GSOE9820 – Engineering Project Management

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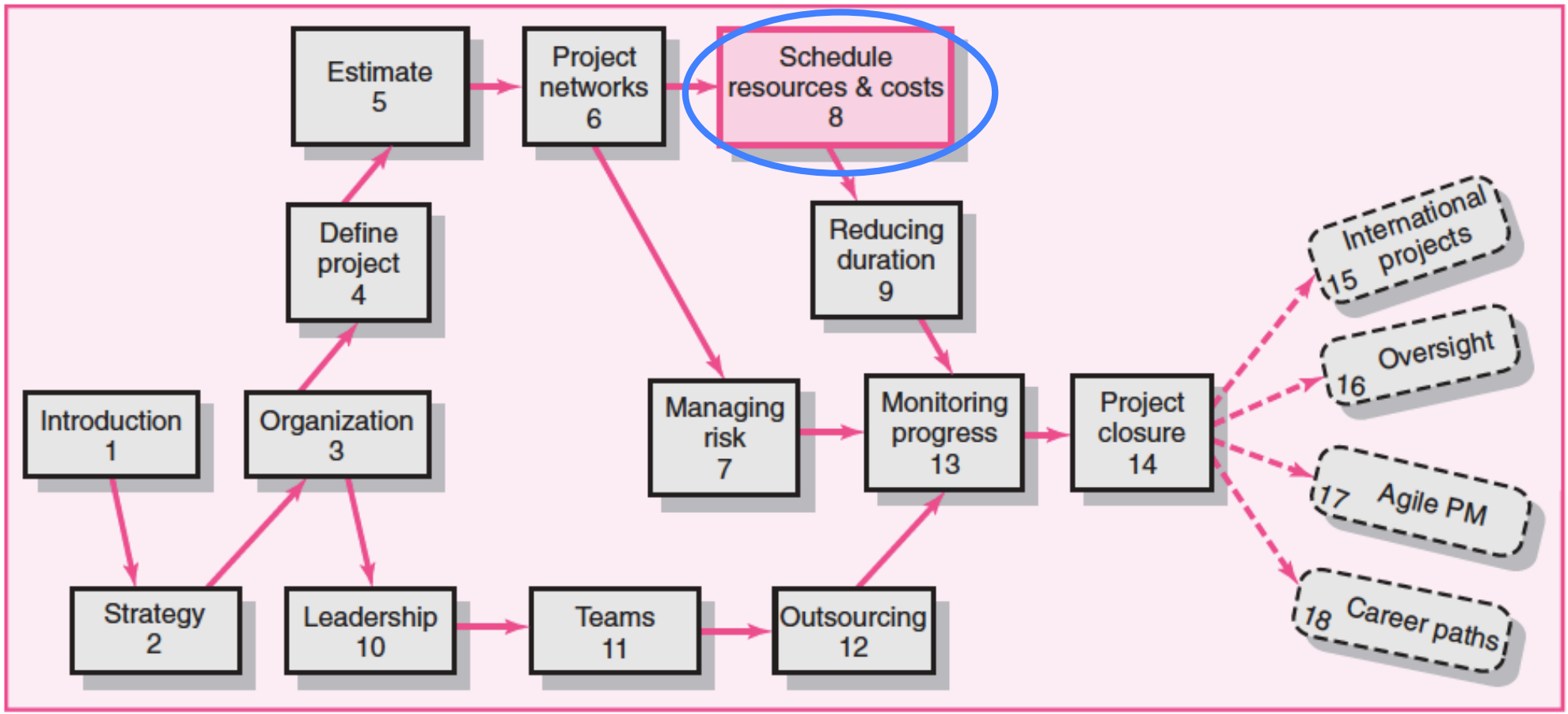
Never Stand Still | Faculty of Engineering | School of Mechanical and Manufacturing Engineering

Week 7
Scheduling Resources and Costs

Course Roadmap



Scheduling of project activities

Up to now the start and sequencing of activities has been based solely on technical or logical considerations.

E.g. design → code → test

A study by Woodworth and Willie found that the duration of a project increased on average by 38% when resources were added to the schedule.

Project baseline / master plan

A baseline is the value or condition against which all future measurements will be compared.

- The baseline is a point of reference.
- Time-phasing baselines are important for a reliable measure of information and control for project status and tracking.

In project management there are three baselines

1. Scope baseline
2. Schedule baseline
3. Cost/budget baseline

The resource problem

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.

Question # 2

The project to create a new market report is to be completed in 12 weeks at an estimated cost of $40,000 (or $3,333 per week)

By the end of the 2nd week, the actual cost is recorded as $9,000.

Are we:

A) Under budget
B) On budget
C) Over budget?

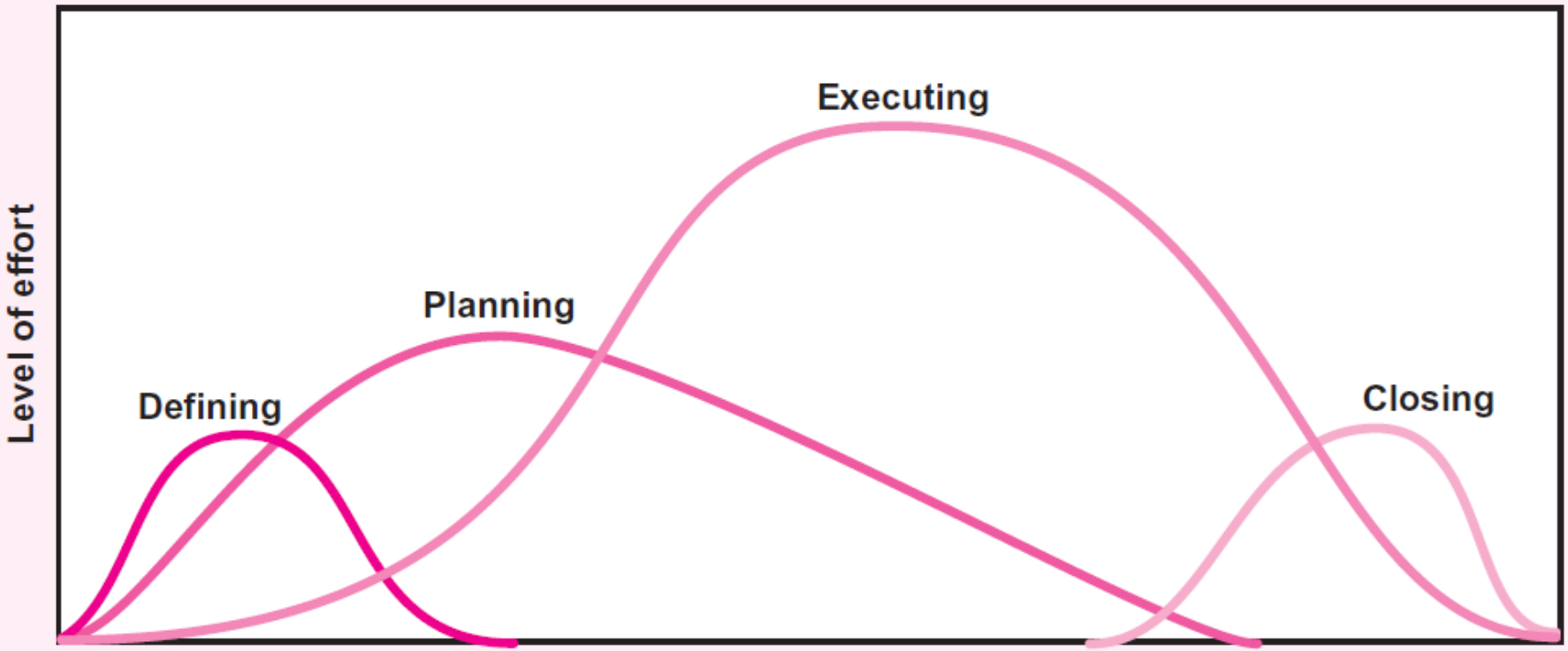
Answer:

You may incorrectly calculate it as ($3,333 x 2 = $6,667), leading you to the conclusion that the project is A) Over budget by $2,333.

However, you CANNOT tell because the budget is not ‘time-phased’.

What is time-phased

Is the distribution of activities, resources and costs over an appropriate time scale for the scheduled completion of a project.



Defining	Planning	Executing	Closing
1. Goals	1. Schedules	1. Status reports	1. Train customer
2. Specifications	2. Budgets	2. Changes	2. Transfer documents
3. Tasks	3. Resources	3. Quality	3. Release resources
4. Responsibilities	4. Risks	4. Forecasts	4. Evaluation
	5. Staffing		5. Lessons learned

Benefits of scheduling resources

Leaves time for consideration of reasonable alternatives:

