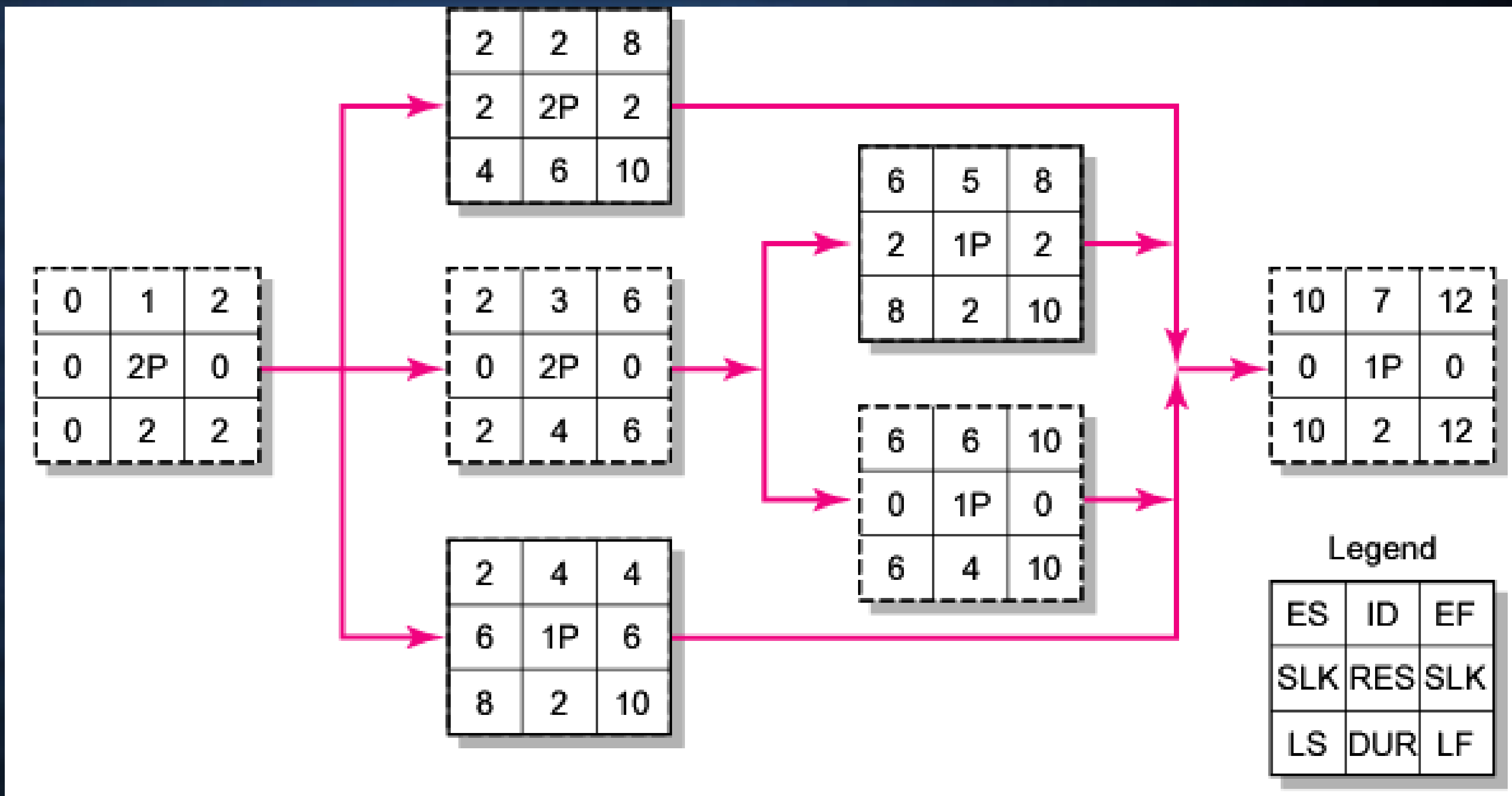


FIGURE 8.4

Resource-Constrained Schedule through Period 2–3

ES resource load chart

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

FIGURE 8.4 (cont'd)

Resource-Constrained Schedule through Period 2–3

Resource-constrained schedule through period 2–3

ID	RES	DUR	ES	LF	TS	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	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								
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

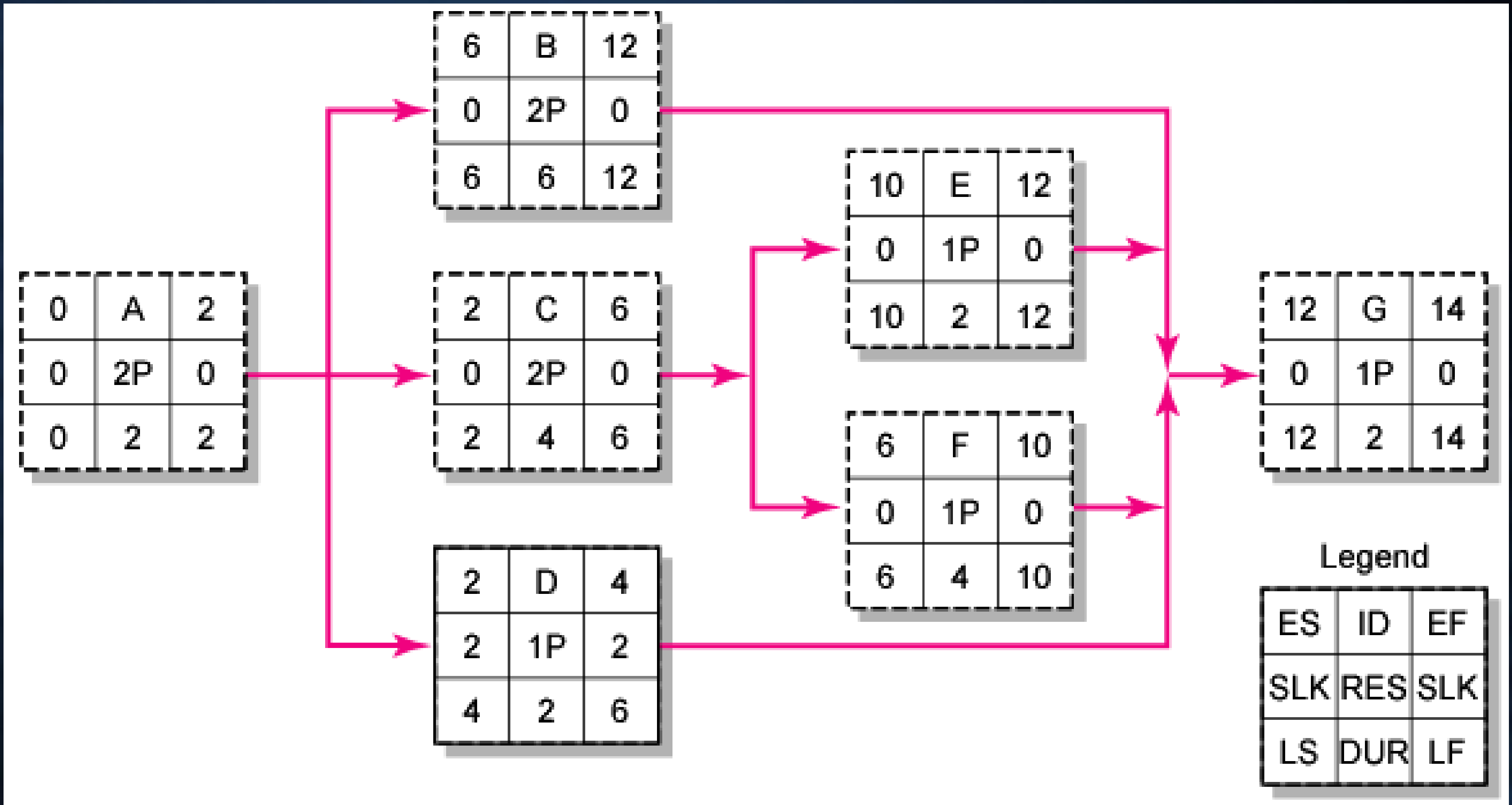
Final resource-constrained schedule

Final resource constrained schedule

ID	RES	DUR	ES	LF	SL	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



New, resource-constrained network

FIGURE 8.5 (cont'd)

Computer Demonstration of Resource-Constrained Scheduling

- EMR Project
  - The development of a handheld electronic medical reference guide to be used by emergency medical technicians and paramedics
- Problem
  - There are only eight design engineers who can be assigned to the project due to a shortage of design engineers and commitments to other projects.

