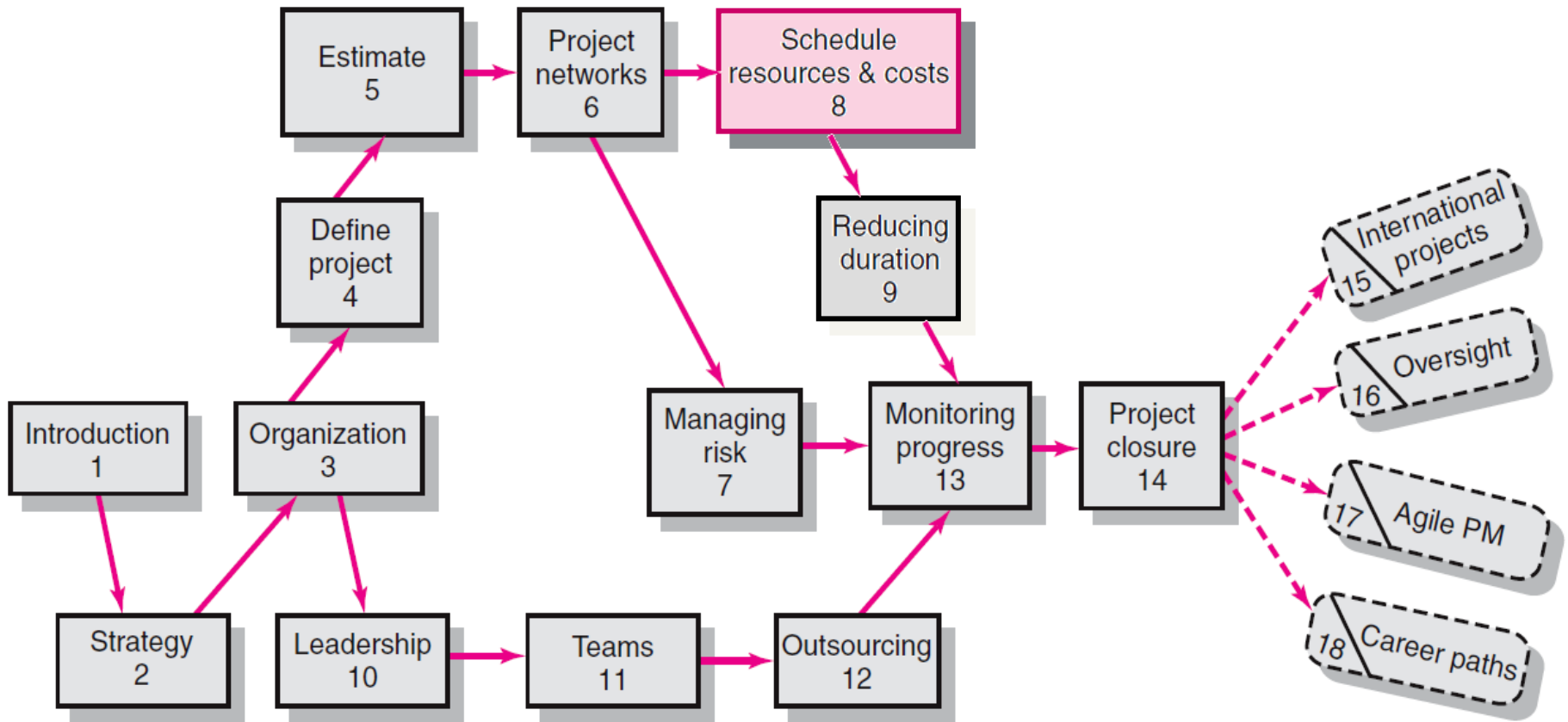


MGMT 4135  
**Project Management**

**Chapter-8**

**Scheduling Resources  
and Costs**

# Where We Are Now



## Master Project Plan

- Define project
- Estimate durations and costs
- Develop project network
- Schedule resources and costs

*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.*

## **Types 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

- **Kinds of Resource Constraints**

People, materials, equipment

## Terminology

- **Time-phased schedule:** comparison made between actual and planned schedule and costs
- **Resource smoothing (leveling):** Because demand resources will vary over the life of the project, it may be necessary to delay non-critical activities in order to even out resources.

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.