- cost–time tradeoffs
- changes in priorities

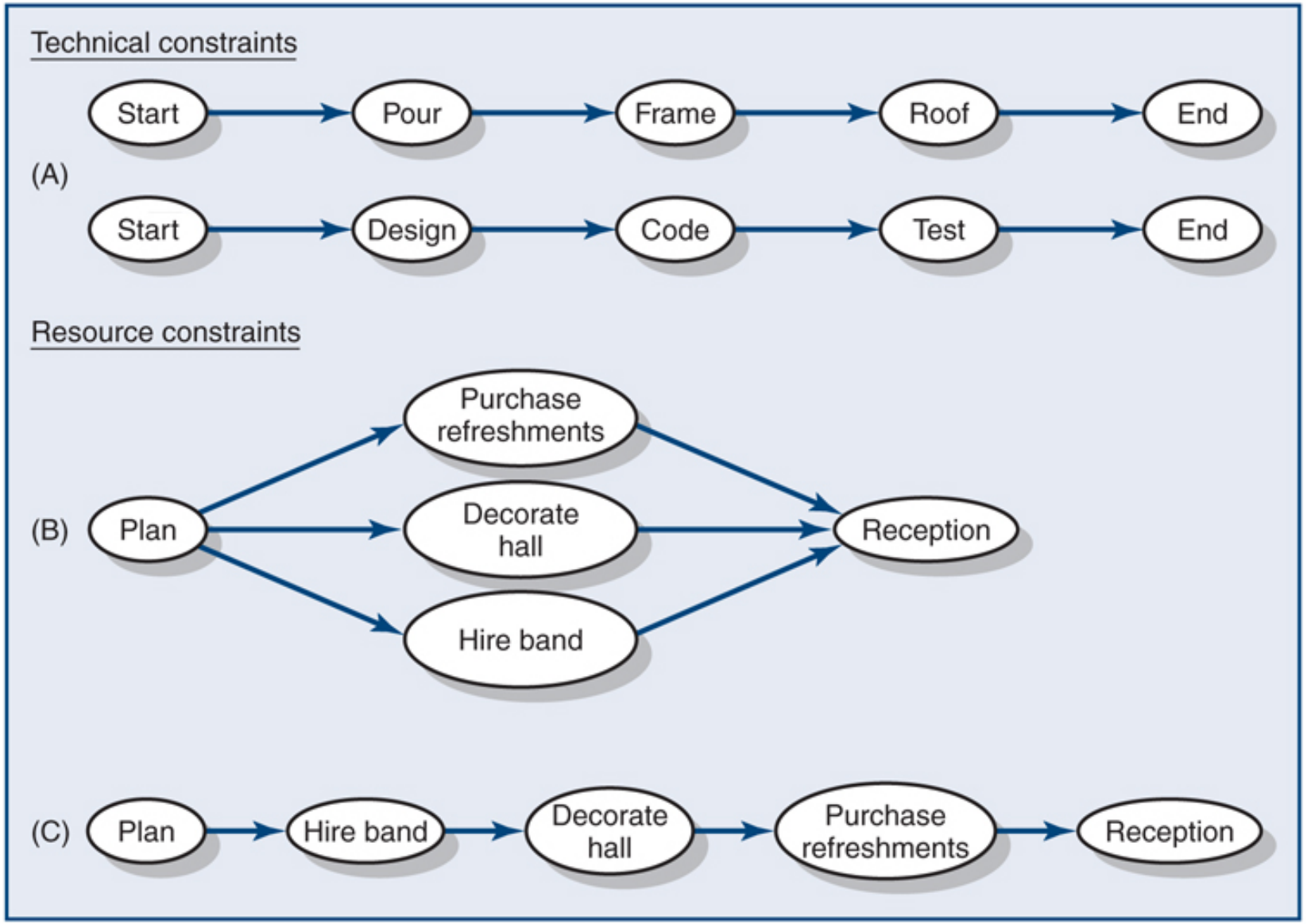
Provides information for time-phased work package budgets to assess:

- impact of unforeseen events
- amount of flexibility in available resources
- Helpful to assess availability of resources when you receive requests from other PM's to borrow resources.

Classification of project constraints

Technical or logic constraints	• Constraints related to the networked sequence in which project activities must occur
Physical constraints	• Activities that cannot occur in parallel or are affected by contractual or environmental conditions
Resource constraints	• The absence, shortage or unique interrelationship and interaction characteristics of resources that require a particular sequencing of project activities

Figure 8.2 CONSTRAINT EXAMPLES



Types of resource constraints

People

Materials

Equipment

Time or Resource constrained?

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.

Resource-constrained project

- 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

Limiting 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.

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.

Resource allocation methods

Resource smoothing (or levelling)

- Involves attempting to even out varying demands on resources by using slack (delaying non-critical activities) to manage resource utilisation 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.

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 utilisation 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 minimised.

Example # 1 - Botanical Garden

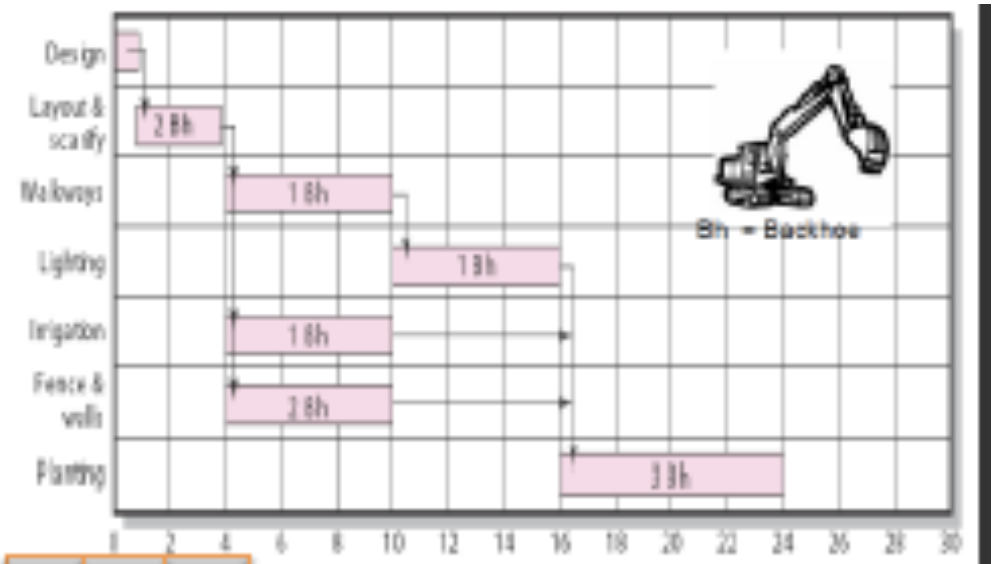
Project is to complete a new garden at the botanical gardens.

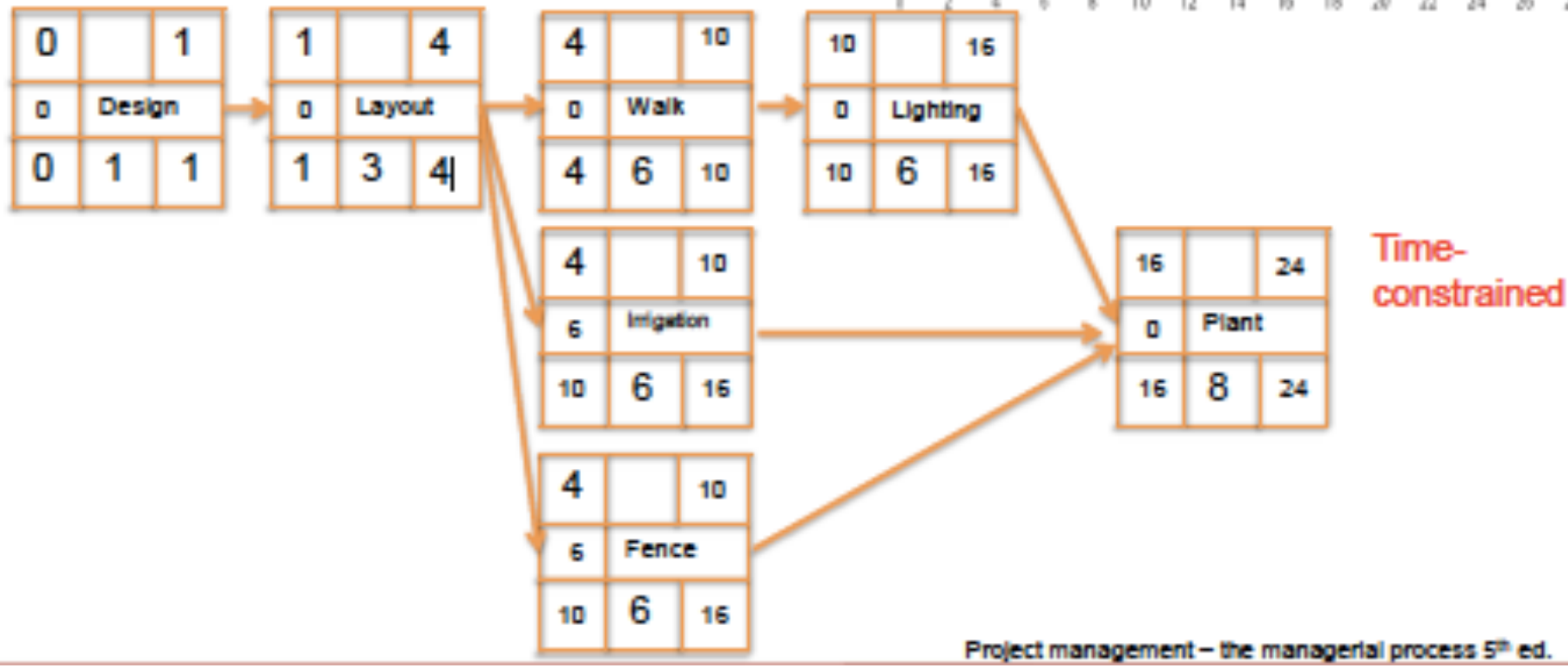
For the purpose of the demonstration, the Botanical Garden example only uses 1 resource (backhoes).

All backhoes are interchangeable.

This example is assumed to be Time-constrained.

