

# Scheduling – PERT Networks and Linear Operations

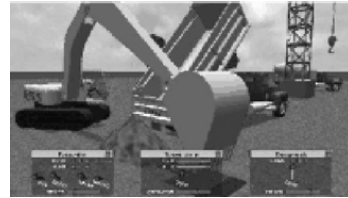
By  
Dr. Ibrahim Assakkaf

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## VRML Applications in Construction

- The Need
  - Traditionally, construction process information is communicated with paper document and 2D CAD drawings,
  - Recently, the industry has embraced many kinds of web-based technologies, but construction still uses document-based models.
  - It is believed that transition to model-based information can be done through web-based 3D user interfaces.

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### **Chapter-Opener (p. 128)**

VRML Model of the NIST Fire Research Facility Emissions Control System

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## VRML Applications in Construction

- The Technology
  - The applicability of the Virtual Reality Modeling Language (VRML) is being investigated for visualizing the activities at a construction site and creating an advanced web-based 3D user interface for construction process information.
  - The Computer-Integrated Construction Group at the National Institute for Standards and Technology (NIST) in Gaithersburg, Maryland is developing this concept

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## VRML Applications in Construction

- The Technology (cont'd)
  - In principle, VRML is an open standard that offers the possibility of accessing many types of construction project data readily available and well-accepted graphical user interfaces.
  - These interfaces are based on web-based 3D visualizations of a model.
  - In order to view the VRML world, the users should have a VRML browser, which can be stand-alone application, a helper application, and/or a plug-in.
  - Using this environment, models such as these pictures on the next slide can be readily developed.

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## Introduction

- Bar charts and critical path method (CPM) network assume that all activity durations are constant or deterministic.
- An estimate is made of the duration of each activity prior to the commencement of a project, and the activity duration is assumed to remain the same (e.g., a nonvariable value) throughout the life of the project.

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## Introduction

- In fact, this assumption is not realistic.
- As soon as work begins, due to actual working conditions, the assumed durations for each activity begin to vary.
- The variability of project activities is addressed in a method developed by the U.S. Navy at approximately the same time as CPM.

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## Introduction

- This method was called the Program Evaluation and Review Technique.
- It is now widely known as the PERT scheduling method.
- PERT incorporates uncertainty into the project by assuming that the activity durations of some or all of the project activities are variable.

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## Introduction

- The variability is defined in terms of three estimates of the duration of each Activity as follows:
  1. Most pessimistic duration
  2. Most optimistic duration
  3. Most likely duration

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## Introduction

- Example:
  - Let's assume that a 20,000-sq ft slab on grade is to be cast in place.
  - For scheduling purposes, the project superintendent is asked for three duration (i.e., most pessimistic, etc.) rather than for a single constant duration.
  - The three estimates are used to calculate an expected activity duration.

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# Introduction

- Example (cont'd):
  - The calculations are loosely based on concepts from mathematical probability.
  - The expected duration,  $t_e$ , is assumed to be the average value of a probability distribution defined by the three-estimate set.
  - The expected duration,  $t_e$ , of each activity with variable characteristics is given by

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# Introduction

- Example (cont'd):

$$t_e = \frac{[t_a + 4t_m + t_b]}{6}$$

$t_a$  = the most optimistic duration estimate  
 $t_m$  = the most likely duration estimate  
 $t_b$  = the most pessimistic duration estimate

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# Introduction

- Example (cont'd):
  - For instance, if for the slab pour, the three estimates from the superintendent are:

$$t_a = 5 \text{ days}$$

$$t_m = 8 \text{ days}$$

$$t_b = 12 \text{ days}$$

- The expected activity duration is calculated as:

$$t_e = \frac{[5 + 4(8) + 12]}{6} = 8.17 \text{ days, say } 9 \text{ working days}$$

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# Introduction

- Once the  $t_e$  values for each variable duration activity have been calculated, the longest path and project duration are determined using the same methods developed in CPM.
- The probability of completing the project within a predetermined time duration is calculated by assuming that the probability distribution of the total project duration is normally distributed with the longest path of  $t_e$  values as a mean value of the normal distribution.

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## Introduction

- The normal distribution is defined by its mean value  $\bar{x}$  (i.e., in this case the value of the longest path through the net work) and the value,  $\sigma$ , which is so-called “standard deviation” of the distribution.
- The standard deviation of the distribution is a measure of how widely about the mean value the actual observed values are spread or distributed.

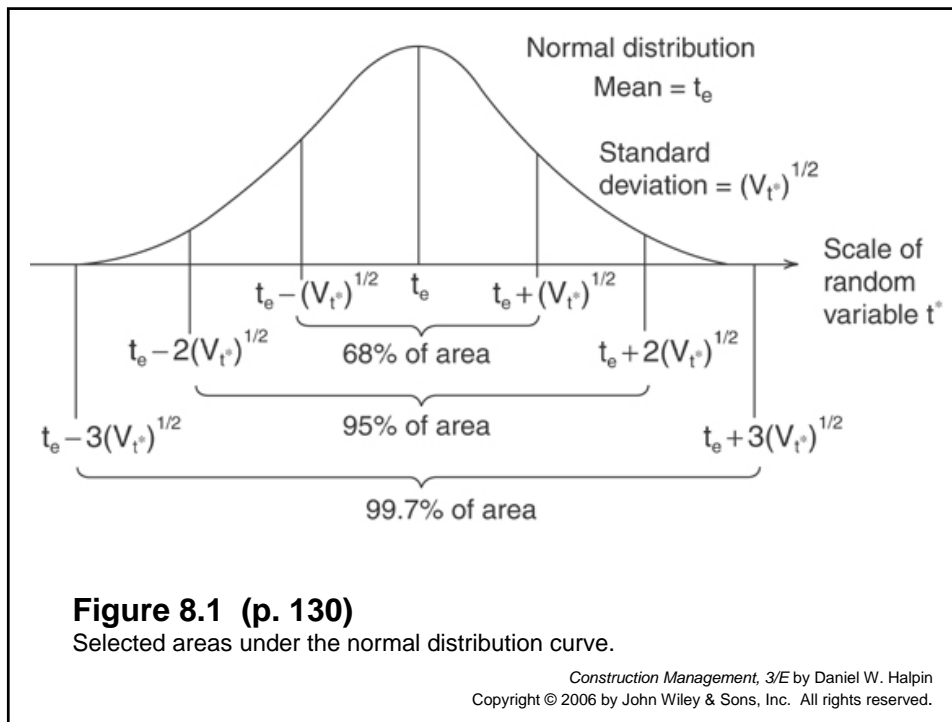
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## Introduction