EMR Project: Network View of Schedule before Resources Leveled

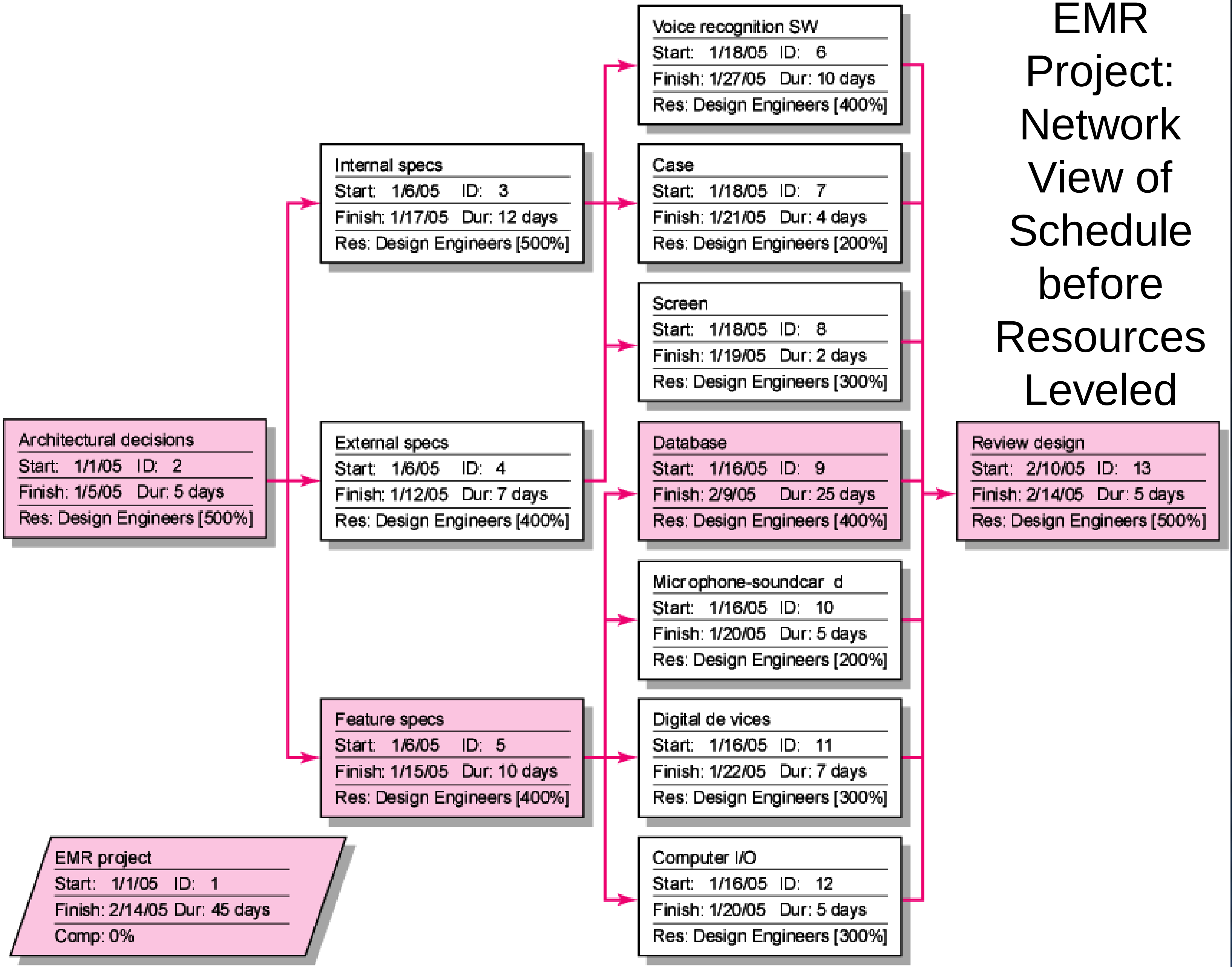


FIGURE 8.6

EMR Project before Resources Added

ID	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	**MRE project**	**Tue 1/1/05**	**Thu 2/14/05**	**Tue 1/1/05**	**Thu 2/14/05**	**0 days**	**0 days**
2	Architectural decisions	Tue 1/1/05	Sat 1/5/05	Tue 1/1/05	Sat 1/5/05	0 days	0 days
3	Internal specs	Sun 1/6/05	Thu 1/17/05	Sat 1/19/05	Wed 1/30/05	0 days	13 days
4	External specs	Sun 1/6/05	Sat 1/12/05	Thu 1/24/05	Wed 1/30/05	5 days	18 days
5	Feature specs	Sun 1/6/05	Tue 1/15/05	Sun 1/6/05	Tue 1/15/05	0 days	0 days
6	Voice recognition SW	Fri 1/18/05	Sun 1/27/05	Thu 1/31/05	Sat 2/9/05	13 days	13 days
7	Case	Fri 1/18/05	Mon 1/21/05	Wed 2/6/05	Sat 2/9/05	19 days	19 days
8	Screen	Fri 1/18/05	Sat 1/19/05	Fri 2/8/05	Sat 2/9/05	21 days	21 days
9	Database	Wed 1/16/05	Sat 2/9/05	Wed 1/16/05	Sat 2/9/05	0 days	0 days
10	Microphone-soundcard	Wed 1/16/05	Sun 1/20/05	Tue 2/5/05	Sat 2/9/05	20 days	20 days
11	Digital devices	Wed 1/16/05	Tue 1/22/05	Sun 2/3/05	Sat 2/9/05	18 days	18 days
12	Computer I/O	Wed 1/16/05	Sun 1/20/05	Tue 2/5/05	Sat 2/9/05	20 days	20 days
13	Review design	Sun 2/10/05	Thu 2/14/05	Sun 2/10/05	Thu 2/14/05	0 days	0 days

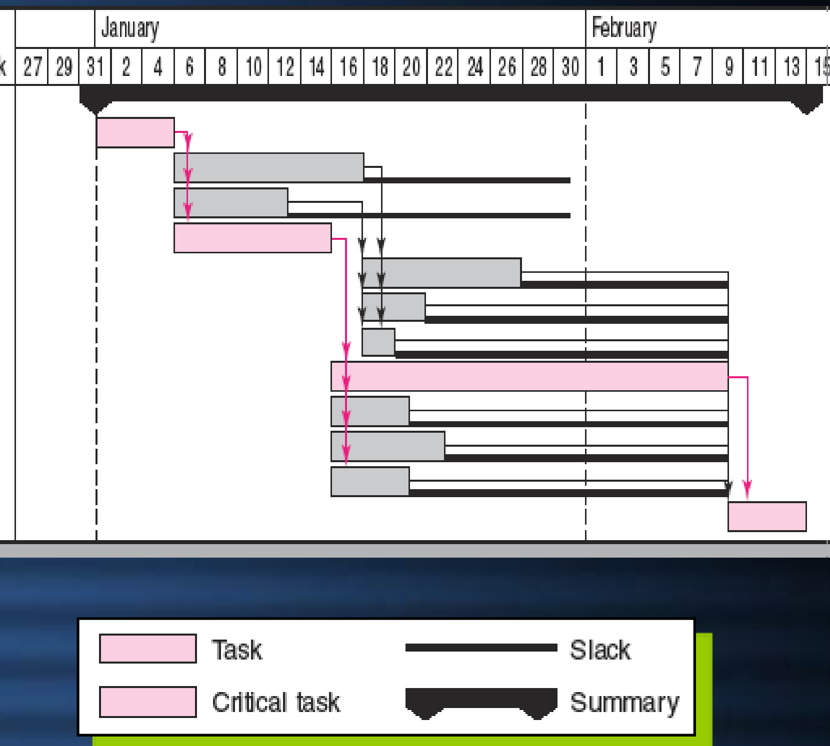


FIGURE 8.7

EMR Project—Time Constrained Resource Usage View, January 15–23, 2005

Resource Name	Work	Jan 15, '05						Jan 21, '05		
		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, 2005