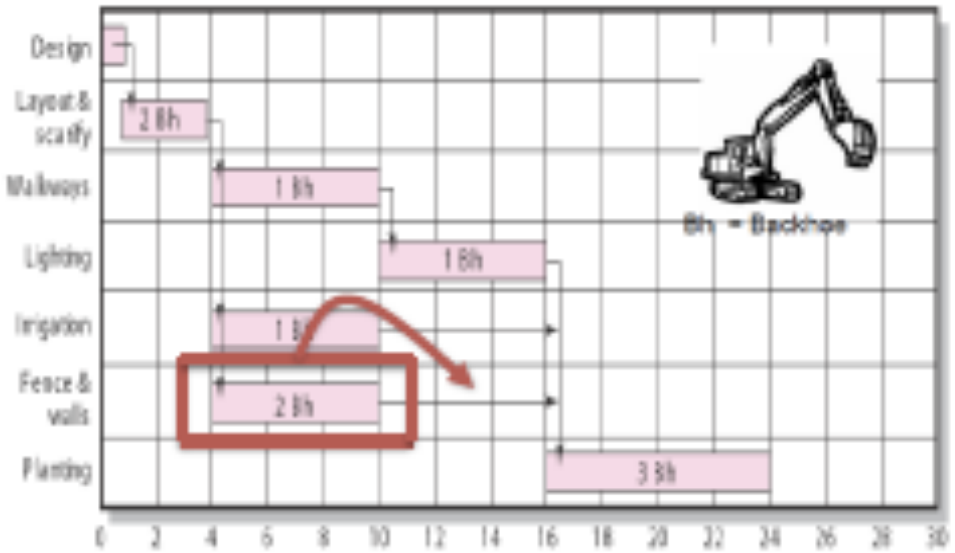
Example: Time-Constrained Project

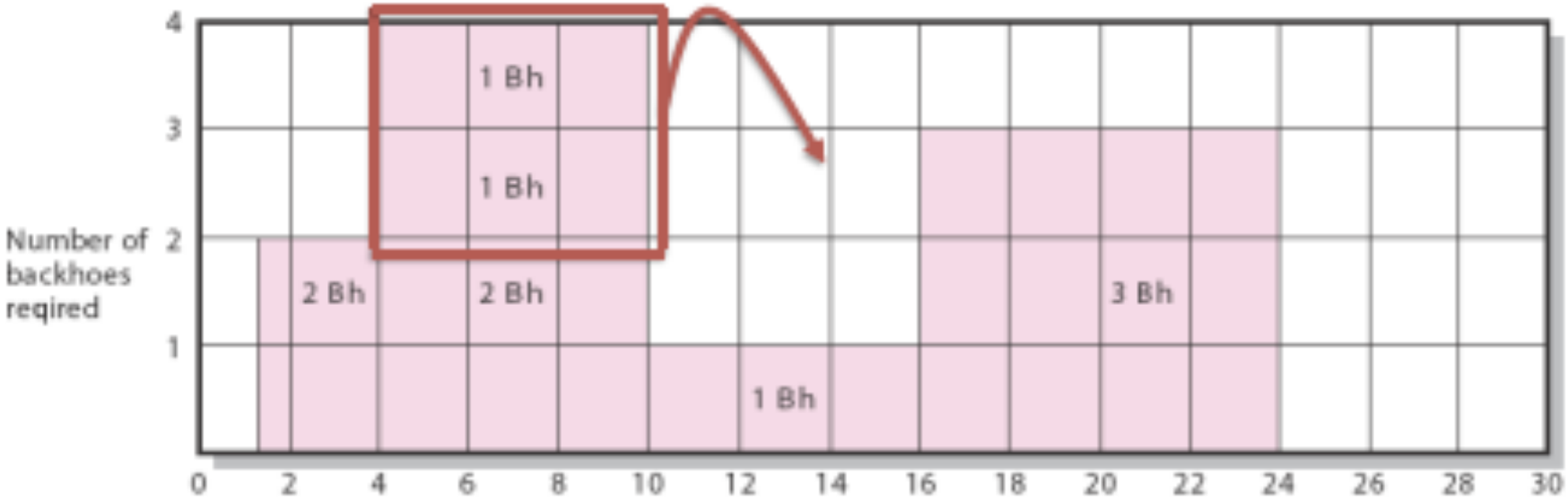


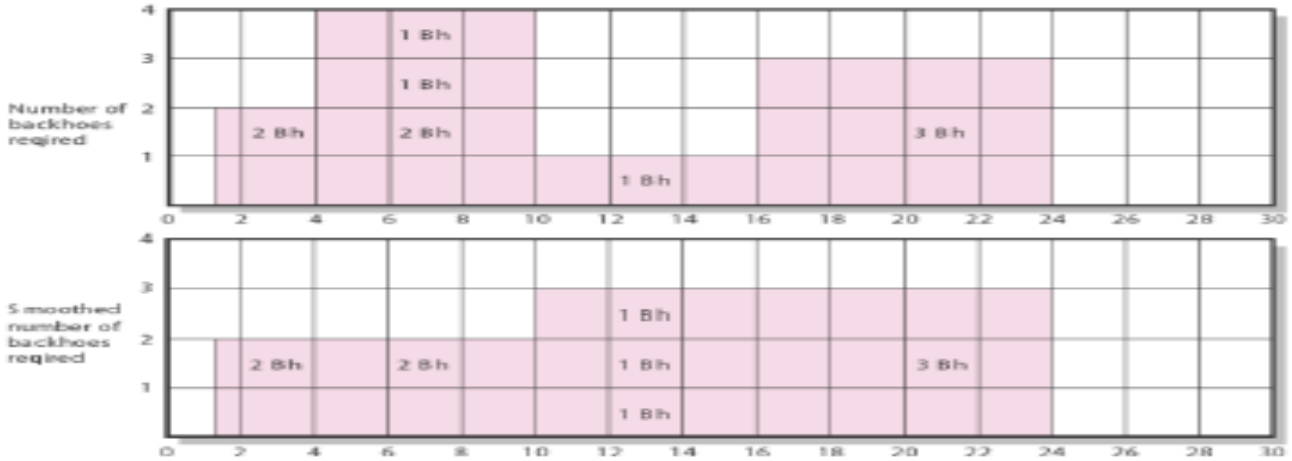


Time-constrained

Project management – the managerial process 5th ed.


Design
Layout & scarify
Walkways
Lighting
Irrigation
Fence & walls
Planting
2 Bh
1 Bh
1 Bh
1 Bh
2 Bh
3 Bh
Bh = Backhoe
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30


Number of backhoes reqired
4
3
2
1
1 Bh
1 Bh
2 Bh
2 Bh
1 Bh
3 Bh
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30



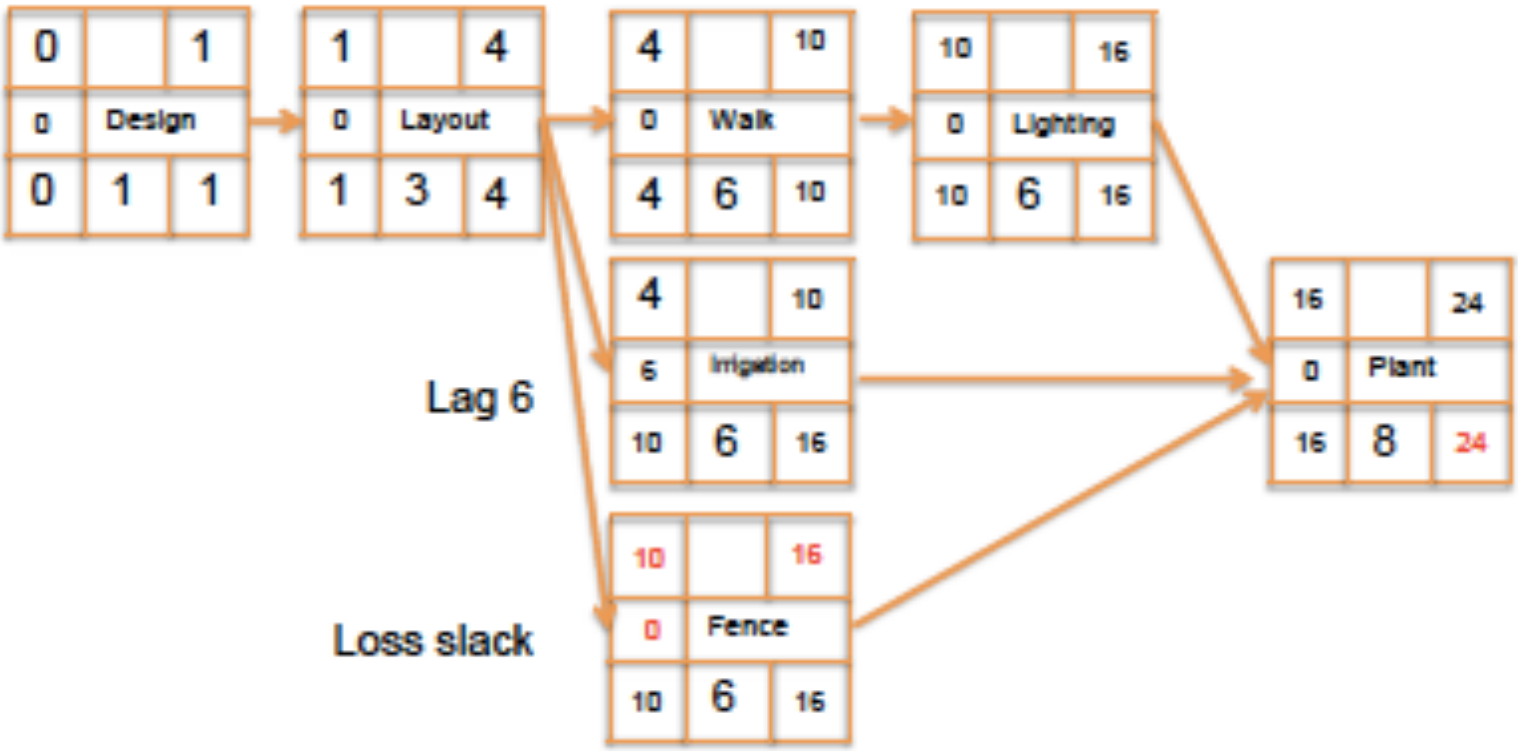
Resource smoothing has achieved the goals of:

- The peak of demand for the resource was reduced from 4 to 3 (25% reduction)
- Resources over the life of the project have been reduced;
- The fluctuations in the resource demand were minimised. (This is helpful as there are often costs involved in the movement of resources (equipment or people).

The downside of leveling is a loss of flexibility by reducing slack and the potential in creating more critical activites.

WARNING: Computer software programs have levelling tools to do this automatically. They however use activities with the most slack to reschedule them, however they do not consider the risk. It is assumed that those activities with the most slack pose the least risk, which may not be the actual case for your project!

New network diagram



Pros and cons: Resource demand leveling techniques

Advantages

- Peak resource demands are reduced
- Resources over the life of the project are reduced
- Fluctuation in resource demand is minimised

Disadvantages

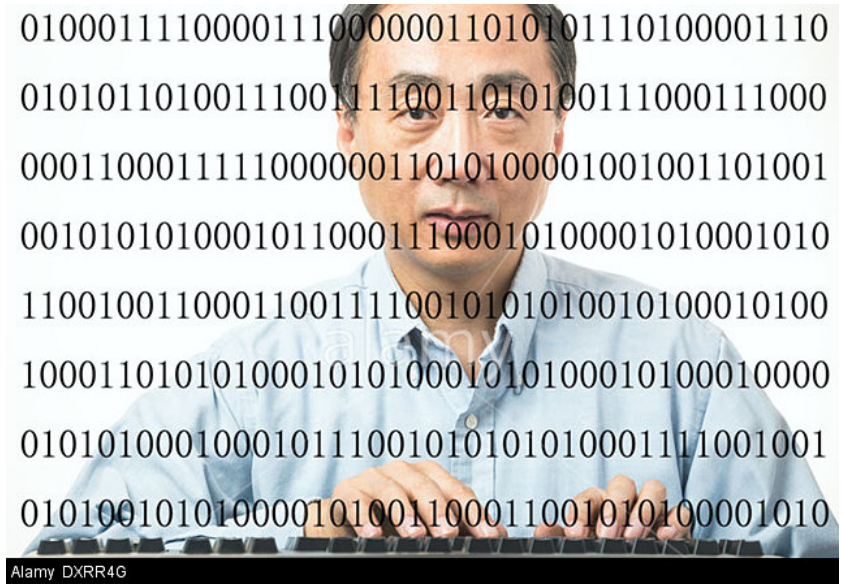
- Loss of flexibility that occurs from reducing slack
- Increases the criticality of all activities and hence sensitivity of the project.