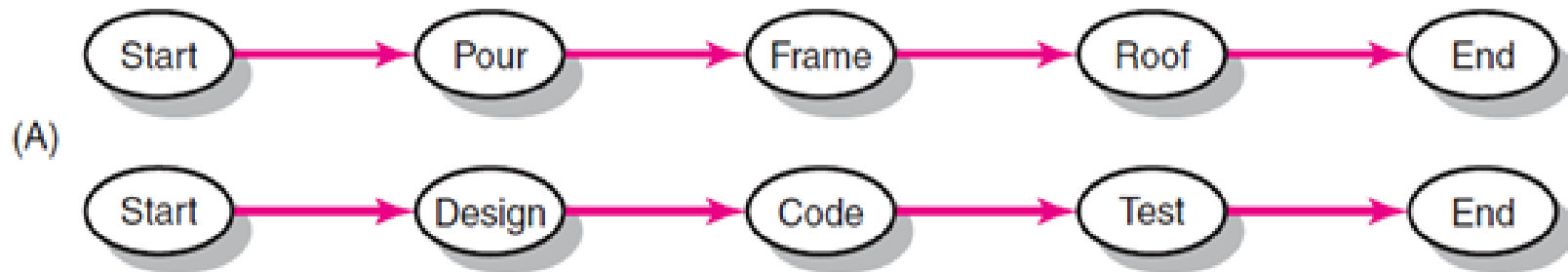
## New Terminology

- **Heuristics:** Often called “rule of thumb,” is used to develop a good schedule. It allocates resources to activities in such a way as to minimize project delay.
- The parallel method is widely used when applying heuristics, and is shown to consistently minimize project delay.

## Overview of Resource Scheduling Problem

- Up to now, the start and sequence of activities has been based solely on technical or logical steps.

Technical constraints

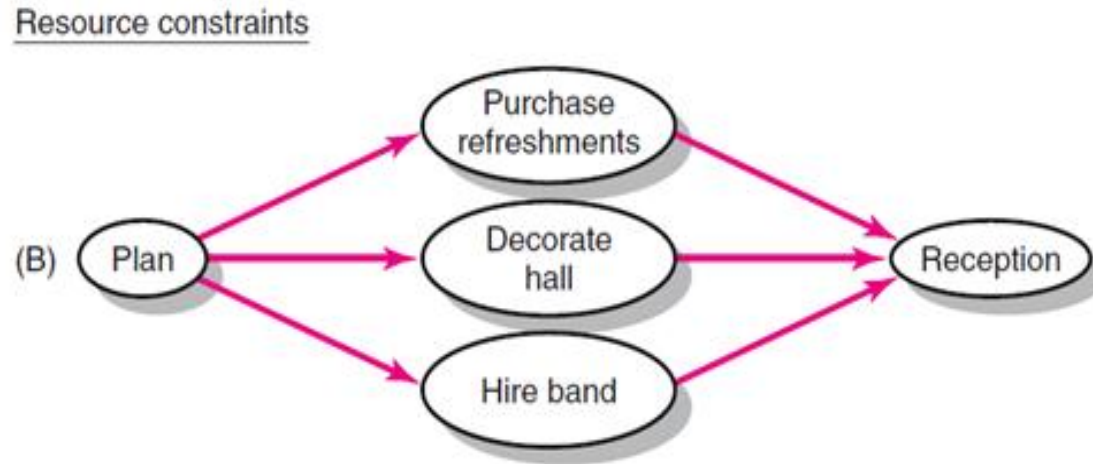


- These networks assume that the people and equipment are available to perform the required work.
- Absence or shortage of resources can drastically change the technical constraints.



## Overview of Resource Scheduling Problem

- Parallel activities have the potential for resource conflict. In this example, planning a wedding reception includes these activities:

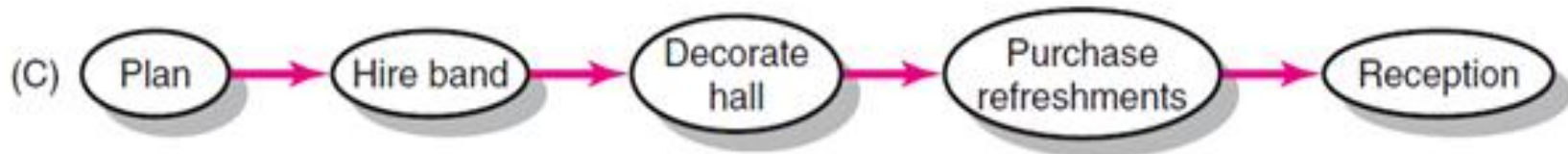


- This parallel network likely assumes that there is a resource available for each of the parallel tasks. But what if the same resource is responsible for all of these tasks?



## Overview of Resource Scheduling Problem

- Only one person performing all these activities now requires that the activities now be performed in sequence:



- As a result, the duration has now been extended due to lack of resources.
- When resources are not available to meet peak demands, the late start of some activities must be delayed and duration of the project increased. This is call **resource-constrained scheduling**.

## Types of Resource Constraints

- **People:** Human resources are typically classified by the skills they bring to the project: programmer, mechanical engineer, welder, inspector, etc. These many skills of human resources add to the complexity of scheduling projects.
- **Materials:** Chemicals for a scientific project, concrete for a road project, survey data for a marketing project. Material availability and shortages have been blamed for the delay of many projects.
- **Equipment:** Equipment is usually presented by type, size, and quantity and is often overlooked as a constraint. The most common mistake is assuming the resource pool is adequate for the project. Recognition of equipment constraints before the project begins can avoid high crashing or delay costs.