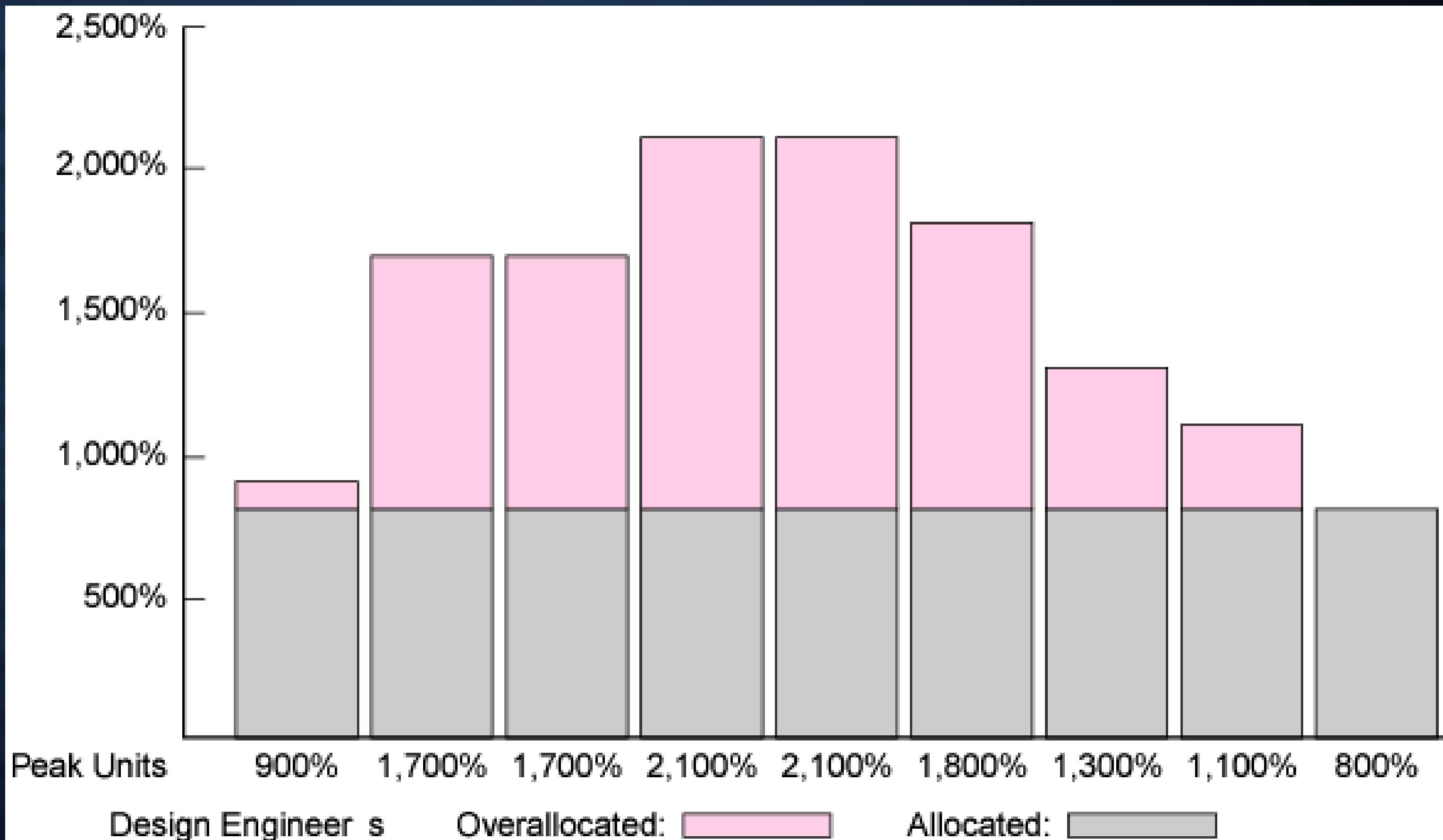


FIGURE 8.A8B

EMR Project Network View Schedule after Resources Leveled

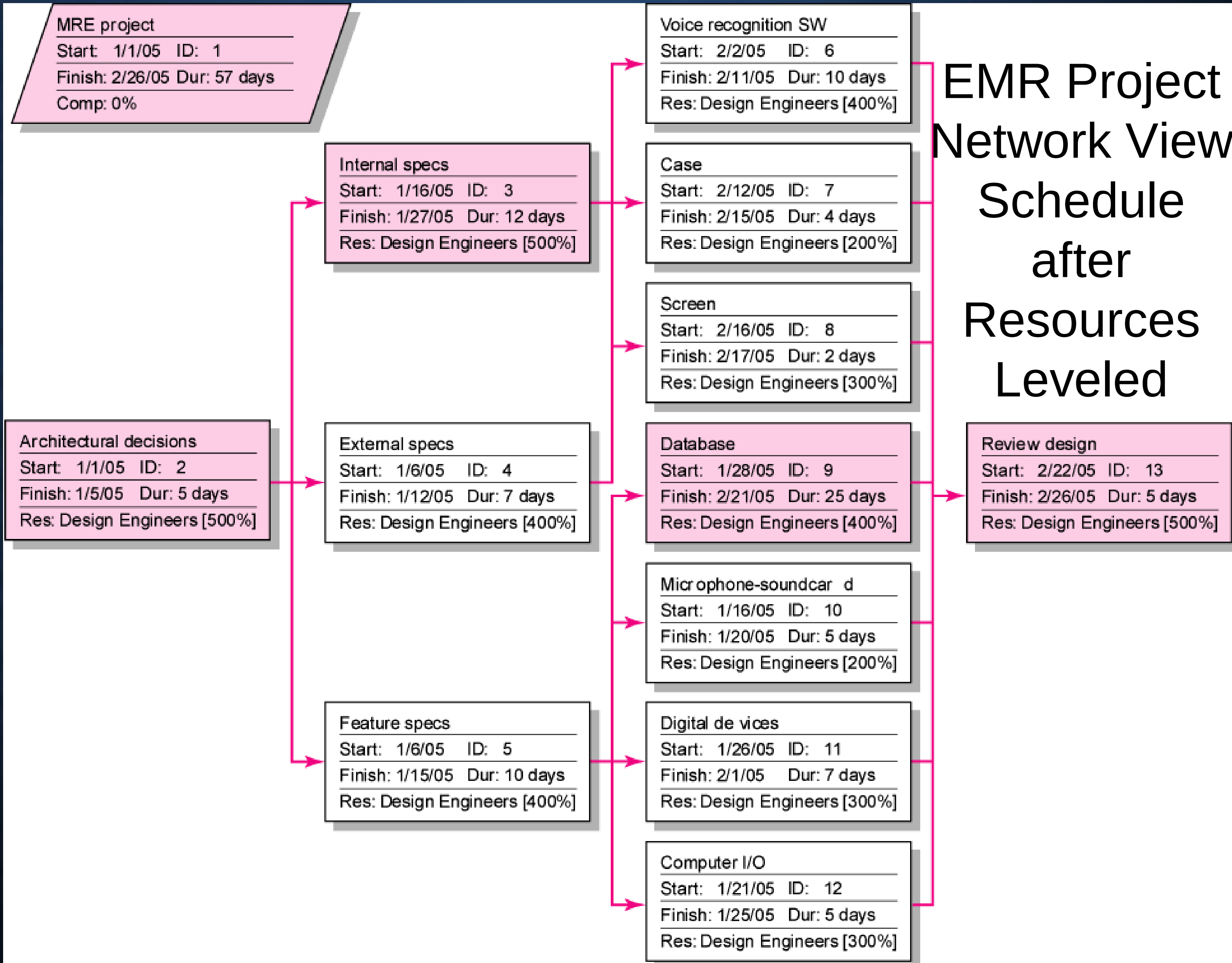


FIGURE 8.9

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

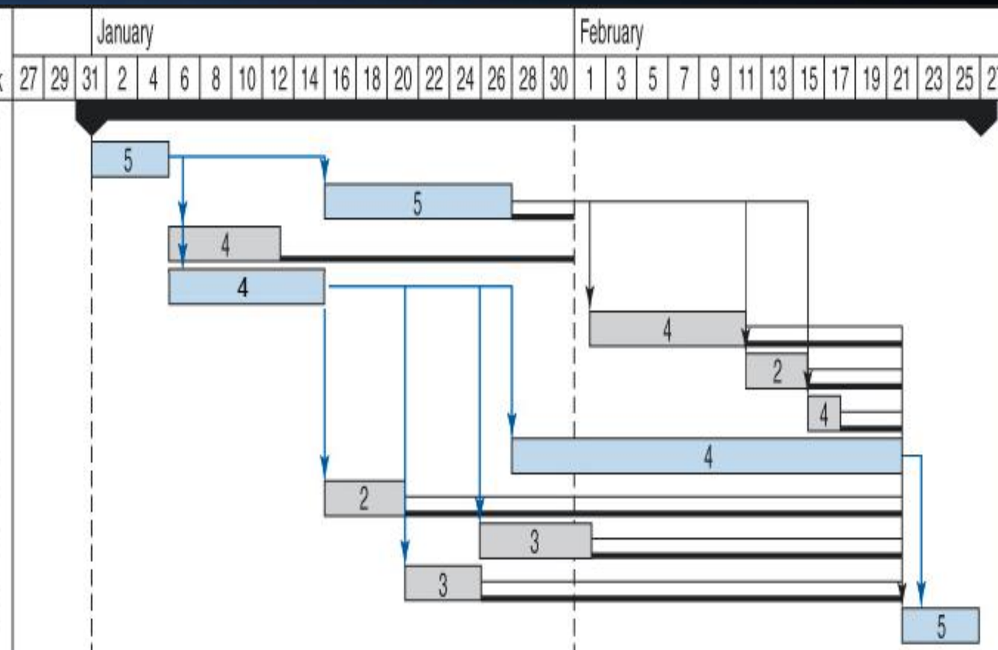


FIGURE 8.10

The Impacts of Resource-Constrained Scheduling

- Reduces delay but reduces flexibility
- Increases sensitivity of the network
- Increases scheduling complexity
- May make traditional critical path no longer meaningful
- Can break sequence of events
- May cause parallel activities to become sequential and critical activities with slack to become noncritical

Splitting/Multitasking

- Splitting/Multitasking
  - A scheduling technique use to get a better project schedule and/or increase resource utilization
    - 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