- Another parameter called the variance is the square of the standard deviation or  $\sigma^2$ .
- It can be shown mathematically that 99.7% of the values of distributed variables will lie in a range defined by three standard deviations below the mean and three standard deviations above the mean (*see the figure on the next slide*)

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## Introduction

- In BERT, the standard deviation  $\sigma^2$  of the normal distribution for the total project duration is calculated using the variance of each activity on the critical path.
- The variance for PERT activity is defined as:

$$\sigma^2 = \left[ \frac{(t_b - t_a)}{6} \right]^2$$

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## Introduction

- If the variance of each activity on the longest path is summed, that value is assumed to be the variance of the normal distribution of the entire project duration values.
- The fact that the Normal Distribution is used to present the probability distribution of the possible total project durations is based on a basic concept from probability theory called the **Central Limit Theorem**.

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## Introduction

- This is explained by Moder and Phillips as follows:
  - Suppose  $m$  independent tasks are to be performed in order; (one might think of these as the  $m$  tasks that lie on the critical path of a network). Let  $t_1^*$ ,  $t_2^*$ , .....  $t_m^*$  be the times at which these tasks are actually completed.
  - Note that these are random variables with true means  $t_1, t_2, \dots, t_m$ , and true variance  $Vt_1^*, Vt_2^*, \dots, Vt_m^*$ , and actual times are known until these specific tasks are actually performed.

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# Introduction

- Now define  $T^*$  to be the sum of
- And note that  $T^*$  is also a random variable and thus has a distribution. The Central Limit Theorem states that if  $m$  is large, say four or more, the distribution of  $T^*$  is approximately normal with mean  $T$  and variance  $V_{T^*}$  given by

$$T^* = t_1^* + t_2^* + \dots + t_m^*$$

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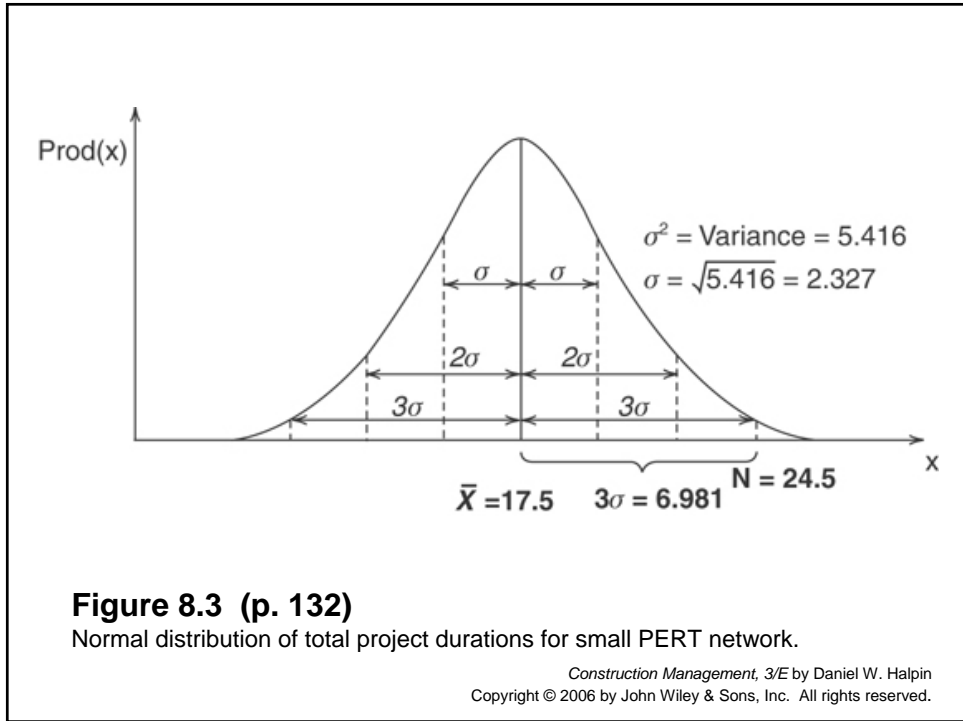
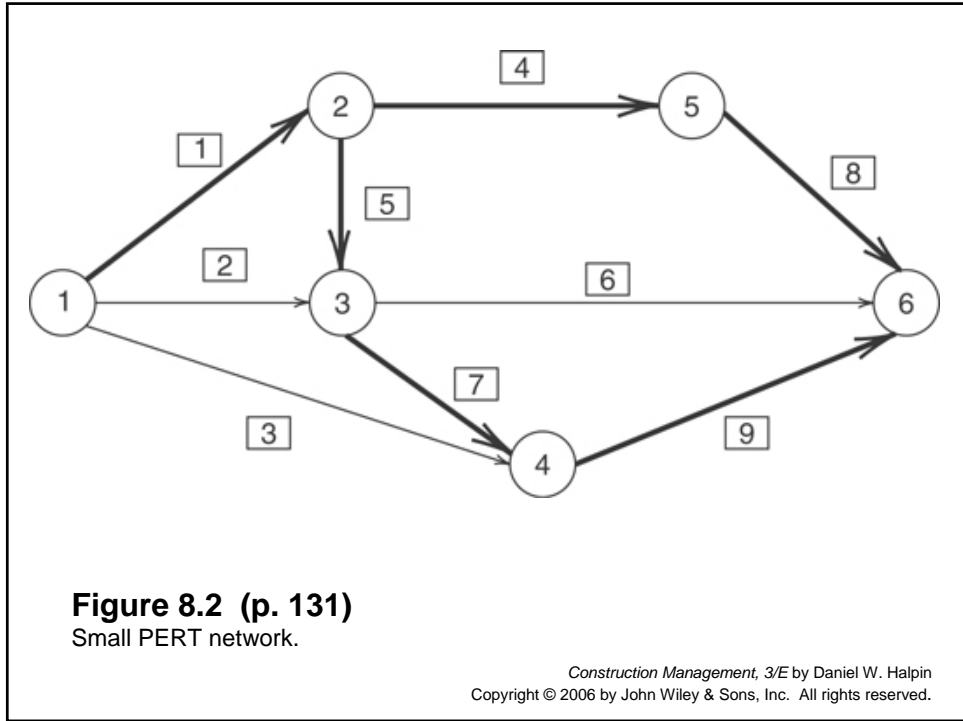
**Table 8.1** Three Estimate Values and Calculated Values for Each Activity