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.

Example # 2 – Software project

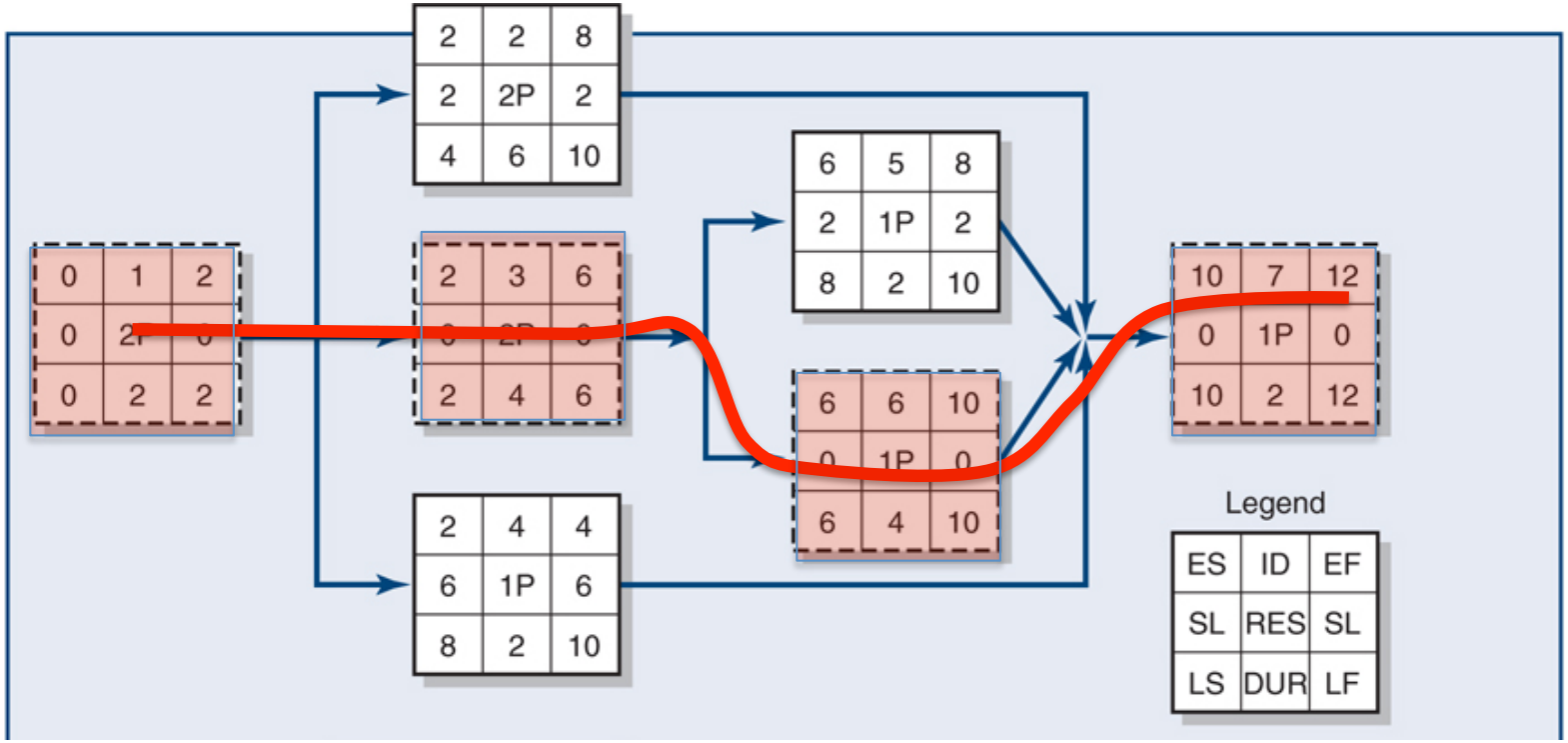


Project is to complete a new software application

For the purpose of the demonstration, the main resource is programmers.

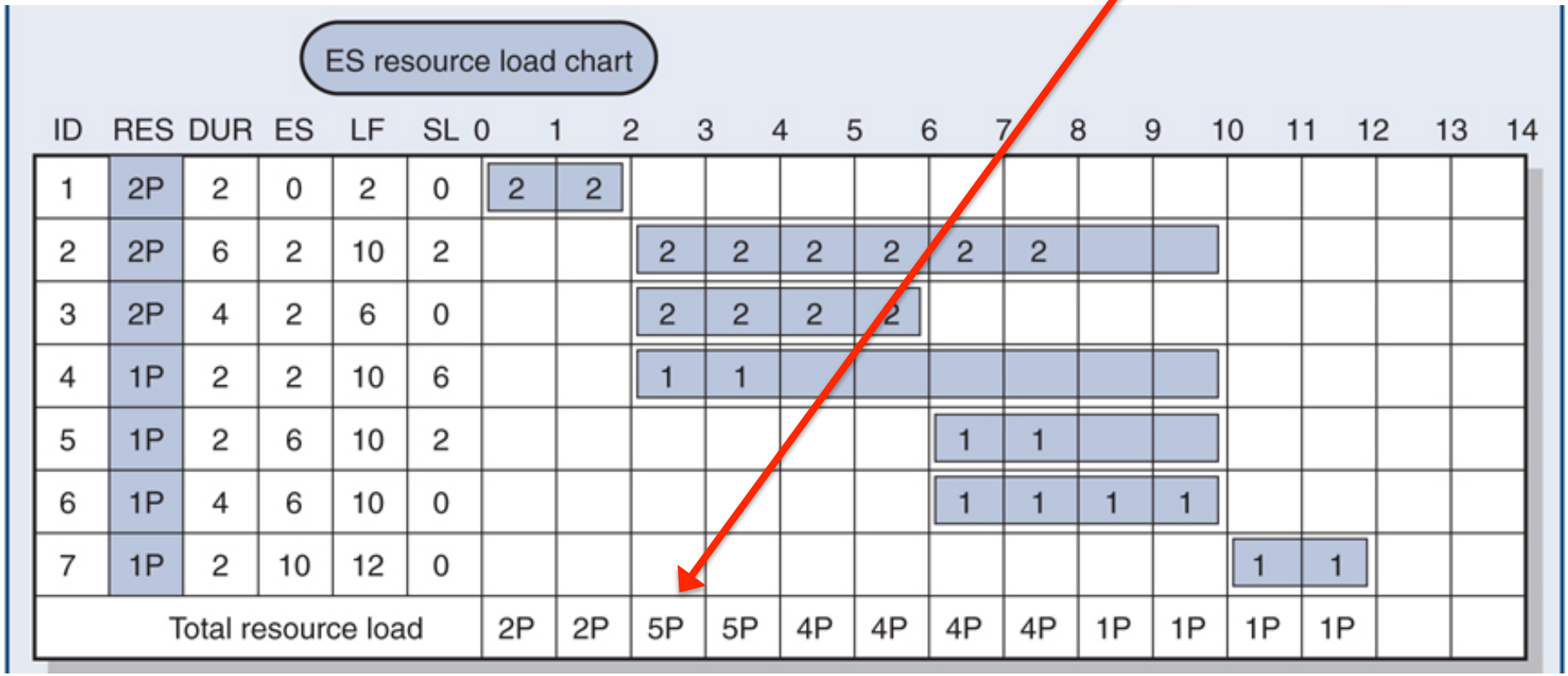
This example is assumed to be resource-constrained with a maximum limitation of 3 programmers available at any one time.