# Classification of Scheduling Problems

## 1. Classification of Problem

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

## 2. 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.

## 3. 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**

### **1. Limiting Assumptions**

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

### **2. Risk Assumptions**

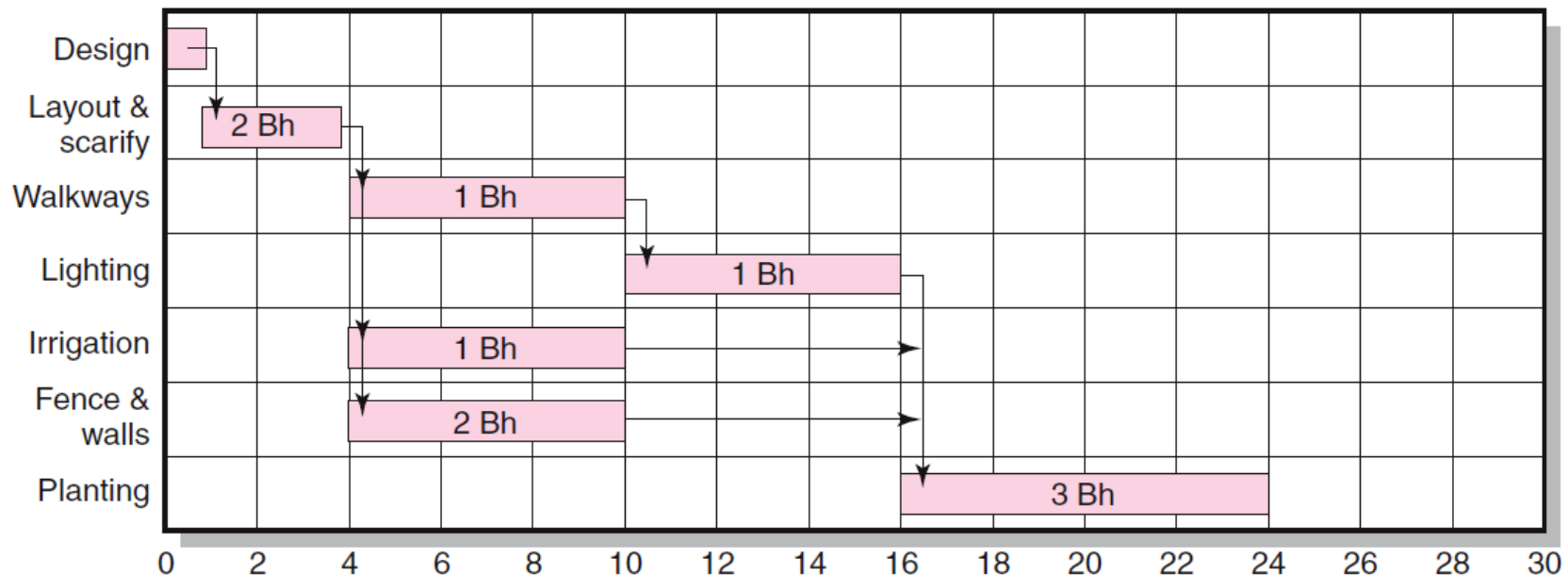
- Activities with the most slack pose the least risk.
- Reduction of flexibility does not increase risk.
- The nature of an activity (easy, complex) doesn't increase risk.

## Resource Allocation Methods

- **Time-constrained projects: Smoothing Resource Demand.**
  - This method focuses on resource utilization. It is difficult to manage a schedule when resource availability is erratic.
  - Project managers typically resolve this by using **resource leveling** techniques that balance or smooth resource demand.
  - Leveling basically delays non-critical activities using slack (float) to reduce peak demand.
  - **Benefit:** Peak resource demands are reduced, resources over the life of the project are reduced, and fluctuation in resource demand is minimized.