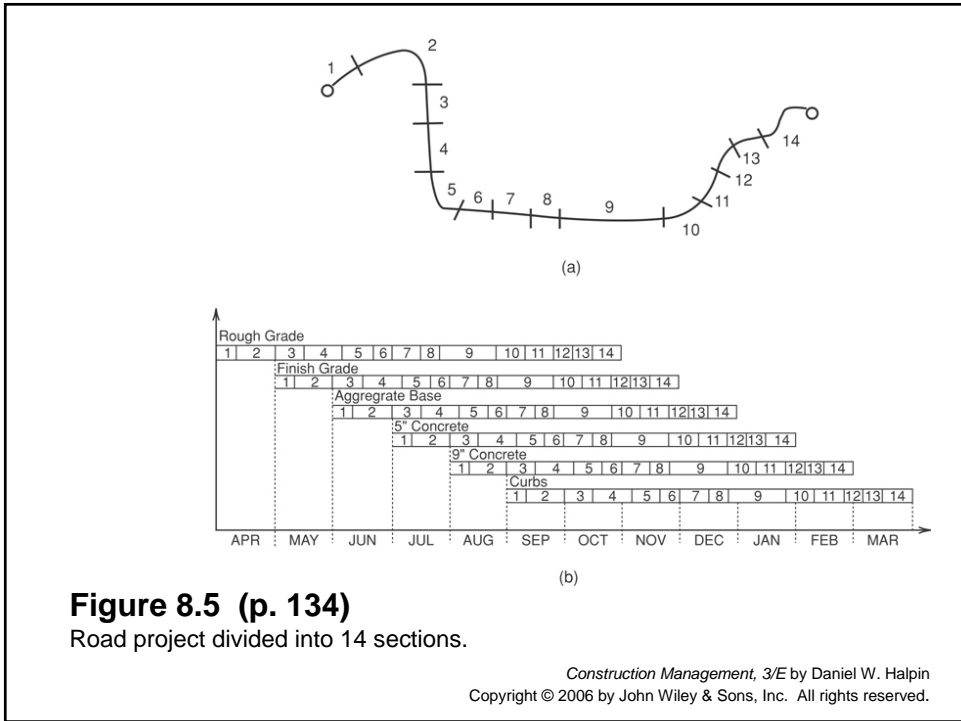
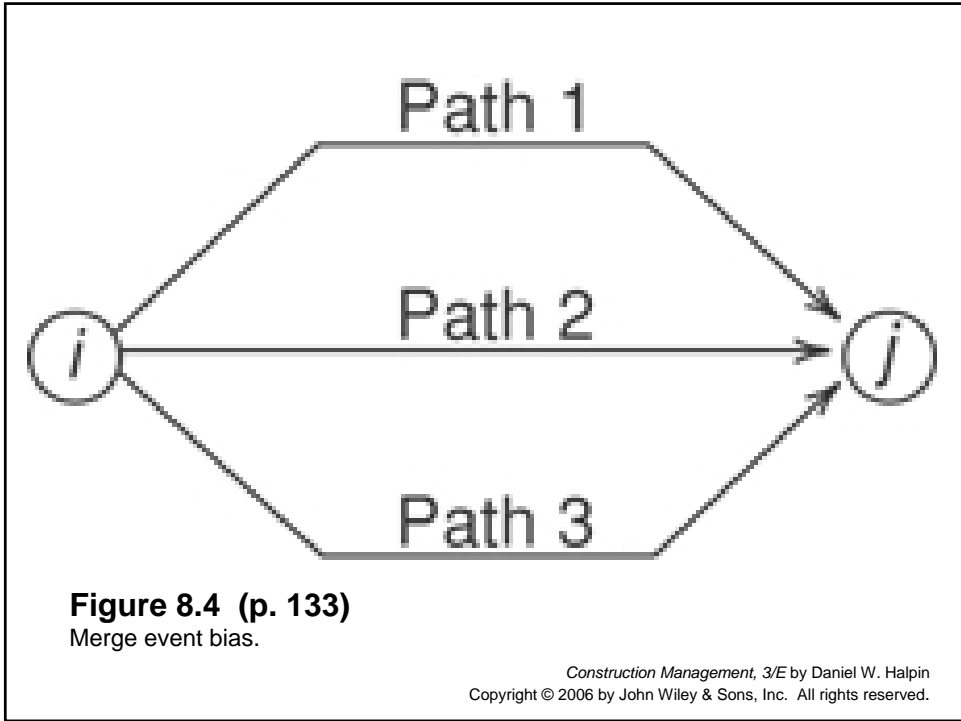
Activity	$t_m$	$t_a$	$t_b$	$t_e$	Var
1	3	1	5	3	0.44
2	6	3	9	6	1.00
3	13	10	19	13.5	2.25
4	9	3	12	8.5	2.25
5	3	1	8	3.5	1.36
6	9	8	16	10	1.23
7	7	4	13	7.5	2.25
8	6	3	9	6	1.00
9	3	1	8	3.5	1.36