    - Is considered the major reason why projects fail to meet schedule

Splitting/Multitasking

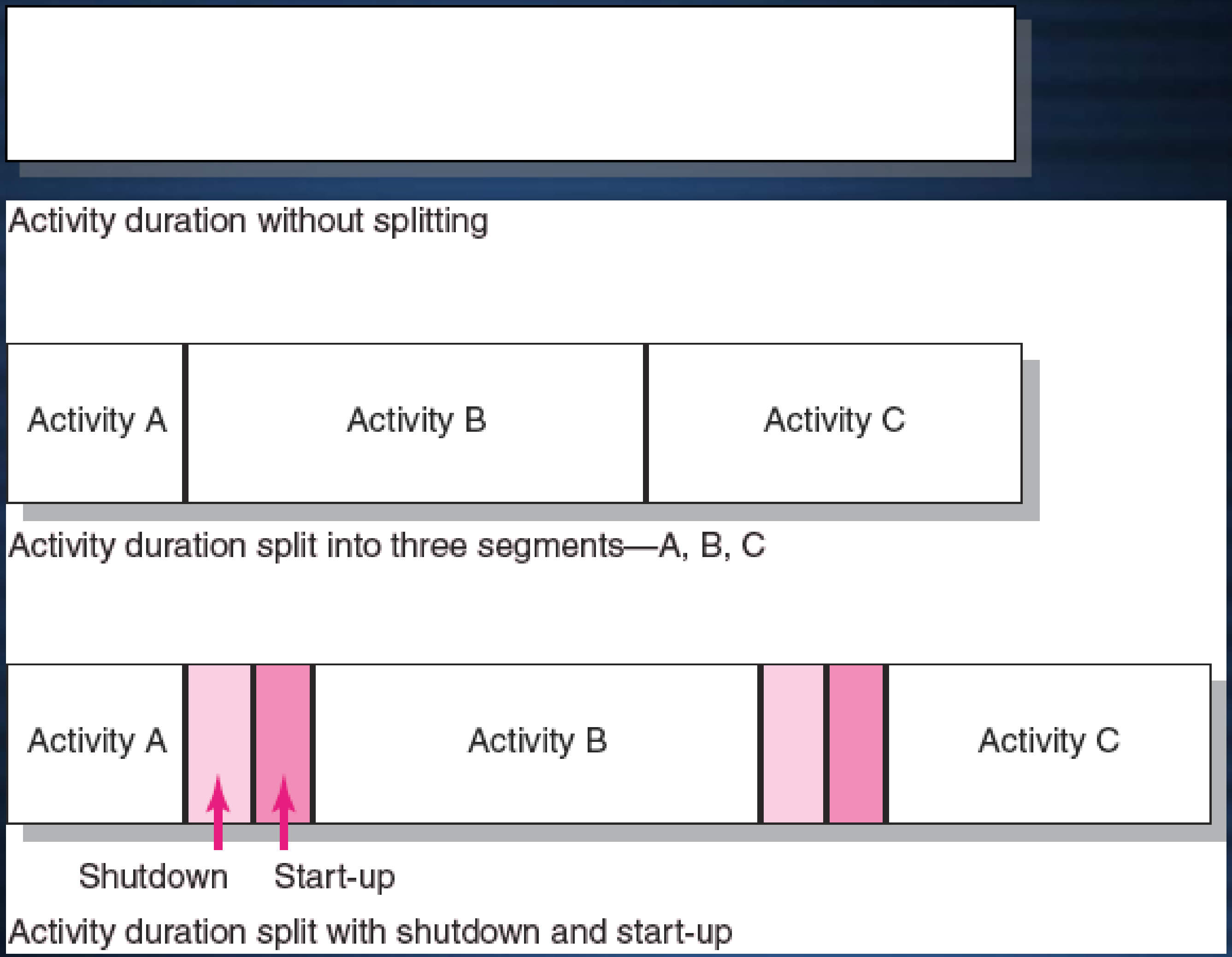


FIGURE 8.11

Assigning Project Work

- Factors to Consider in Assigning Work:
  - Don’t always pick the same people for the toughest assignments.
  - Choose people with an eye to fostering their development through participation on the project.
  - Pick people with compatible work habits and personalities but who complement each other.
  - Team-up veterans with new hires to share experience and socialize newcomers into the organization.
  - Select people who may need to learn work together on later stages of the project or other projects.

Multiproject Resource Schedules

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

Multiproject Resource Schedules

- 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.