# Resource Allocation Methods

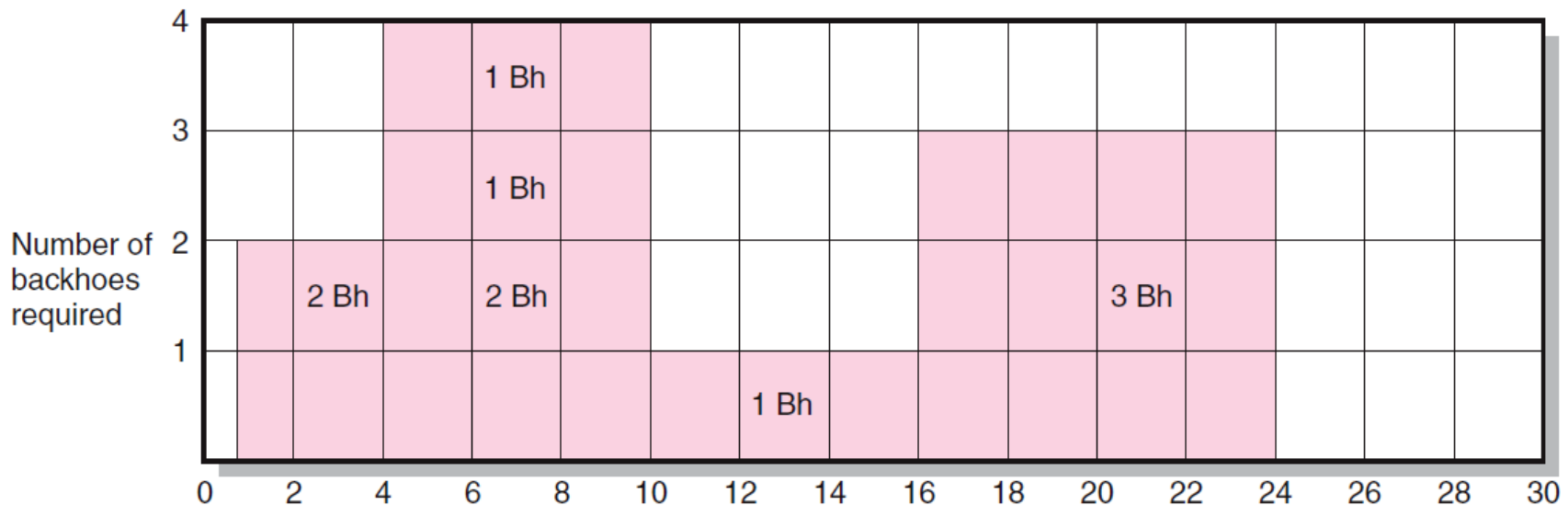
- **Figure 8.3 Botanical Garden example:** Project uses only one resource (backhoes) and all backhoes are interchangeable.
- This bar chart shows activities on a time scale.  
dependencies=vertical arrows; horizontal arrows=activity slack.





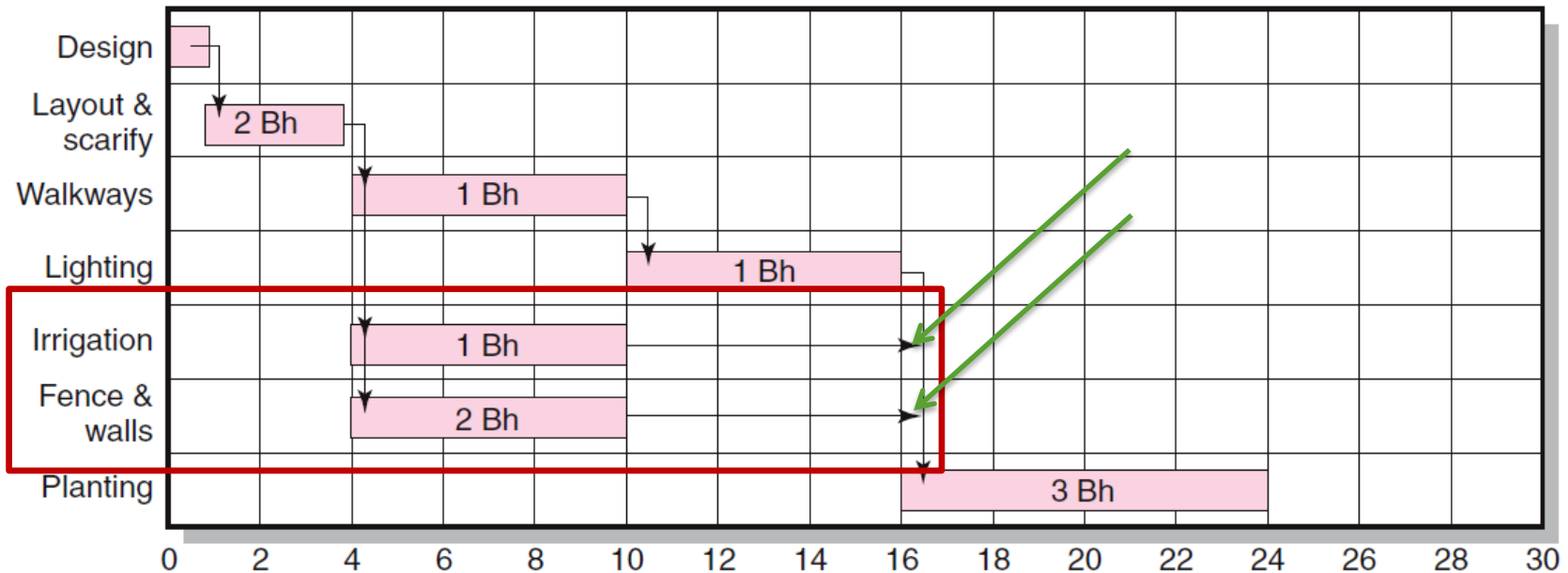
## Resource Allocation Methods

- **Figure 8.3 Botanical Garden example:** This is a resource profile showing when a backhoe is needed and during which periods of the project.
- The resource profile shows the use of 4 backhoes during periods 4 thru 10.