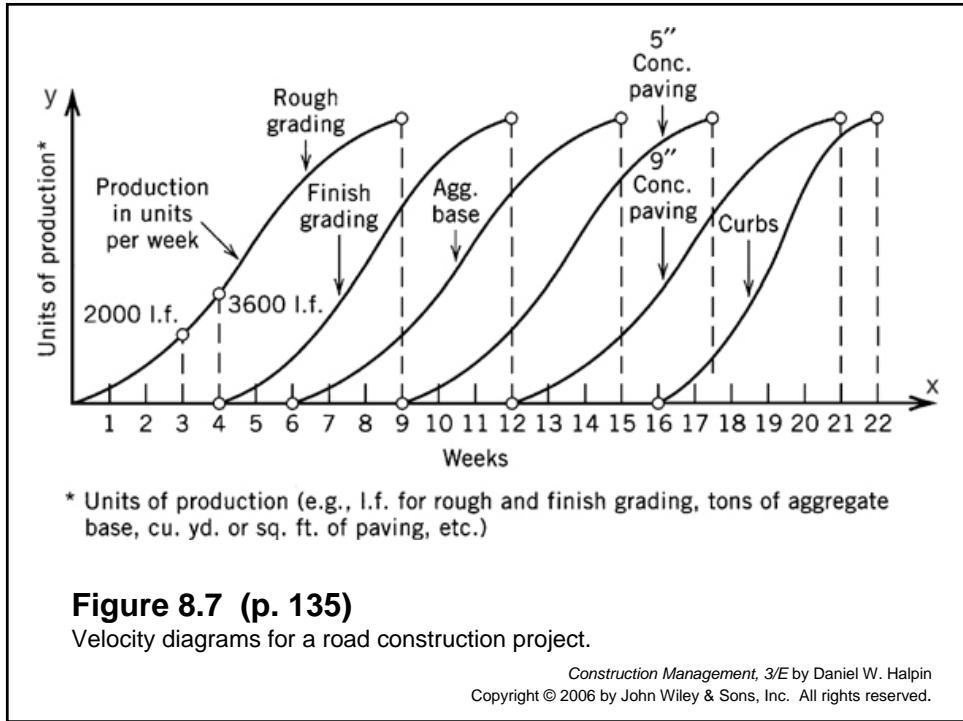
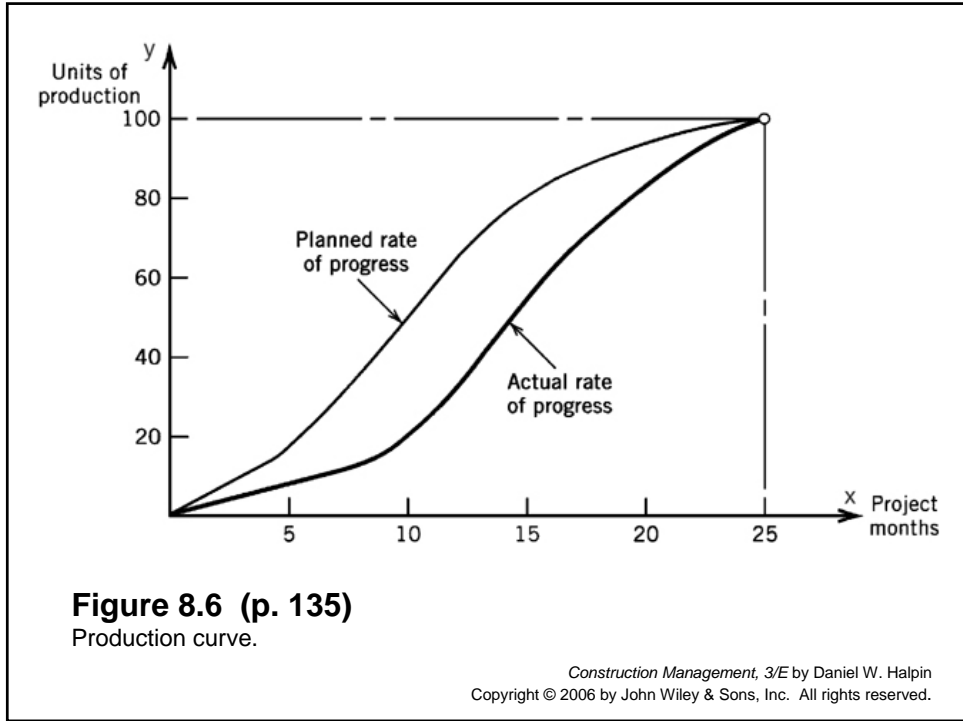
**Table 8.1 (p. 131)**