Example: Original Resource-constrained network diagram



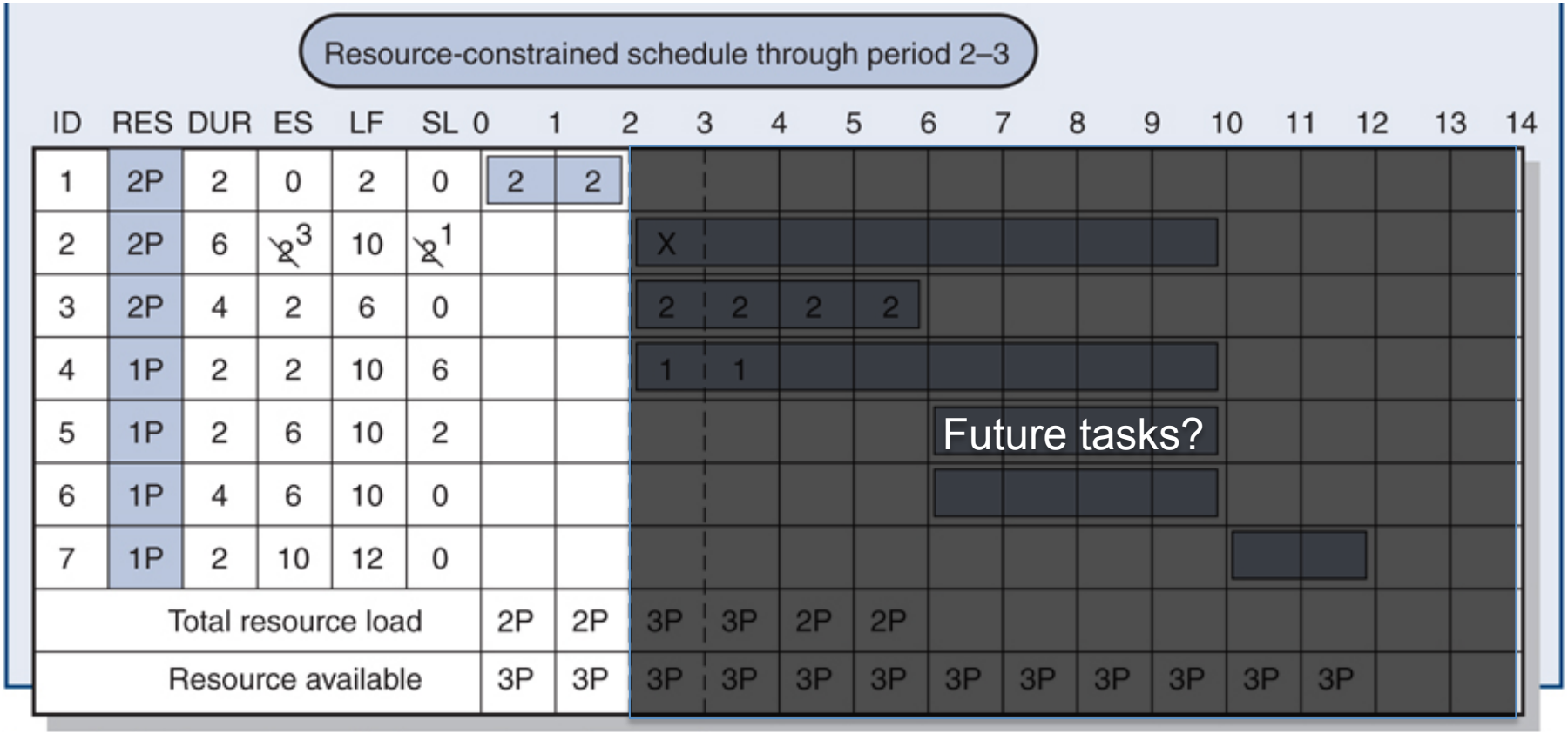
Example: Original Resource-constrained schedule

Note that the limit of 3 programmers will start to delay the project.

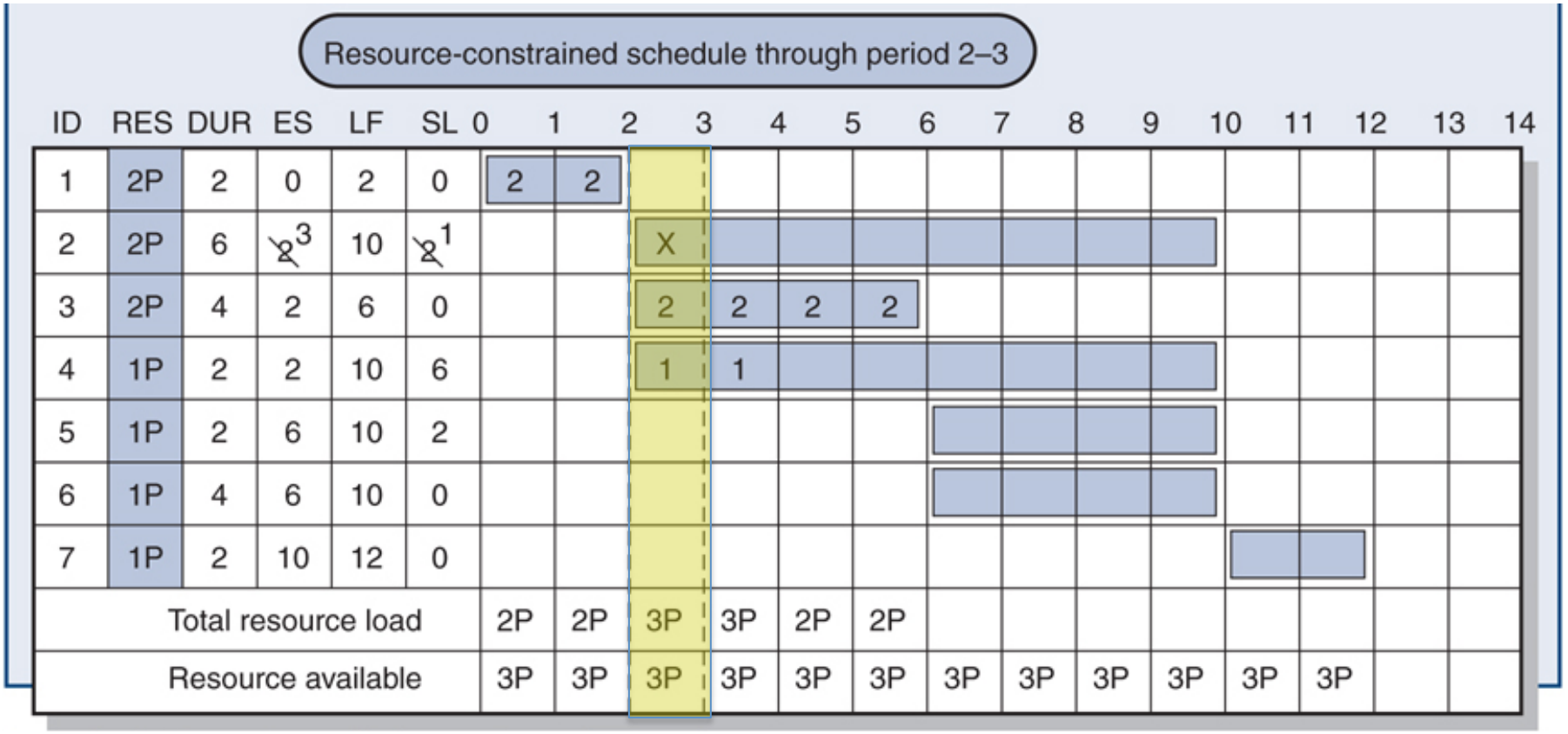


ID	RES	DUR	ES	LF	SL	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2P	2	0	2	0	2	2													
2	2P	6	2	10	2			2	2	2	2	2	2							
3	2P	4	2	6	0			2	2	2	2									
4	1P	2	2	10	6			1	1											
5	1P	2	6	10	2							1	1							
6	1P	4	6	10	0							1	1	1	1					
7	1P	2	10	12	0											1	1			
Total resource load		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

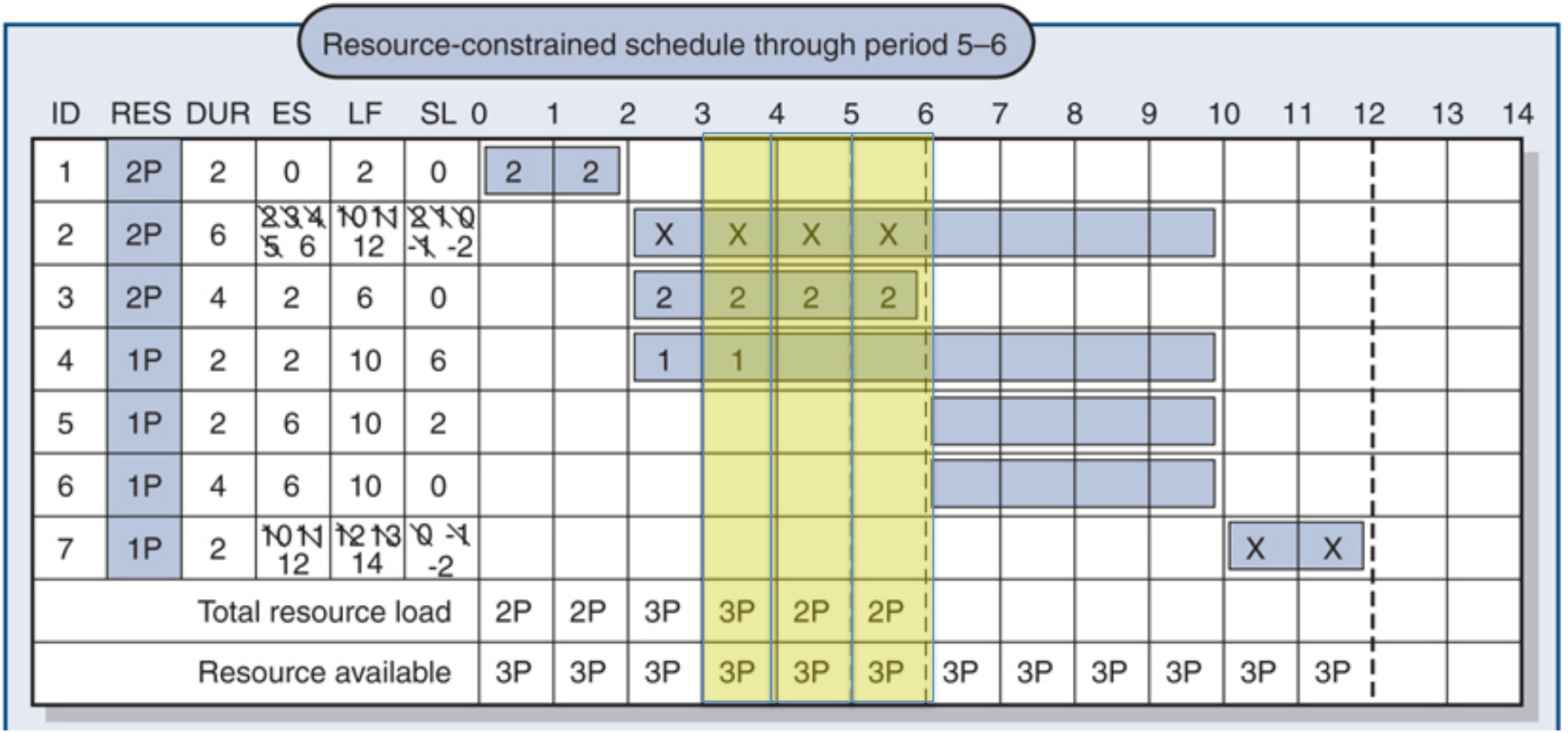
Example: Resource-constrained schedule through to period 2–3