Creating a Time-Phased Budget

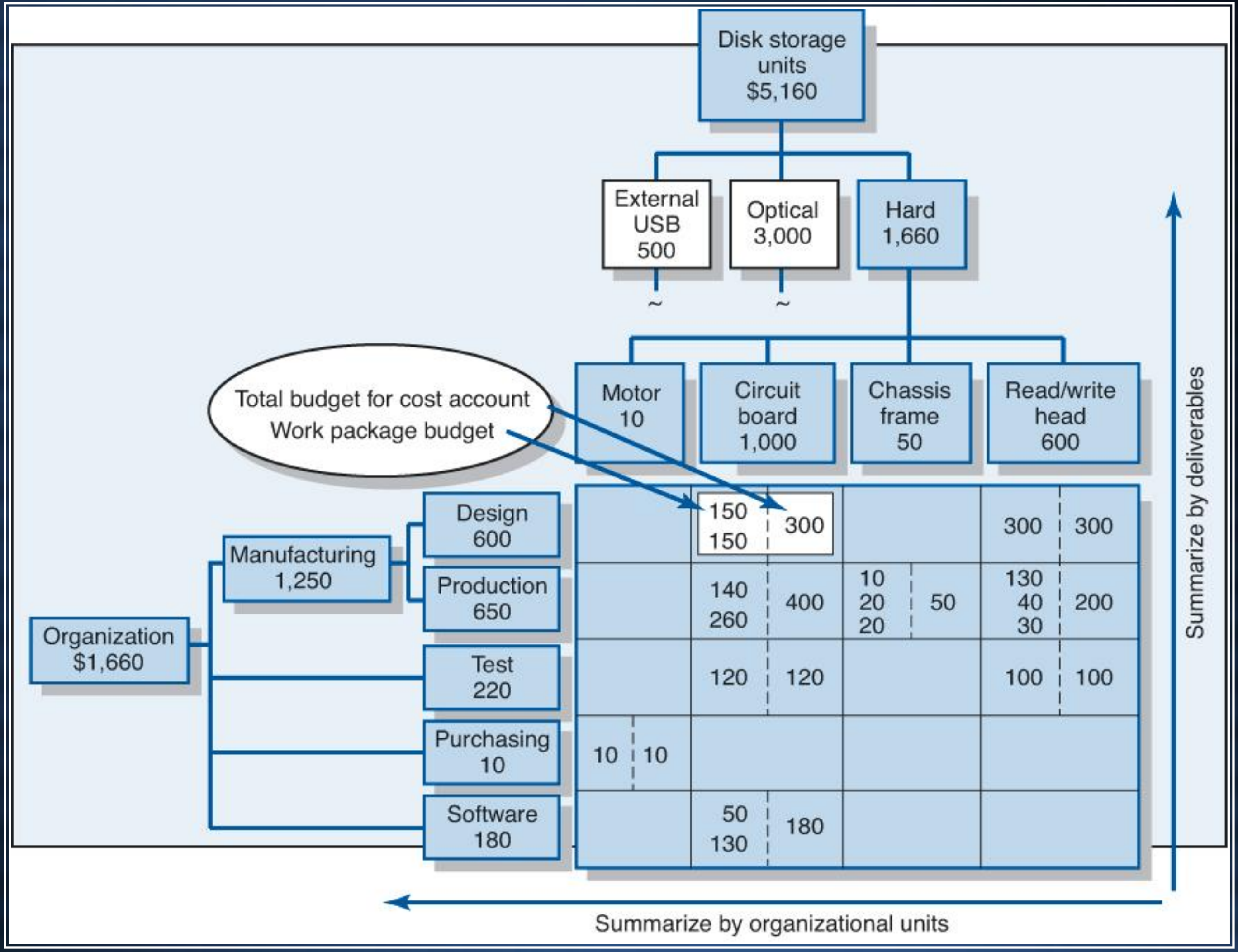


FIGURE 8.12

Creating a Time-Phased Budget (cont'd)

Work Package Time-Phased Budget
Labor cost only

Work Package Description *Test*

Page *1* of *1*

Work Package ID ***1.1.3.2.3***

Project *PC Protoype*

Deliverable *Circuit board*

Date *3/24/xx*

Responsible organization unit *Test*

Estimator *CEG*

Work Package Duration *3* weeks

Total labor cost *$120*

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

FIGURE 8.13

Creating a Time-Phased Budget (cont'd)

Work Package Time-Phased 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 Protoype*

Deliverable *Circuit board*

Date *3/24/xx*

Responsible organization unit *Software*

Estimator *LGG*

Work Package Duration *4* weeks

Total labor cost *$180*

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

Creating a Time-Phased Budget (cont'd)

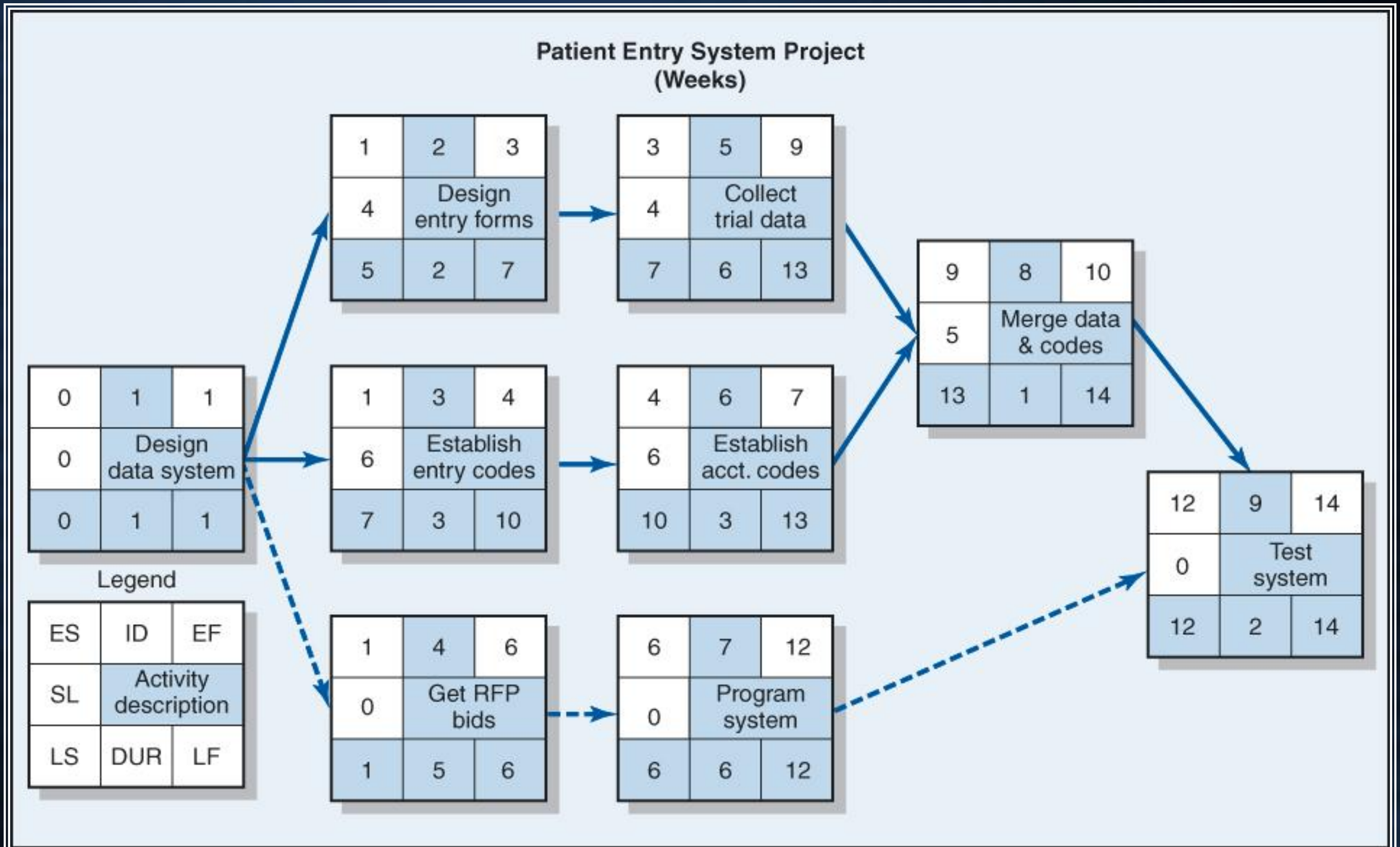


FIGURE 8.15

Creating a Time-Phased Budget (cont'd)

($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

Cumulative Baseline Budget (PV)

FIGURE 8.16

Monthly Cash Flow Statement

	January	February	March	April	May	June	July
CEBOO 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

Resource Usage Table

	12/30/07	1/6/08	1/13/08	1/20/08	1/27/08	2/03/08
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

Heuristic

Leveling/smoothing

Planned value (PV)

Resource-constrained projects

Resource profile

Splitting

Time-constrained projects

Time-phased baseline

Critical Chain Project Management (CCPM)

- **Critical Chain Project Management** is a method of planning and managing projects that puts more emphasis on the resources required to execute project tasks.
- This is in contrast to the more traditional Critical Path and PERT methods, which emphasize task order and rigid scheduling.