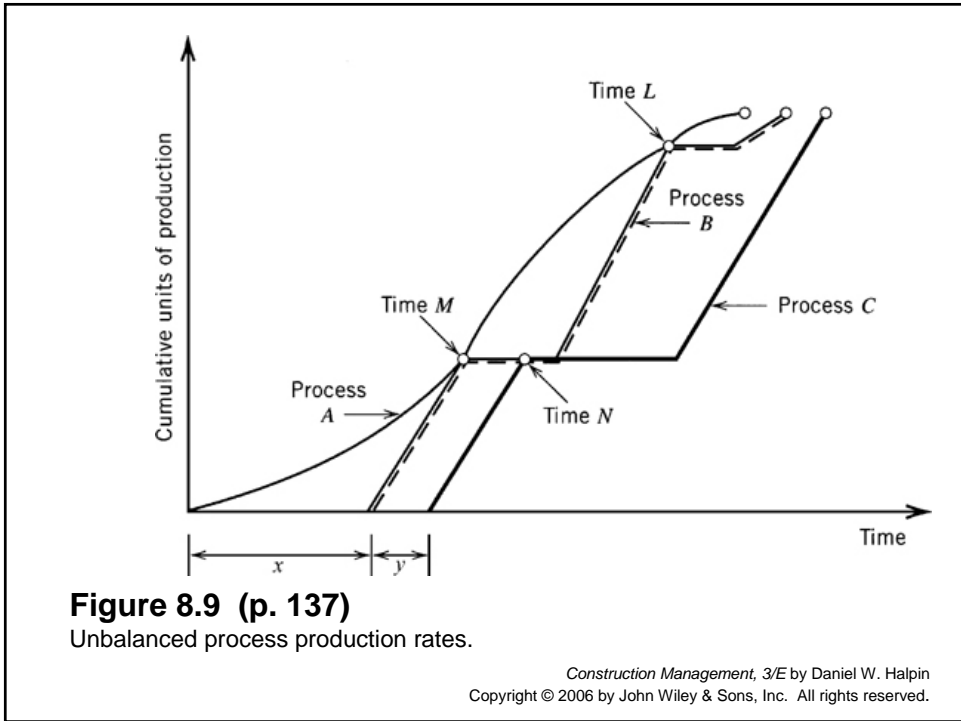
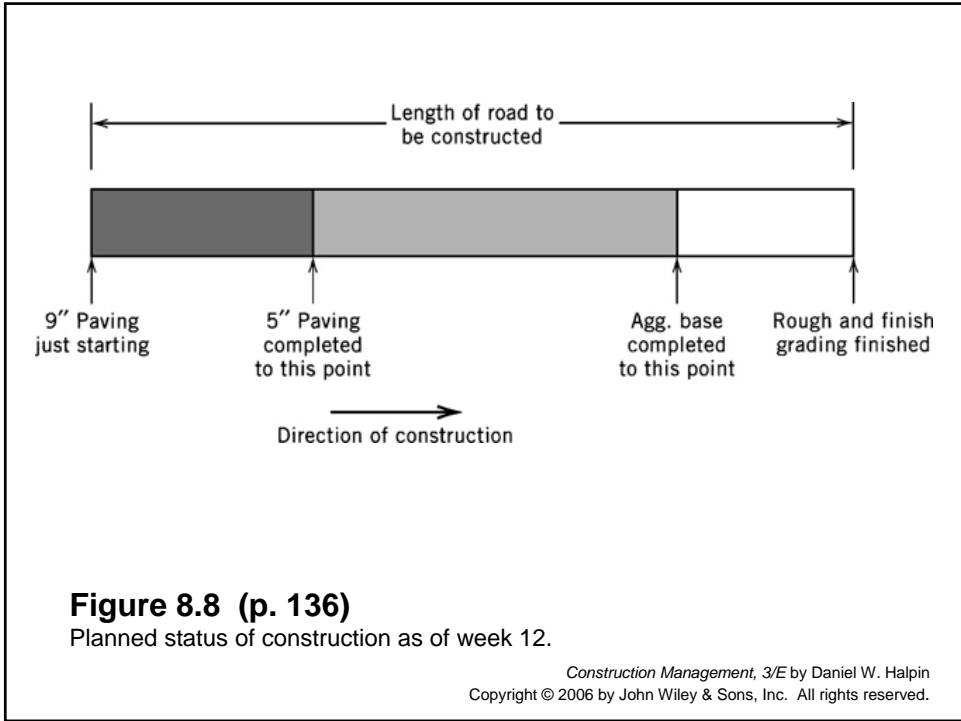
Three Estimate Values and Calculated Values for Each Activity

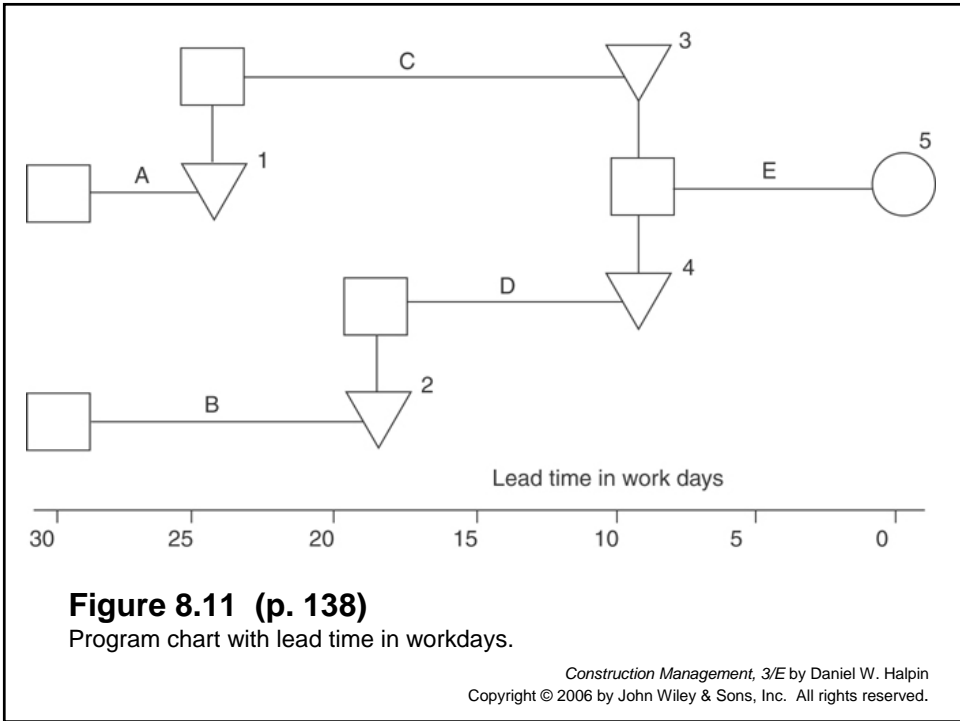
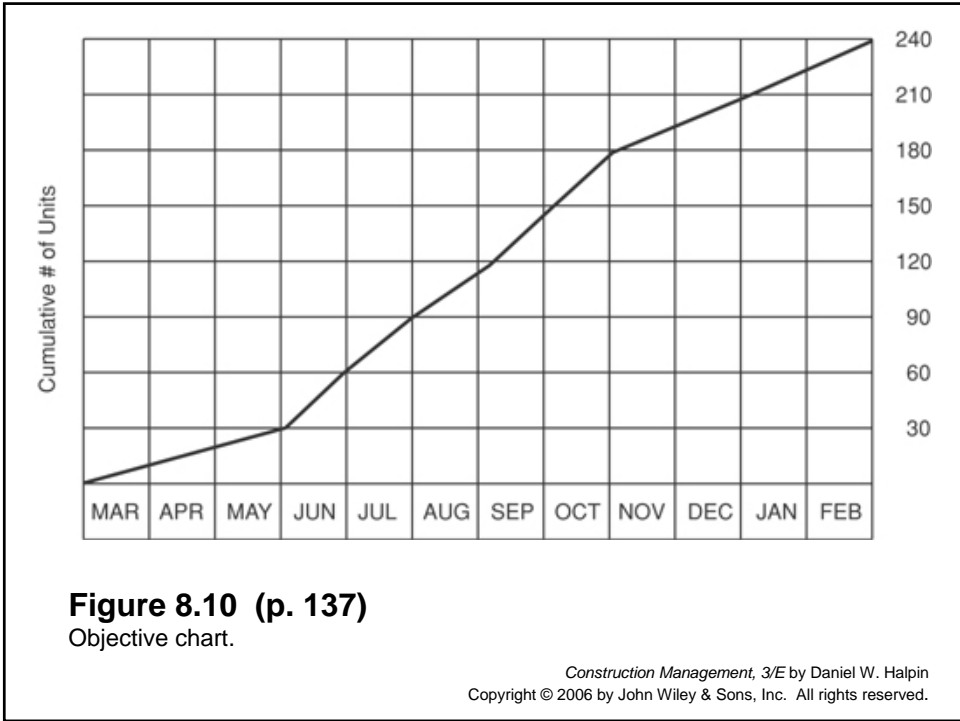
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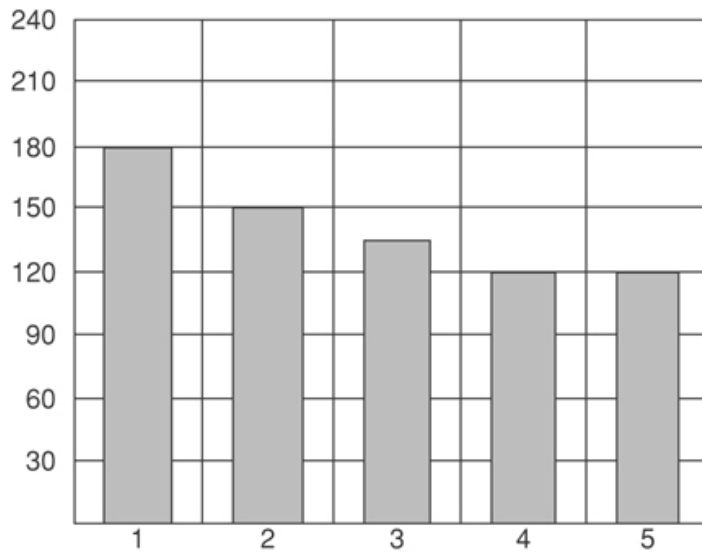