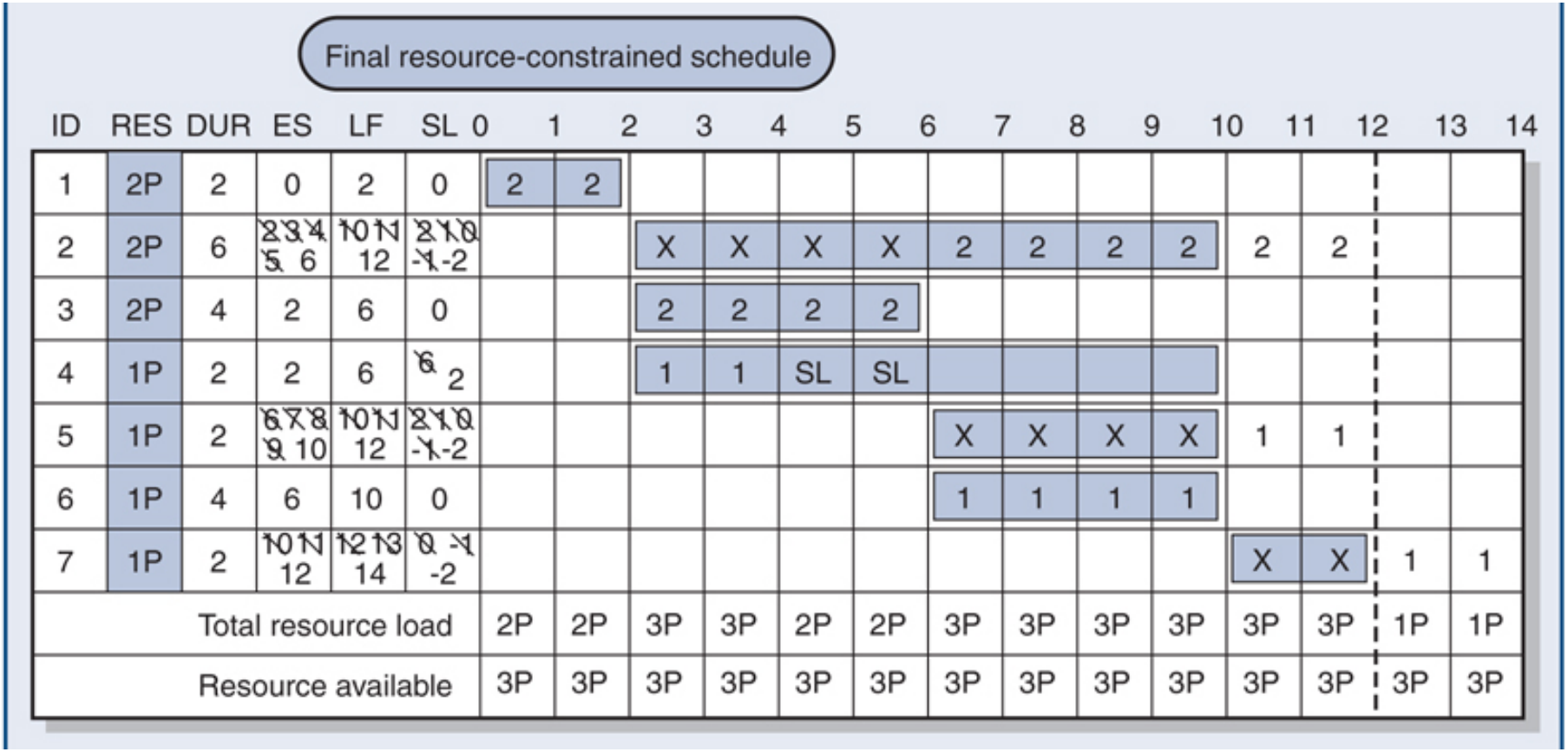
Example: Resource-constrained schedule through to period 2–3



Example: Resource-constrained schedule through to period 5–6

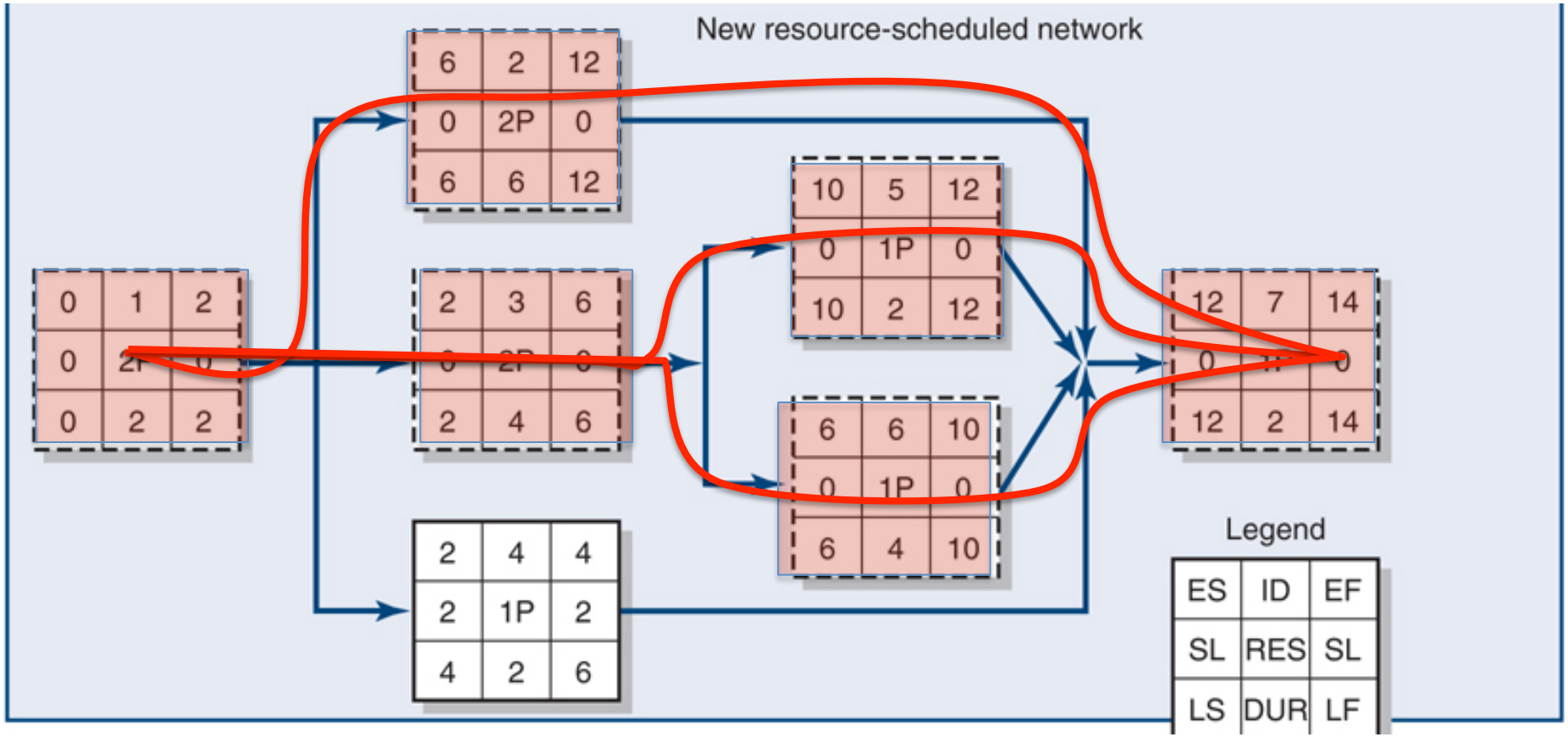


Example: Final resource-constrained schedule



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	

Example: New Resource-constrained network diagram



Outcomes to be observed

- Project duration is now 14 units (original was 12)
- New activity start, finish and slack times
- Activity #6 is still critical (0 slack)
- Slack has been reduced significantly e.g. Activity #4 had 6 units of slack and now only 2.
- The number of critical activities has increased from 4 to 6. (activity #1,2,3,5,6,7)

A note about project management software

The software is not “managing” the project.

It is simply a tool for the project manager to use to view the project from different perspectives and conditions.

Impacts of resource-constrained scheduling

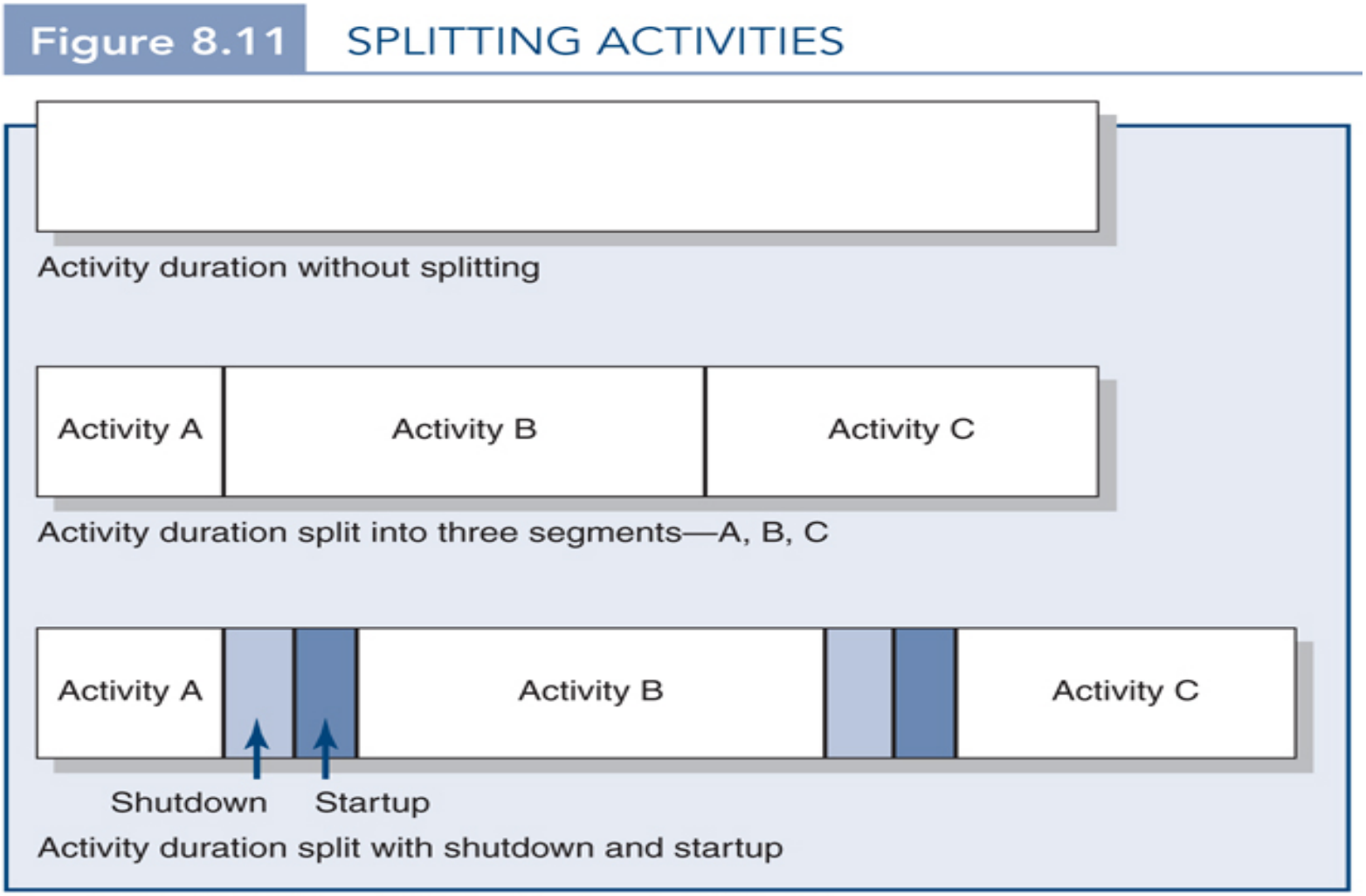
- Reduces delay but reduces flexibility.
- Increases criticality of events.
- Increases scheduling complexity.
- May make the traditional critical path no longer meaningful.
- Can break sequence of events.
- May cause parallel activities to become sequential and critical activities with slack to become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