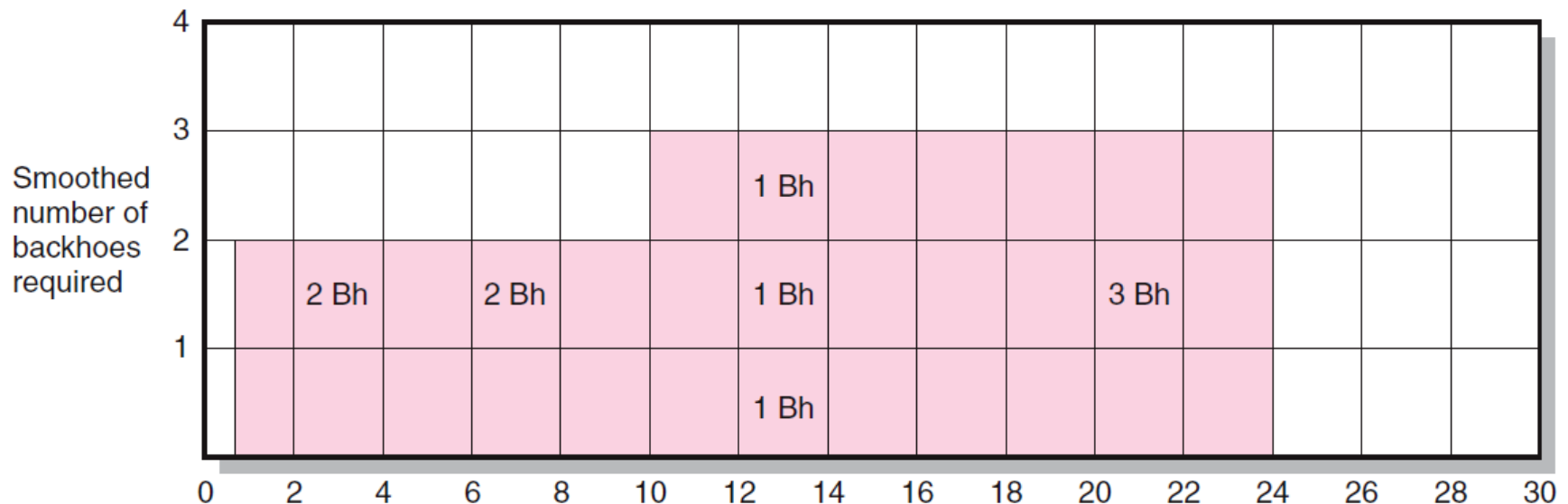
## Resource Allocation Methods

- Figure 8.3 Botanical Garden example:** The goal of this project is to reduce the resource demand on the backhoes. Notice the slack on Irrigation and Fence & Walls activities. These are the only two activities that have slack. *How can the project manager reduce demand and level this resource?*



## Resource Allocation Methods

- Figure 8.3 Botanical Garden example:** The project manager centered on the activity having the least risk of being late: *Fence and walls*. By delaying this one activity and starting it in period 10 instead of 4, the number of backhoes needed over the life of the project had been reduced from 4 down to 3 (25%).