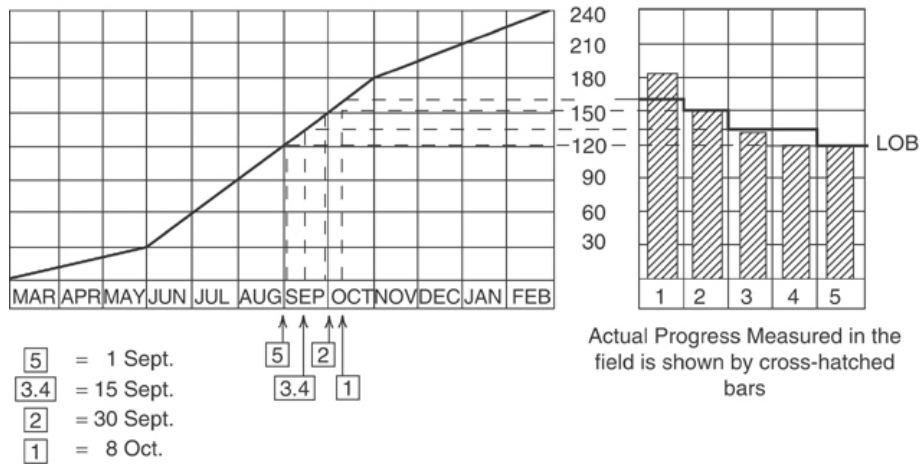






**Figure 8.12 (p. 139)**  
Progress Chart.

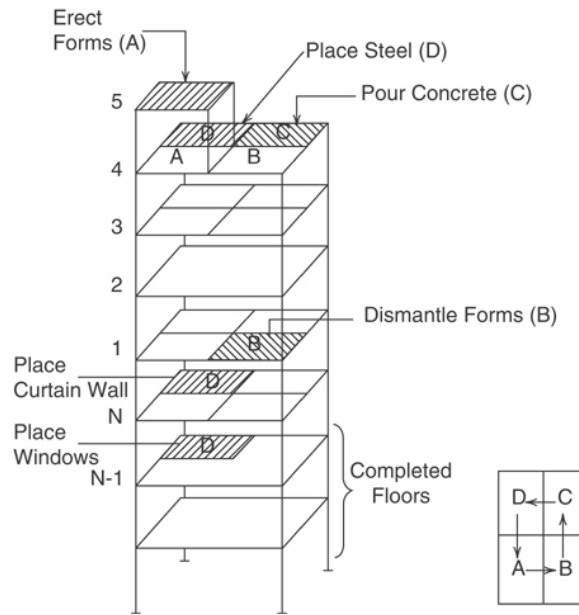
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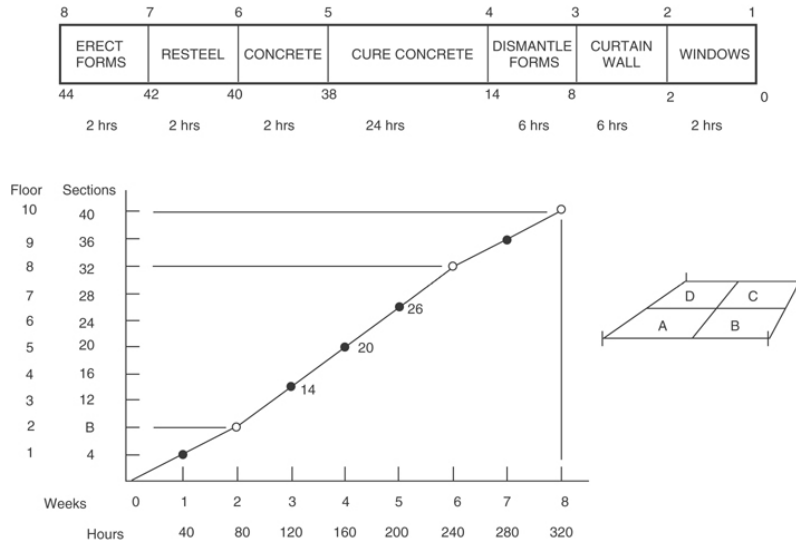
**Figure 8.13 (p. 139)**  
Progress Chart with Line of Balance.