Why, if there is a tendency to overestimate activity durations and add safety to a project, do so many projects come in behind schedule?

- Parkinson’s Law
- Self-protection
- Dropped baton
- Excessive multi-tasking
- Resource bottlenecks
- Student syndrome (procrastination)

CCPM in Action

50/50 Estimates

- Three Kinds of Buffers
  - Project – at the end of project to absorb delays
  - Feeder – where noncritical paths merge with the critical chain to protect critical chain from delays
  - Resource – where scarce resources are need to insure they are available

Air Control Project w/o Resources

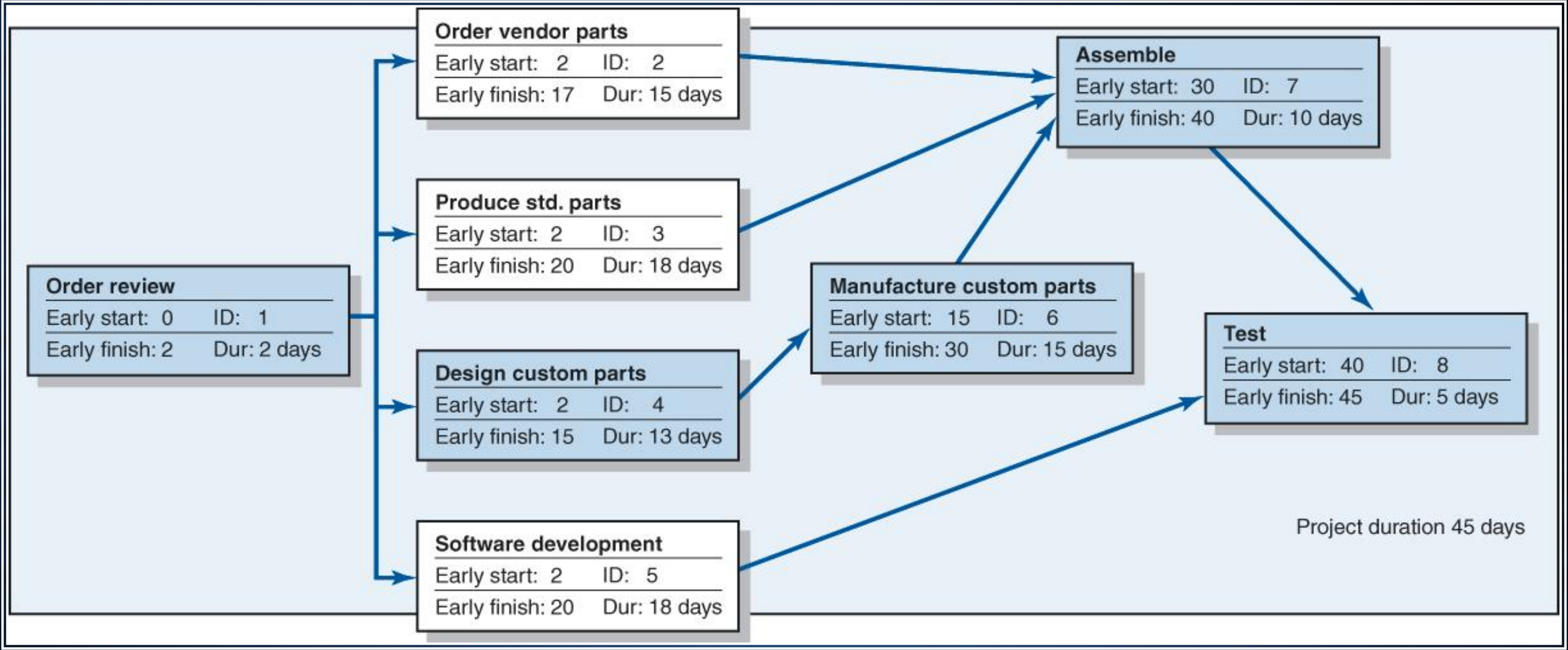


FIGURE A8.1A

Air Control Project: Gantt Chart w/o Resources

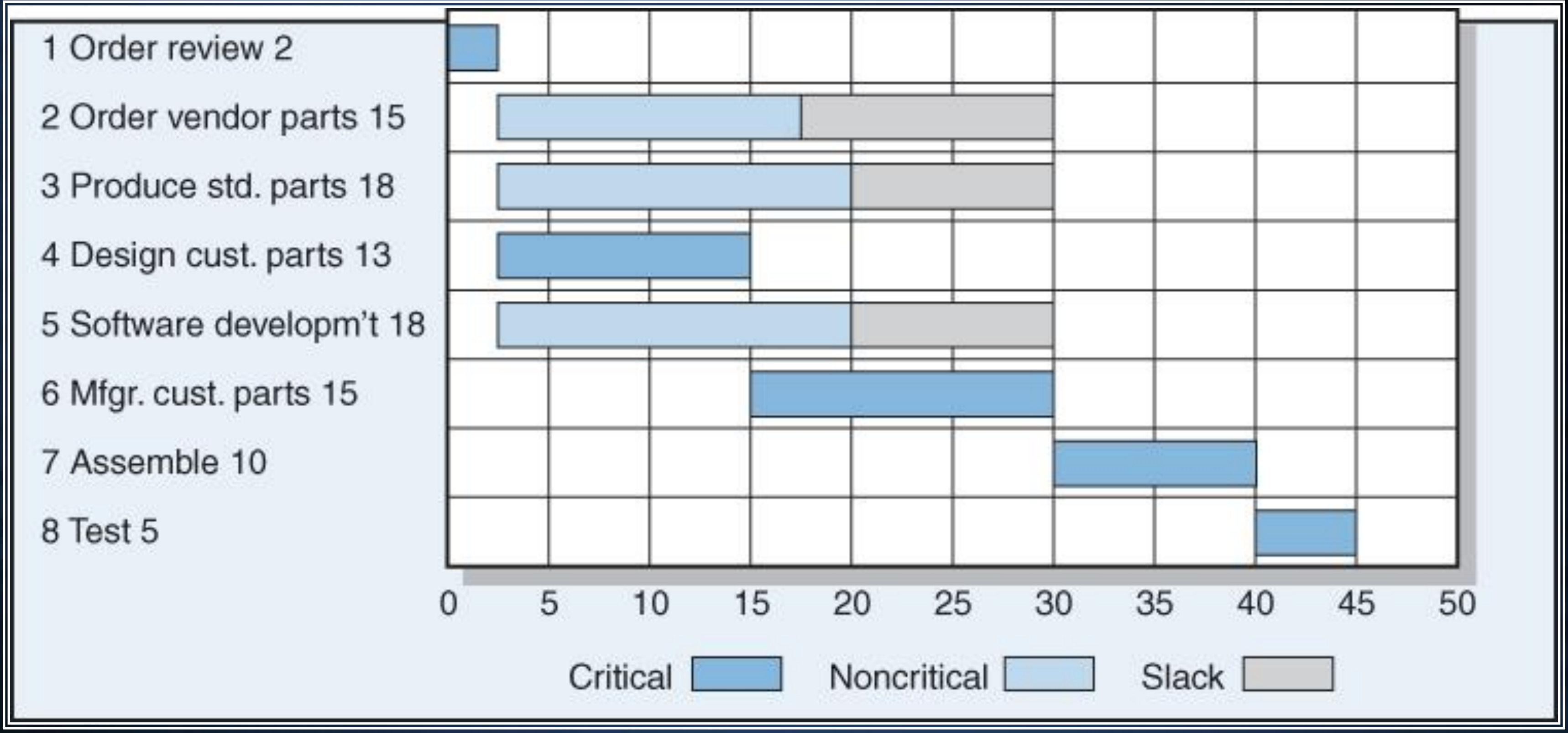


FIGURE A8.1B

Air-Control Project w/ Limited Resources

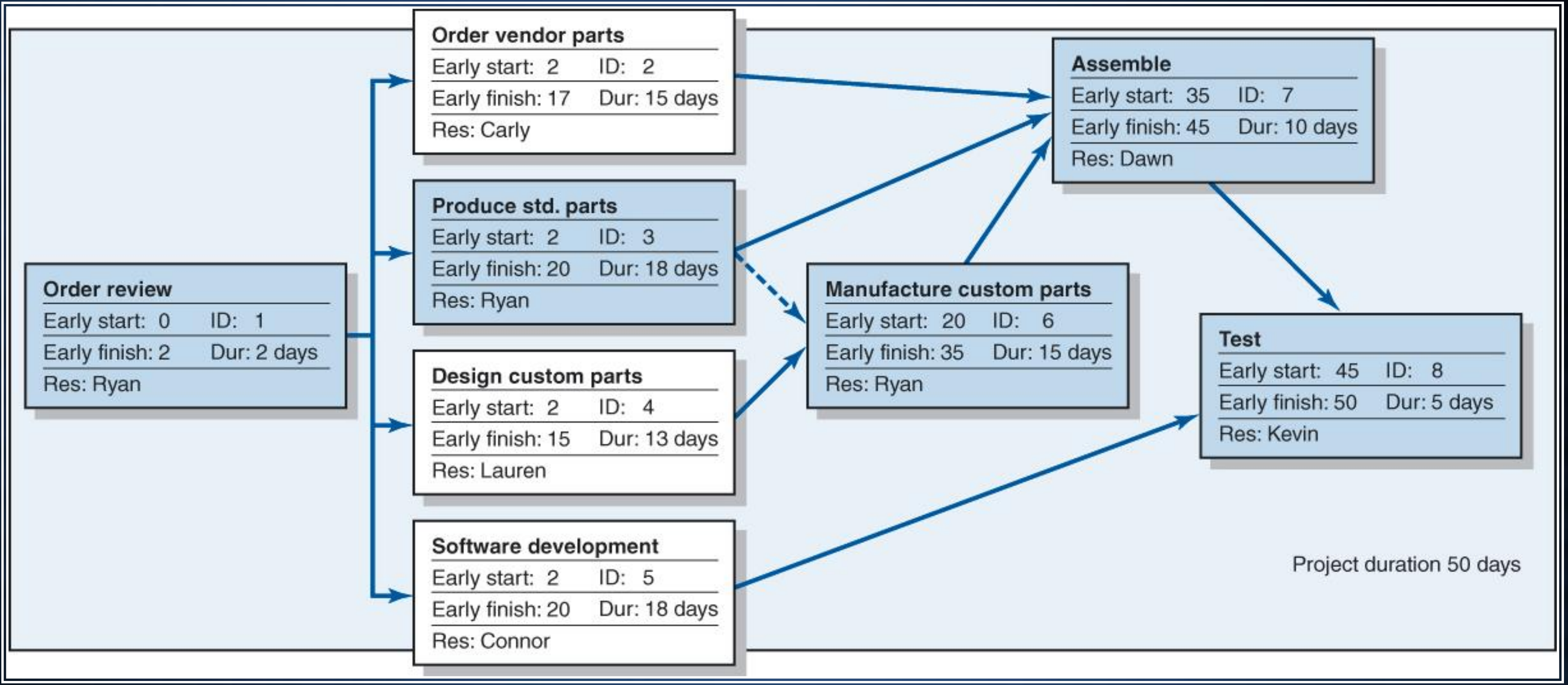


FIGURE A8.2A

Air Control Project: Gantt Chart w/ Limited Resources

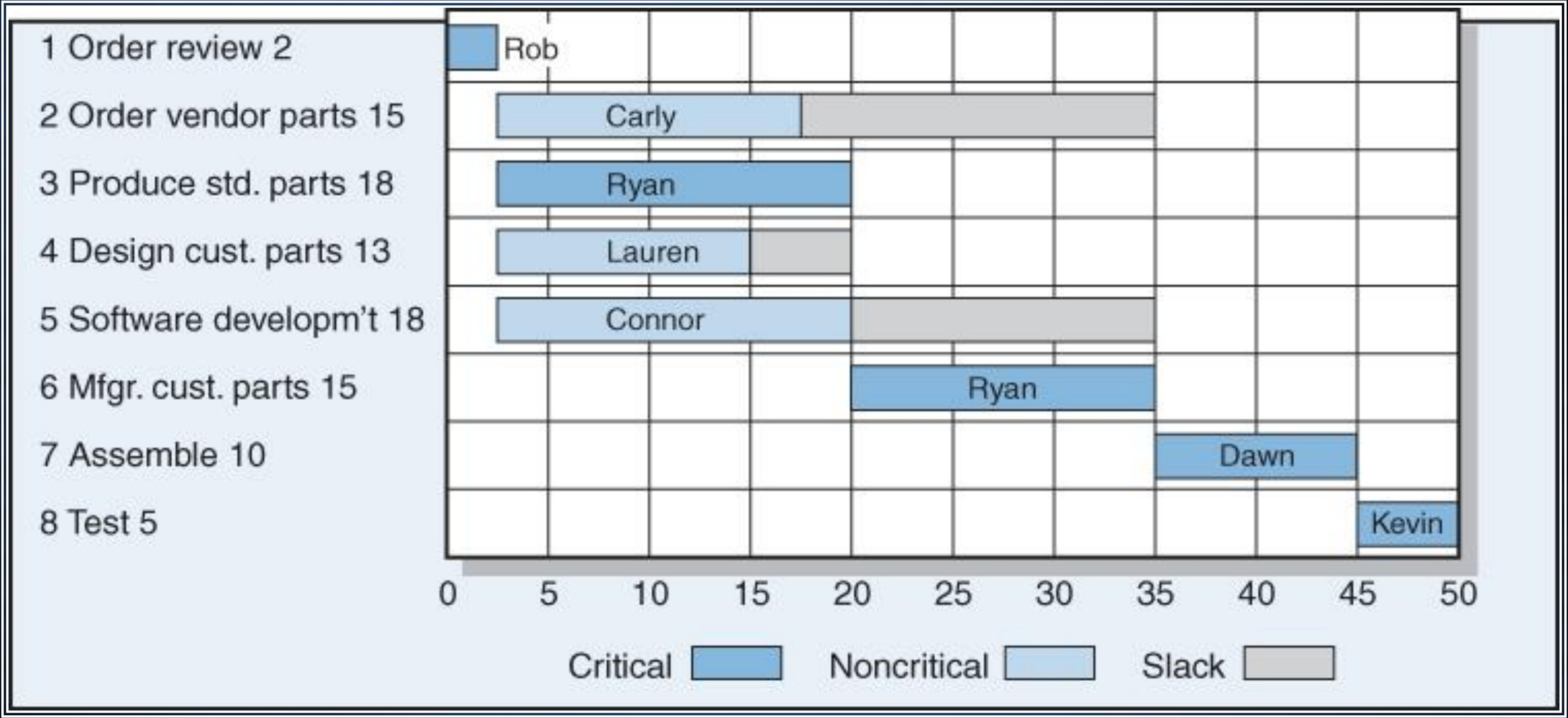


FIGURE A8.2B

Air Control Project: CCPM Network

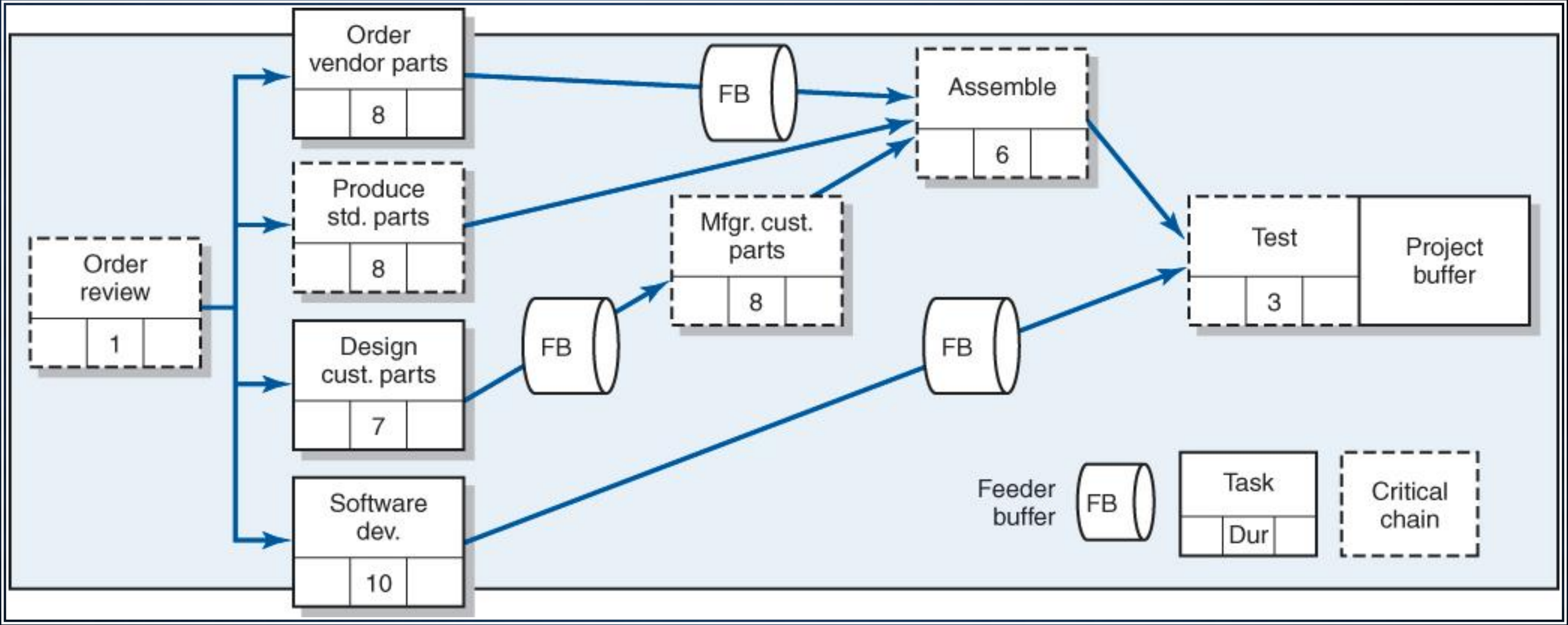


FIGURE A8.3

Air Control Project: CCPM Gantt Chart

Activity	Dur	LS	LF	Buffer
1. Order review	1	0	1	0
2. Order vendor parts	8	7	15	3
3. Produce std. parts	8	1	9	0