## Resource Allocation Methods

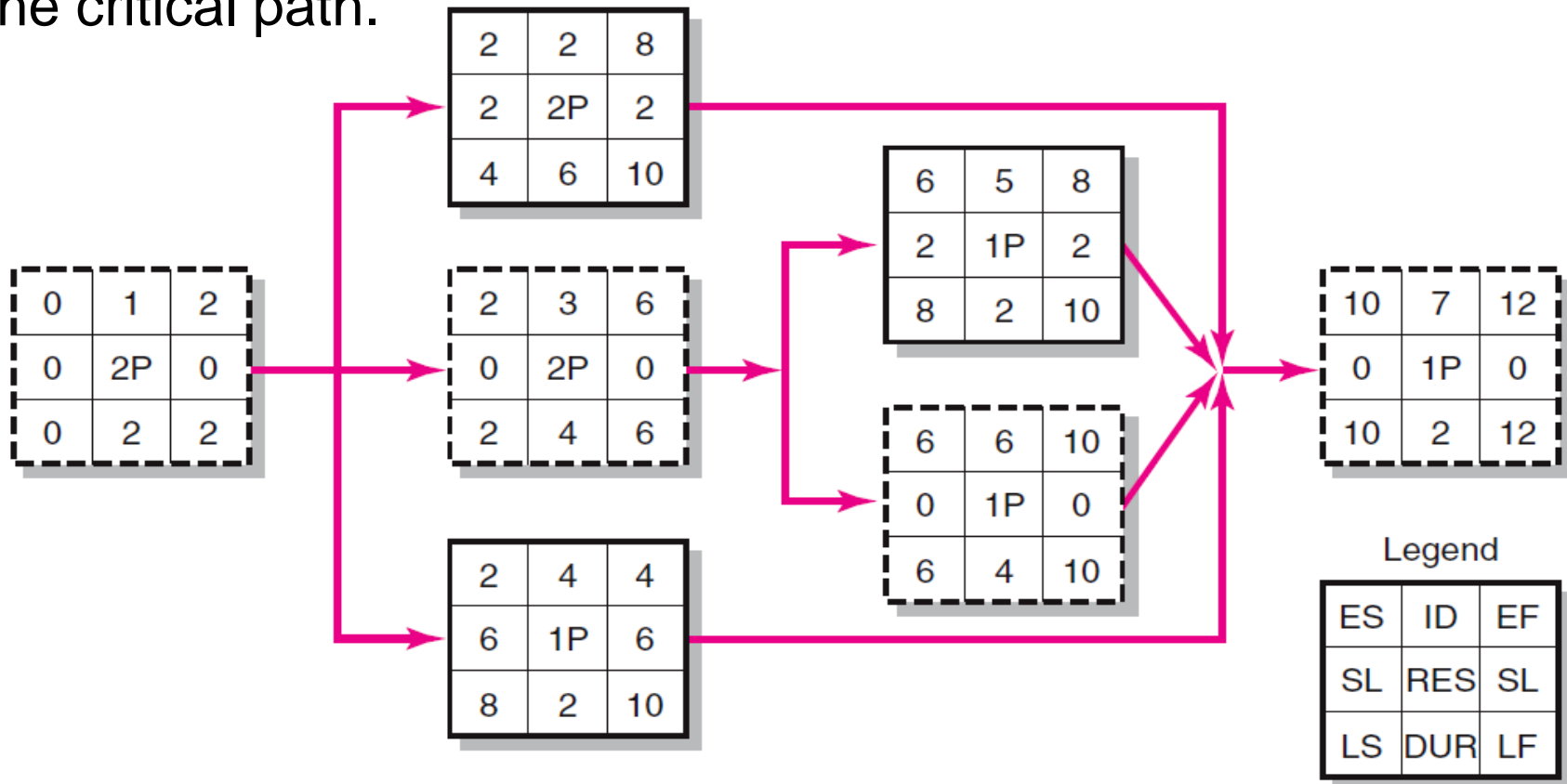
- **Resource Demand Leveling for Time-Constrained Projects:**
  - **Advantages**
    1. Peak resource demands are reduced.
    2. Resources over the life of the project are reduced.
    3. Fluctuation in resource demand is minimized.
  - **Disadvantages**
    1. Loss of flexibility that occurs from reducing slack, in this case, eliminating the slack on “fence & walls” activity.
    2. Increases the criticality of more activities. With “fence & walls” having no slack and this project being time sensitive, nothing could go wrong or else the project would suffer a delay.

## Resource Allocation Methods

- **Resource-Constrained Projects**
  - Resources are limited in quantity and availability
  - Activities are scheduled using **heuristics (or rule-of-thumb)** that focuses on activities having:
    1. Minimum slack
    2. The smallest or least duration
    3. The lowest activity ID number
  - **Heuristics** is applied by using the *parallel method*: an iterative process starting with the first time period and scheduling the start of activities period-by-period by using the 3 priority rules (above).

# Resource Allocation Methods

- Resource-Constrained Projects:** Consider the following network, Figure 8.4, found on pg. 262. Dashed nodes represent the critical path.





# Resource Allocation Methods

- Resource-Constrained Projects:** The following is a resource profile for this project. Go to pages 262 & 263 to follow the sequence of actions taken to level programming resources.

ES resource load chart

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			

## Resource Allocation Methods

- **Resource-Constrained Projects:** Note that the project ended up being extended an additional 2 periods. However, this was not a time constrained project, it was a resource constrained project, therefore increasing the duration of the project was not problematic.
- By leveling (or smoothing) programming needs, each period of the project no longer exceeded the 3 available programmers for the project (figure 8.5).
- Goal of resource-smoothing had been achieved.