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**Figure 8.14 (p. 140)**  
Schematic of floor cycle work tasks.



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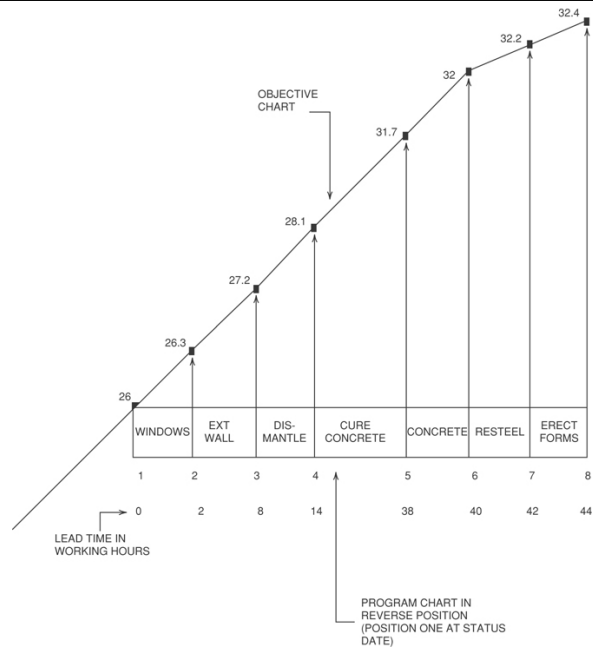


**Figure 8.15 (p. 141)**  
Program chart and objective.

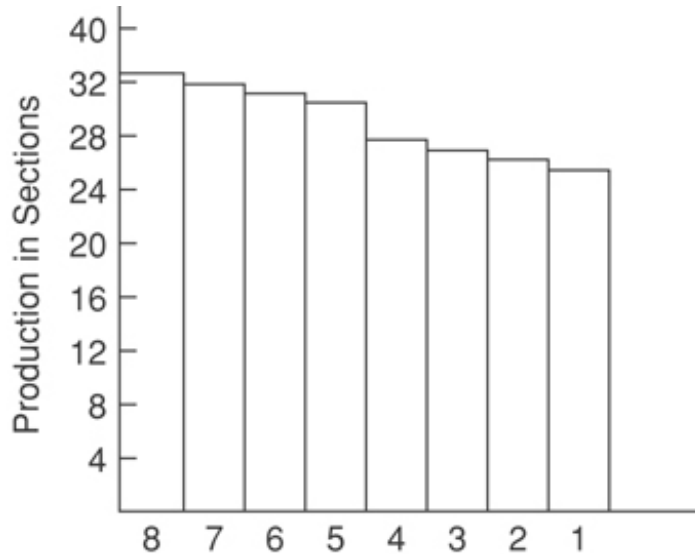
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**Figure 8.16 (p. 142)**

Enlarged projection of program chart onto objective chart.



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**Figure 8.17 (p. 142)**

Line of balance for week 5.

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Activity #	Activity	Type	Duration (Weeks)	Followed by Act #
10	Prefab Wall Forms	constant	2	40
20	Excavate Cols and Walls	constant	3	50, 60, 70
30	Let Elec and Mech Subcontract	$t_s, t_m, t_b$	3, 4, 8	60, 70
40	Deliver wall Forms	constant	4	80, 90, 100
50	Forms, Pour & Cure Wall & Col Fig	$t_s, t_m, t_b$	6, 7, 8	80, 90, 100
60	Rough-in Plumbing	$t_s, t_m, t_b$	5, 7, 10	110
70	Install Conduit	$t_s, t_m, t_b$	9, 11, 15	110
80	Erect Wall Forms & Steel	constant	9	110
90	Fabricate & Set Interior Column Forms	constant	6	120
100	Erect Temporary Roof	$t_s, t_m, t_b$	12, 16, 18	140
110	Pour, Cure & Strip Walls	constant	10	130
120	Pour, Cure & Strip Int. Walls	constant	6	140
130	Backfill for Slab on Grade	constant	1	140
140	Grade & Pour Floor Slab	constant	5	END

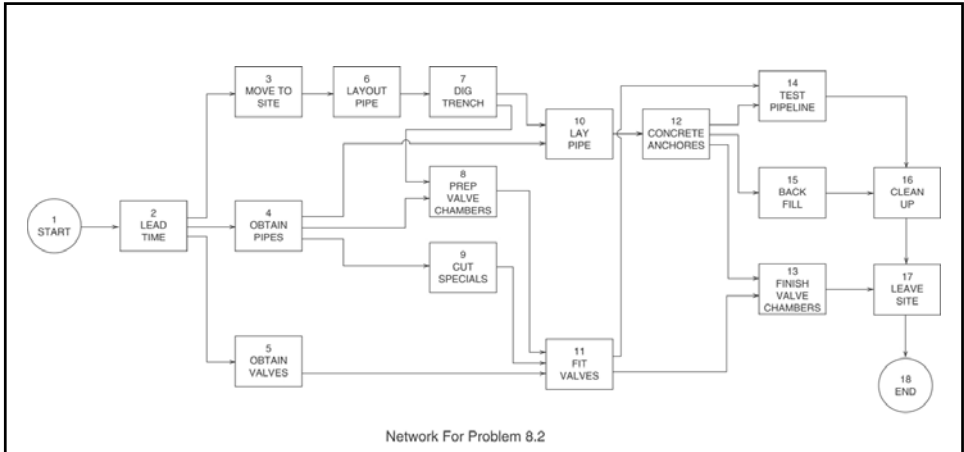
### Problem 8.1 (p. 143)