Splitting activities

A scheduling technique used to get 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;
- Is argued to be one of the major reason why projects fail to meet schedule due to high costs (often hidden) of people switching between jobs.

Splitting activities



Common multi-project scheduling problems

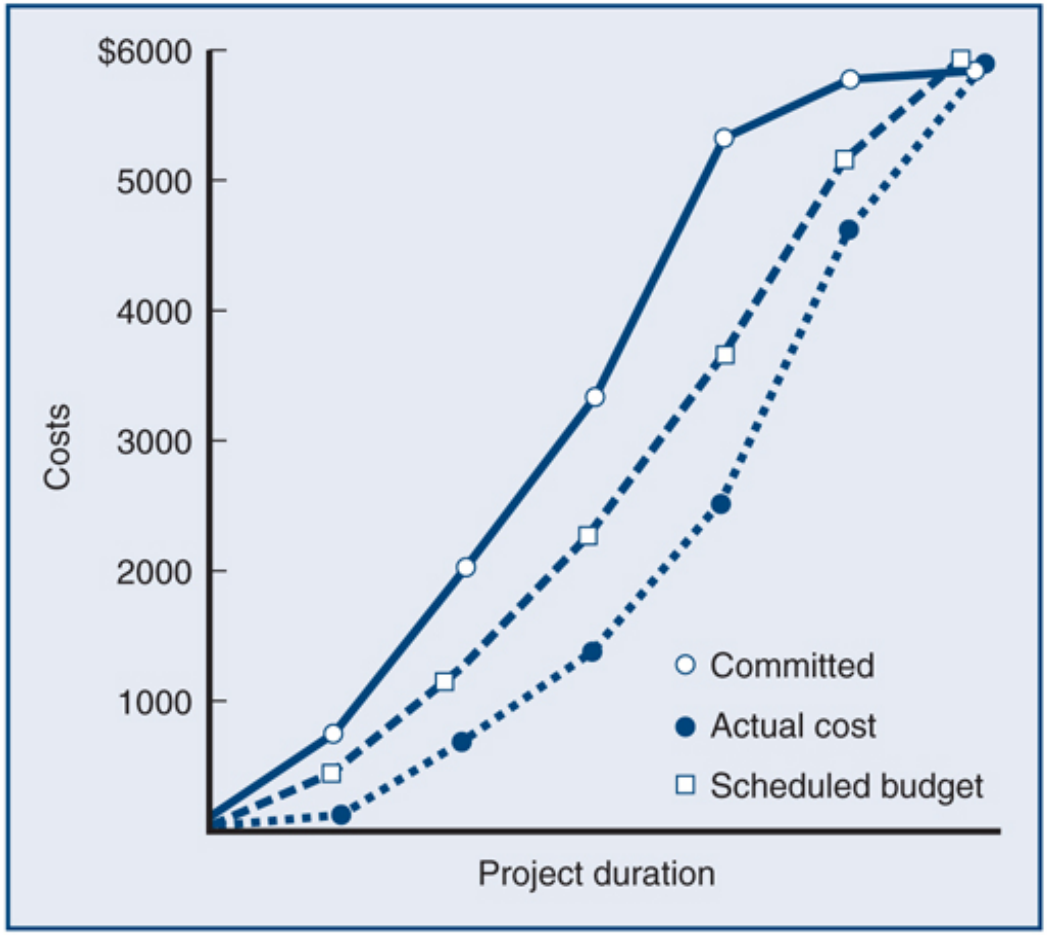
Overall project slippage	• Delay on one project create delays for other projects.
Inefficient resource application	• The peaks and valleys of resource demands create scheduling problems and delays for projects.
Resource bottlenecks	• Shortages of critical resources required for multiple projects cause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

Managing multi-project 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.
- Centralise project management: treat all projects as a part of a ‘megaproject’ (i.e. could be a program)
- Outsource projects to reduce the number of projects handled internally.

Recall: Three views of cost

Figure 5.6 THREE VIEWS OF COST

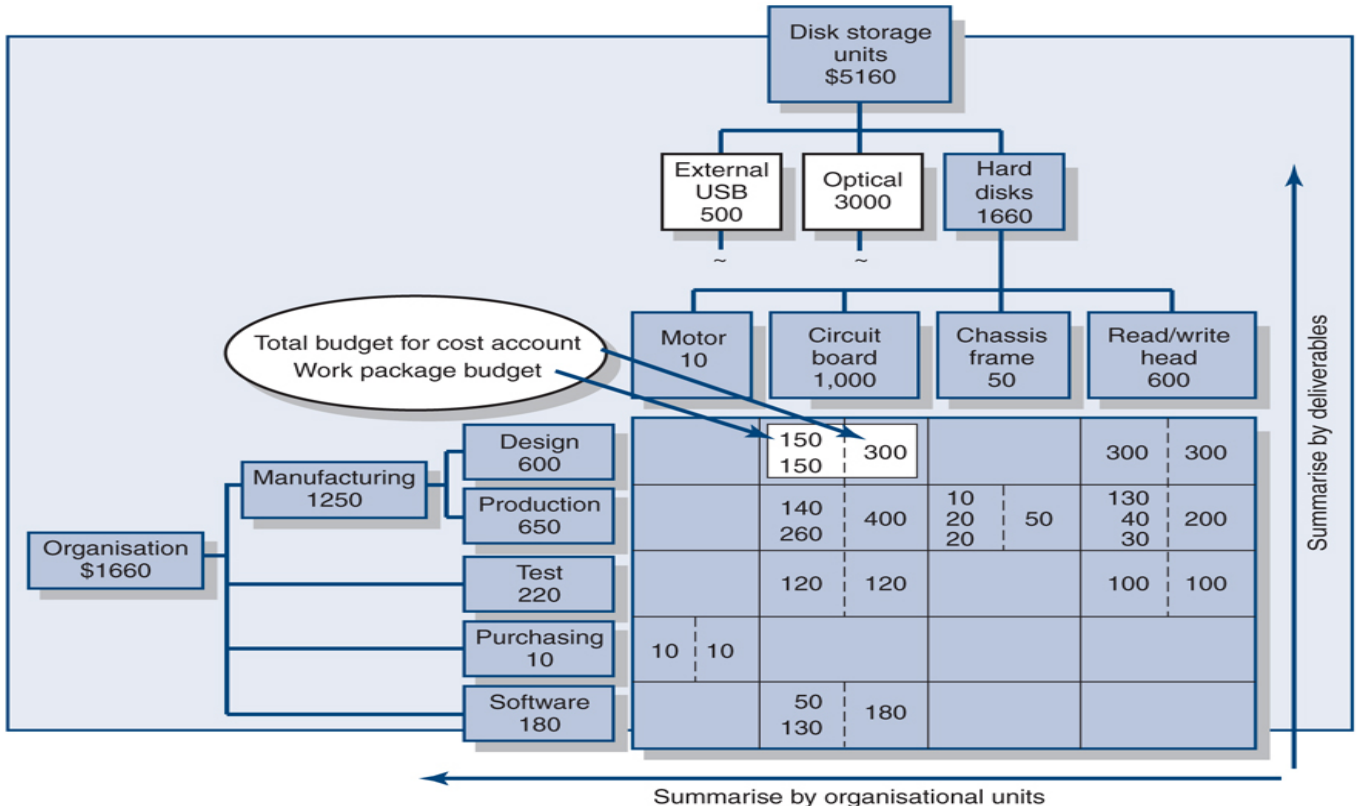


PC Prototype project example # 4:

Developing a time-phased budget baseline

Example: PC Prototype project

Figure 8.12 DIRECT LABOUR BUDGET ROLLUP ($000)



Each intersection of the WBS/OBS matrix shows cost accounts and work package budgets and total cost. The total cost at each intersection is called a cost or control account. WBS is the starting point to time-phase work packages and assign resources to the respective activities.

Example: PC Prototype project *continued*

Figure 8.13 TIME-PHASED WORK PACKAGE BUDGET (LABOUR COST ONLY)

Time-phased work package budget (labour 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 organisation unit *Test* Estimator *CEG*

Work package duration *3* weeks Total labour cost *$120 000*

Time-phased labour budget ($000)

Work package	Resource	Labour rate	Work periods–weeks					
			1	2	3	4	5	Total
Code ***1.1.3.2.3***	Quality testers	$xxxx/ week	$40	$30	$50			$120

Time-phasing the work package is critical for the final step of creating your budget baseline. Most single WPs become an activity so the process of distributing costs is relatively simple. Occasionally an activity will include more than one WP (see next slide).