## **Resource Allocation Methods**

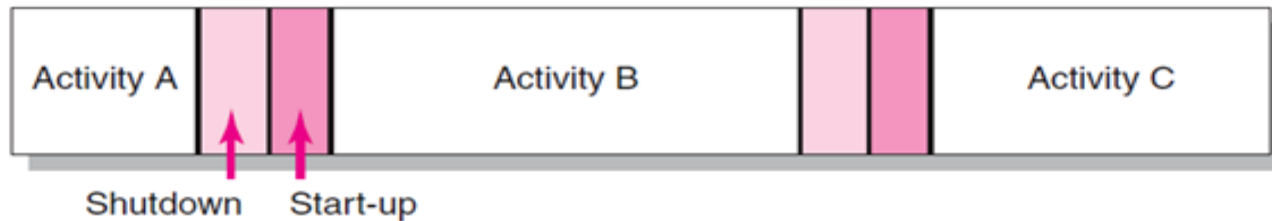
- **Impacts of Resource-Constrained Scheduling:**
  - Usually reduces project slack and thereby reduces flexibility
  - Increases the number of critical and near-critical activities.
  - Scheduling complexity increases because resource constraints are now added to the normal technical constraints of managing the project and flow of activities.
  - The critical path is no longer meaningful.
  - Resource constraints can break the sequence and leave the network with a set of disjointed critical activities.
  - Parallel activities can now become sequential.

## **Splitting Activities**

- **This is a scheduling technique used to obtain a better project schedule but has a down side in that it can also increase resource utilization.**
  - Involves interrupting work on an activity to use the resource on another activity, then returning the resource to finish the interrupted work.
  - Is feasible only when startup and shutdown costs are low.
  - Is considered the major reason why projects fail to meet schedule objectives.

## Splitting Activities:

- Consider having a bridge designer take time off to work on a design problem on another project. This designer may easily love 4 days shifting conceptual gears in and out of two activities. The cost may be hidden, but the cost of splitting is real.



- Schedulers and planners should avoid splitting activities as much as possible except when:
  - There is no alternative for resolving a scarce resource problem.
  - Costs of splitting are known to be small and insignificant to the project.

## Benefits of Scheduling Resources:

- If a project is truly dealing with limited or scarce resources, the schedule will end up being a resource-constrained schedule, not time-constrained.
- Schedule should be created before the project begins. This allows time to consider other reasonable alternatives such as Cost-Time tradeoffs and Changes in Priorities.
- Resource scheduling also provides information for time-phased work package budgets in order to assess the impact of unforeseen events as well as the amount of flexibility in available resources.



## Multiple Project Resource Schedules - Problem

- **Overall project slippage** – a delay on one project can create delays for other projects as well.
- **Inefficient resource allocation** – the peaks and valleys of resource demand creates scheduling problems and delays for multiple projects.
- **Resource bottlenecks** – shortage of critical resources required for multiple projects will cause delays and schedule extensions.

## Multiple Project Resource Schedules - Problem

- **Managing the Solution:** Many companies create project offices (PMOs) or specific departments to oversee resource scheduling across multiple projects.
  - First come first serve
  - Project selection system
  - Project priority models (described in Chapt-2)
  - Centralize project management and treat all projects as part of a “megaproject” or program.
  - Outsource projects to reduce the number of project handled internally.

## Using Resource Schedule to Develop a Project Cost Baseline

- **Baseline:** The original plan plus all the changes.
  - Each time a significant change in the schedule is needed, the project manager saves the schedule as a baseline then applies the new changes.
  - This is now the new schedule. It includes the original schedule plus all the changes.
- **Time-phase:** Using the project schedule, you can *time-phase* work packages and assign resources.
  - When all work packages are assigned, you are able to develop a budget schedule for the entire life of the project.
  - Remember, resources are people, places, and things.

## Using Resource Schedule to Develop a Project Cost Baseline

- **Baseline:** The original plan plus all the changes.
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  - Remember, resources are people, places, and things.

# Using Resource Schedule to Develop a Project Cost Baseline

- **Why a Time-Phased Budget Baseline is Needed**
  - **Example:** Development of a new product to be completed in 10 weeks at an estimated cost of \$400,000 per week for a total project cost of \$4 million.
    - At 5 weeks, management receives a status report:
      - **Planned costs for first 5 weeks are \$2 million**
      - **Actual costs for this period are \$2.4 million**
    - One may assume that the project is experiencing overruns.
    - The \$400K might have been spent to move the project ahead of schedule.

## Using Resource Schedule to Develop a Project Cost Baseline

- **Why a Time-Phased Budget Baseline is Needed**
  - **Example:** Development of a new product to be completed in 10 weeks at an estimated cost of \$400,000 per week for a total project cost of \$4 million.
    - What if at 5 weeks, management receives a different status report:
      - **Planned costs for first 5 weeks are \$2 million**
      - **Actual costs for this period are \$1.7 million**
    - Is the project costing \$300K less than expected?
    - Is the project running behind schedule and \$300K worth of work has not yet started?