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Activity	Description	$t_s$	$t_m$	$t_b$	Followed by Activity
1	Start	0	0	0	2
2	Lead Time	10	10	10	3, 4, 5
3	Move to Site	18	20	22	6
4	Obtain Pipes	20	30	100	8, 9, 10
5	Obtain Valves	18	20	70	11
6	Lay Out Pipeline	6	7	14	7
7	Dig Trench	20	25	60	8, 10
8	Prepare Valve Chambers	17	18	31	11
9	Cut Specials	7	9	17	11
10	Lay Pipes	18	20	46	12
11	Fit Valves	8	10	12	13, 14
12	Concrete Anchors	11	12	13	13, 14, 15
13	Finish Valve Chambers	8	8	8	17
14	Test Pipeline	5	6	7	16
15	Backfill	8	10	20	16
16	Clean Up	2	3	10	17
17	Leave Site	3	4	5	18
18	End				

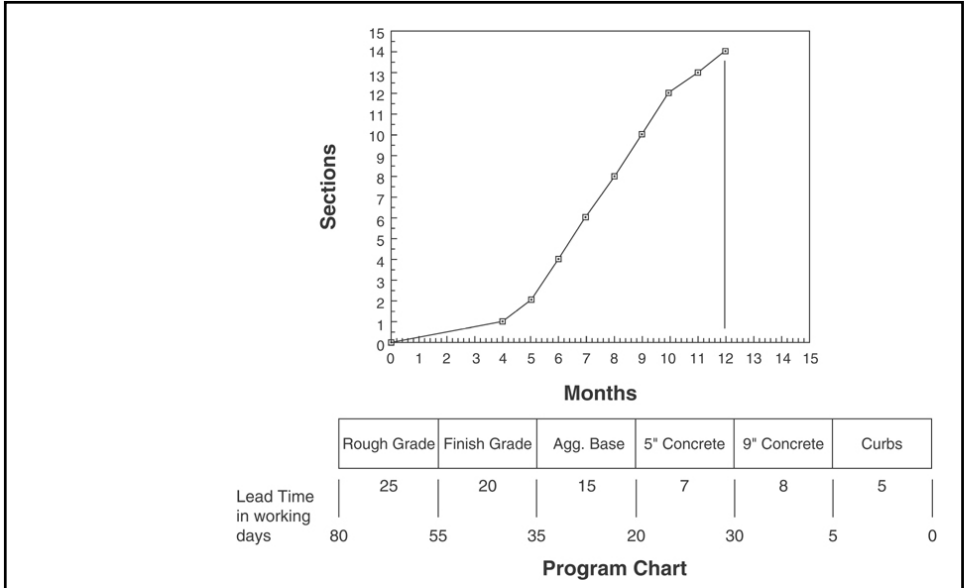
### Problem 8.2a (p. 143)

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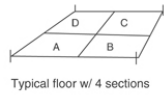
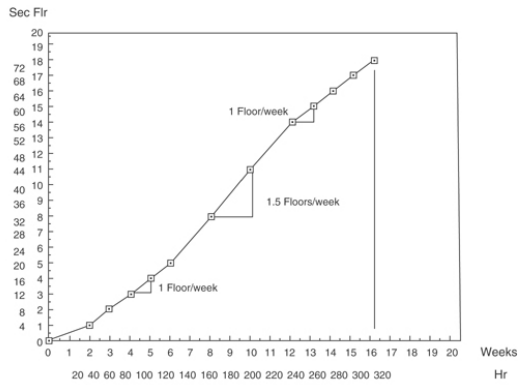
**Problem 8.2b (p. 144)**

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**Problem 8.3 (p. 145)**

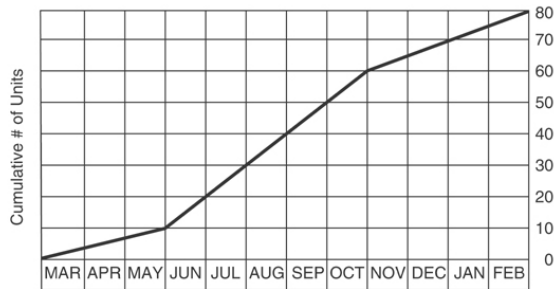
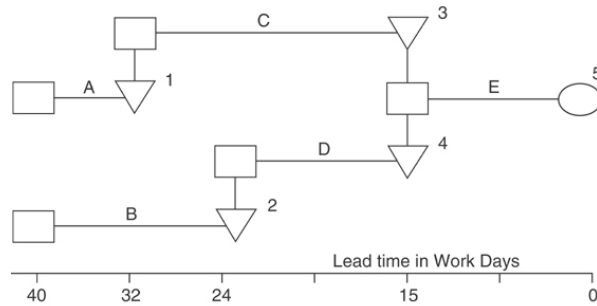
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Control Pts	1	2	3	4	5	6	7	8
	ERECT FORMS	RESTEEL	CONCRETETEL	CURE CONCRETE	DISMANTLE FORMS	BRICK	WINDOWS	
Lead Time in hours	120	112	102	96	24	10	4	0
	2 hrs	2 hrs	2 hrs	72 hrs	6 hrs	6 hrs	4	0

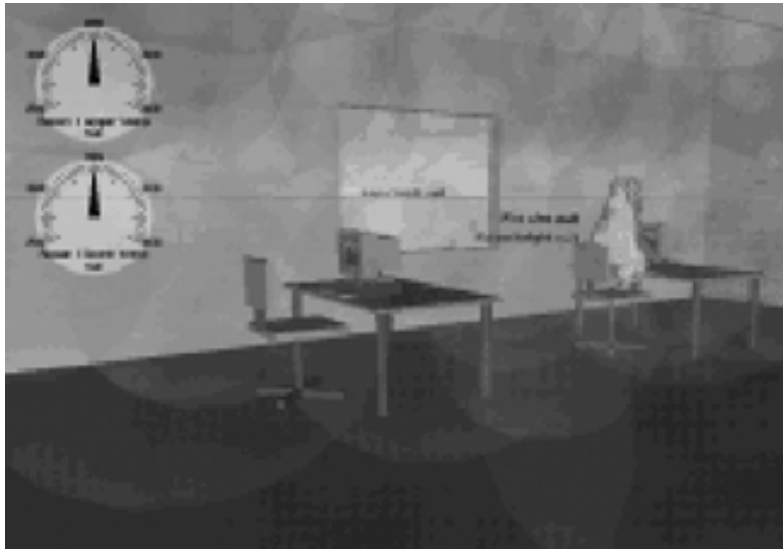
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**Problem 8.5 (p. 146)**

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