Example: PC Prototype project *continued*

Figure 8.14 TWO TIME-PHASED WORK PACKAGES (LABOUR COST ONLY)

Time-phased work package budget
(labour 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 organisation unit *Software*
Work package duration *4* weeks

Page *1* of *1*
Project *PC Prototype*
Date *3/24/xx*
Estimator *LGG*
Total labour cost *$180 000*

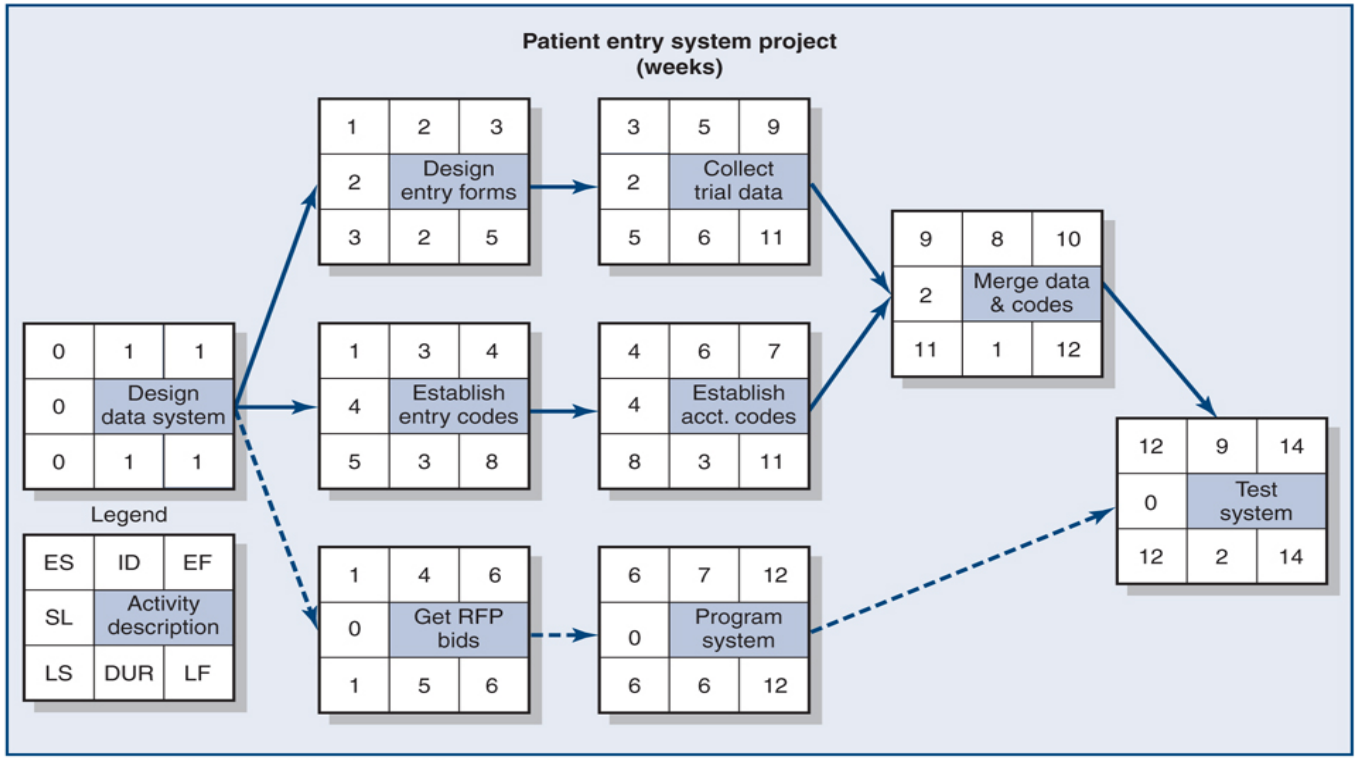
Time-phased labour budget ($000)

Work package	Resource	Labour rate	Work periods–weeks					
			1	2	3	4	5	Total
Code ***1.1.3.2.4.1***	Program'rs	$2000/ week	$20	$15	$15			$50
Integration ***1.1.3.2.4.2***	System/ program'rs	$2500/ week			$60	$70		$130
Total			$20	$15	$75	$70		$180

Where there is more than one WP to an activity, the WPs are consolidated into one activity. The above example shows two time-phased WPs. These are taken from WBS and placed into the project schedule as they are expected to occur over the lifetime of the project.

Example: PC Prototype project *continued*

Figure 8.15 PATIENT ENTRY SYSTEM PROJECT



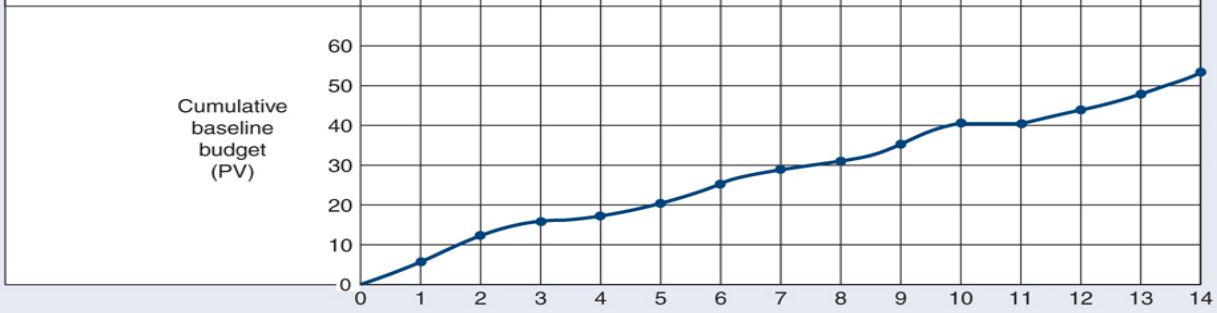
The project network schedule above is used to place the time-phased WPs into the baseline.

Example: PC Prototype project *continued*

Figure 8.16 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	



This is the project time-phased budget with a cumulative graph of the project budget baseline. Note how the time-phased WP costs are placed into the network (placement does not have to be linear). The project baselines will be used to compare planned schedule and costs.

Example: PC Prototype project *continued*

Figure 8.17 CEBOO PROJECT MONTHLY CASHFLOW 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

With the project budget baseline established you are able to generate cash flow statements for the project, as shown above. This shows cost over the lifespan of the project.

Example: PC Prototype project *continued*

Figure 8.18 CEBOO PROJECT WEEKLY RESOURCE USAGE SCHEDULE

	30/12	6/1	13/1	20/1	27/1	3/2
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 documentation						
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						

With resource assignments finalised, you can create resource usage schedules that map out the full deployment of personnel and equipment to generate individual work schedules as above.

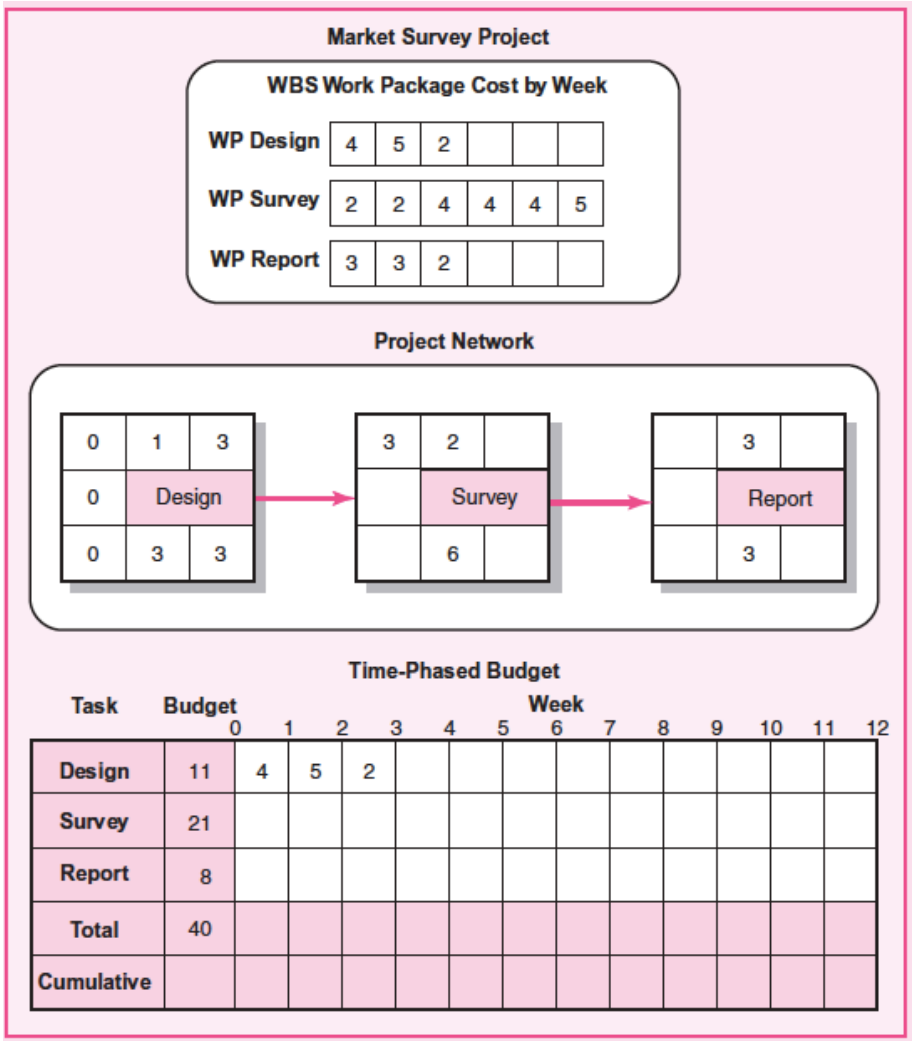
Exercise # 1 revisited

Given the time-phased work packages and network, complete the baseline budget for the project.

By the end of the 2nd week, the actual cost is $9k.

Are we:

A) Under budget
B) On budget
C) Over budget?



Solution

Task	Budget ('000's)	End of Week											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Design	11	4	5	2									
Survey	21				2	2	4	4	4	5			
Report	8										3	3	2
Total	40	4	5	2	2	2	4	4	4	5	3	3	2
Cumulative		4	9	11	13	15	19	23	27	32	35	38	40

Answer

At the end of the 2nd week, we should have a cumulative cost of $9k, thus we are actually On Budget.