# Using Resource Schedule to Develop a Project Cost Baseline

- **Why a Time-Phased Budget Baseline is Needed**
  - Unless you have a time-phased budget, there is no way of knowing the overall health of the project.

Time-Phased Labor Budget (\$000)

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

- Here is a work package having project costs distributed across 3 work periods, totaling \$120. *What if the status report was delivered to management on week-2? What can be said of this work package progress?* Because of this time phased budget for this work package, it is easy to justify.

# Using Resource Schedule to Develop a Project Cost Baseline

- **Why a Time-Phased Budget Baseline is Needed**
  - A time-phased budget for each work package is lifted from the WBS and placed in the schedule as they are expected to be occur.
  - The result of these budget allocations is the **project cost baseline**, also known as **Planned Value (PV)**.
  - Planned value is used to determine cost and schedule variances from the original plan as the project progresses.
  - Planned value is the sum of all the cost accounts, each cost account is the sum of the work packages in the cost account.

# Using Resource Schedule to Develop a Project Cost Baseline

- **Why a Time-Phased Budget Baseline is Needed**
  - This time-phased labor budget for two work packages are budgeted across work periods.

**Time-Phased Labor Budget (\$000)**

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

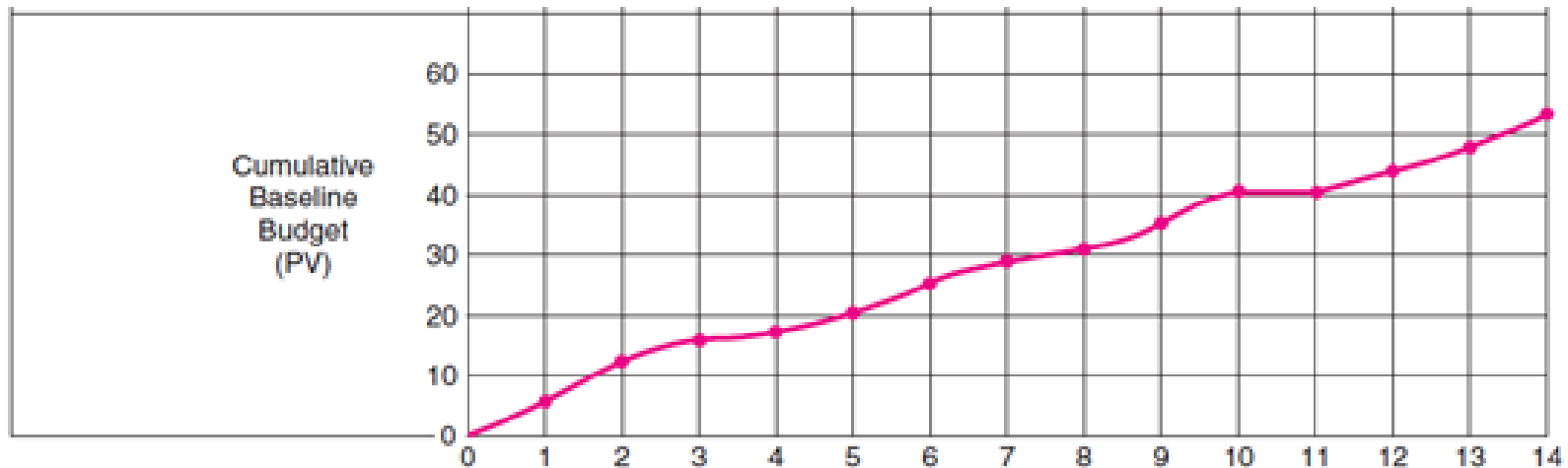
# Using Resource Schedule to Develop a Project Cost Baseline –

- Why a Time-Phased Budget Baseline is Needed
  - Here is a resource profile showing numbers of resources over 14 work periods.

ID	Dur.	Task	Budget	(\$000)															
				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		

## Using Resource Schedule to Develop a Project Cost Baseline –

- **Why a Time-Phased Budget Baseline is Needed**
  - Over time, as the project is worked, the planned value (PV) accumulates over time as each phase is completed.



## Using Resource Schedule to Develop a Project Cost Baseline –

- **Why a Time-Phased Budget Baseline is Needed**
  - Now that a time-phased budget baseline has been established, the planned schedule and planned costs can be compared to the actual schedule and actual costs.
  - Performance reports are also derived from budget baselines and will be further discussed in Chapt-13.
  - Remember, if your budgeted costs are not time-phased, there is really no reliable way to measure performance.



# Chapter-8 Key terms:

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Heuristic, 260

Resource-constrained projects, 257

Leveling, 258

Splitting tasks, 270

Planned value (PV), 278

Time-constrained projects, 257

Resource Smoothing, 254

Time-phased budget baseline, 253

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