4. Design cust. parts	7	1	8	3
5. Software dev.	10	11	21	3
6. Mfgr. cust. parts	8	11	19	0
7. Assemble	6	18	24	0
8. Test	3	24	27	12

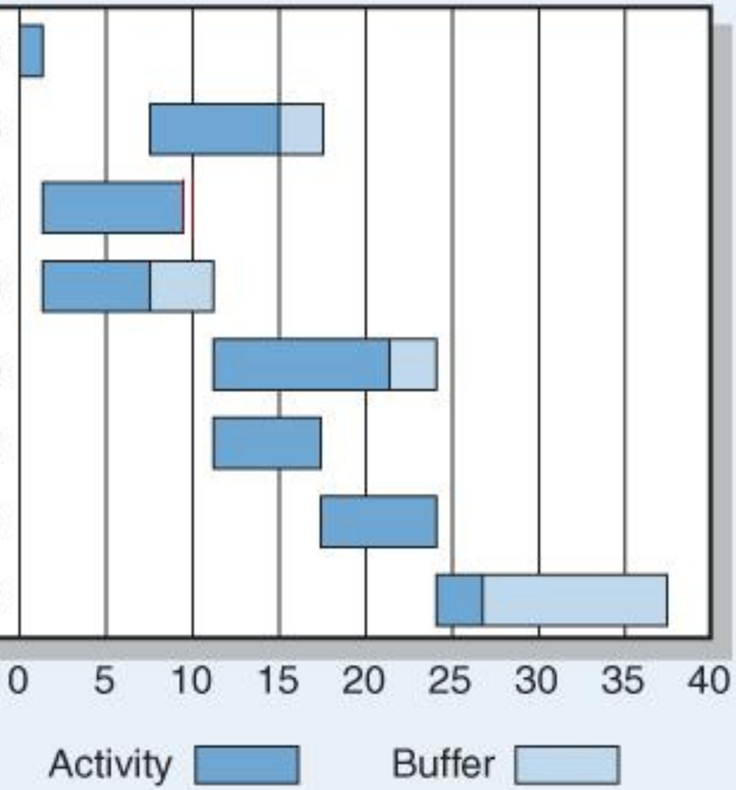


FIGURE A8.4

CCPM: Project Buffer Management

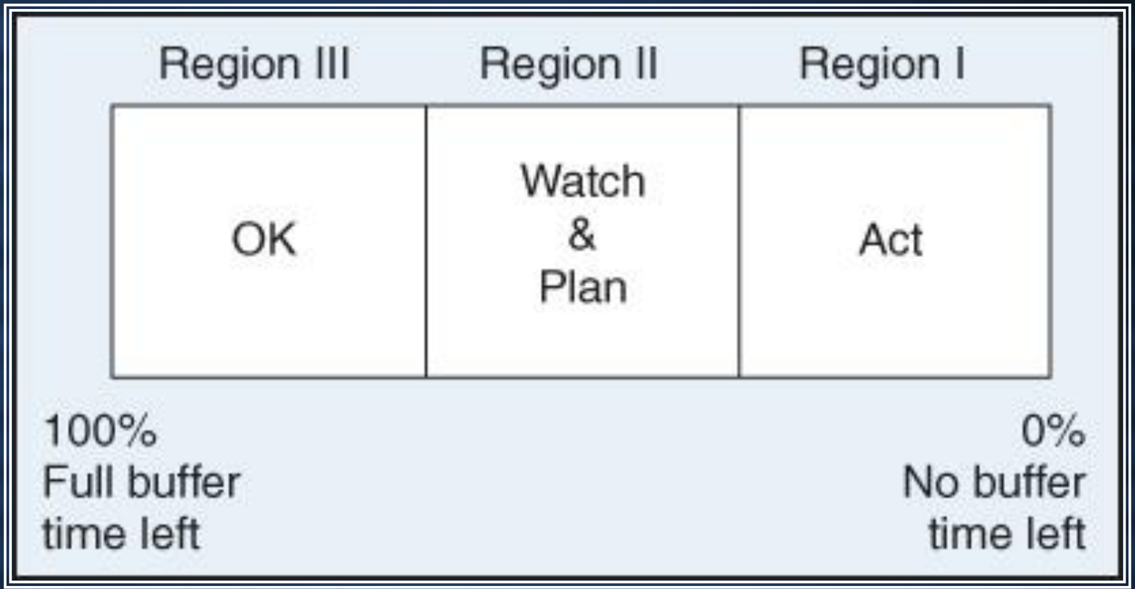


FIGURE A8.5

Critical Chain Project Management (CCPM)

- **Critical Chain is the sequence of both precedence- and resource-dependent activities that prevents a project from being completed in a shorter time, given finite resources.**
- If resources are always available in unlimited quantities, then a project's critical chain is identical to its critical path.