Scheduling – PERT Networks and Linear Operations

By

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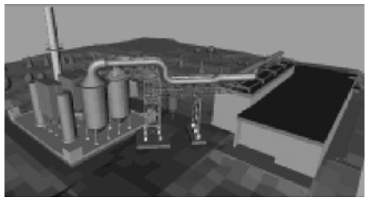
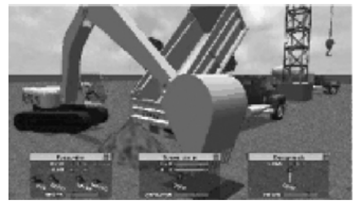
VRML Applications in Construction

- 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.





Chapter-Opener (p. 128)
VRML Model of the NIST Fire Research Facility Emissions Control System

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

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.

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.

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.

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.

Construction Management, 3/E by Daniel W. Halpin
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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

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.

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

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

Introduction

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

    t_a = 5 days

    t_m = 8 days

    t_b = 12 days

  - The expected activity duration is calculated as:

$$t_e = \frac{[5 + 4(8) + t12]}{6} = 8.17 \text{days, say 9 workingdays days}$$

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.

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, σ, 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.

Introduction

- Another parameter called the variance is the square of the standard deviation or σ^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*)

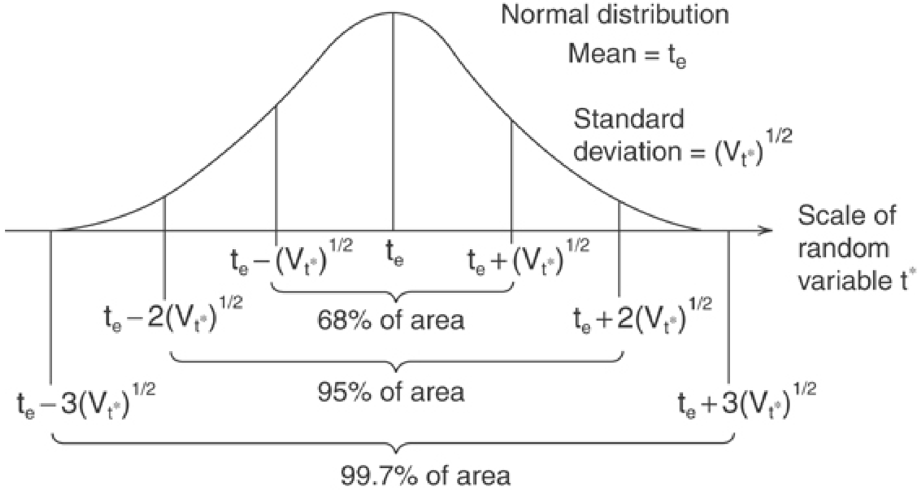


Figure 8.1 (p. 130)
Selected areas under the normal distribution curve.

Introduction

- In BERT, the standard deviation σ^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:

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

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***.

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 $t_1^*, t_2^*, \ldots\ldots t_m^*$ be the times at which these tasks are actually completed.
  - Note that these are random variables with true means $t_1, t_2, \ldots\ldots t_m$, and true variance $Vt_1^*, Vt_2^*, \ldots\ldots Vt_m^*$, and actual times are known until these specific tasks are actually performed.

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

$$T^* = t_i^* + t_2^* + \ldots + t_m^*$$

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

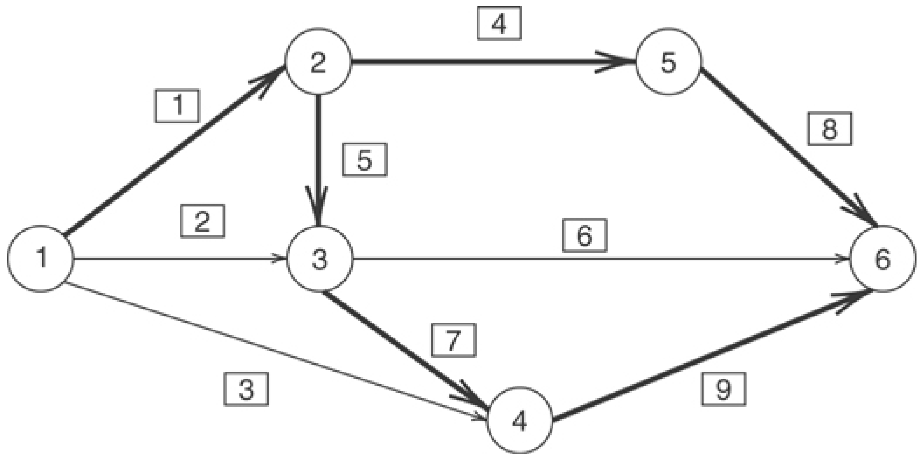


Figure 8.2 (p. 131)
Small PERT network.

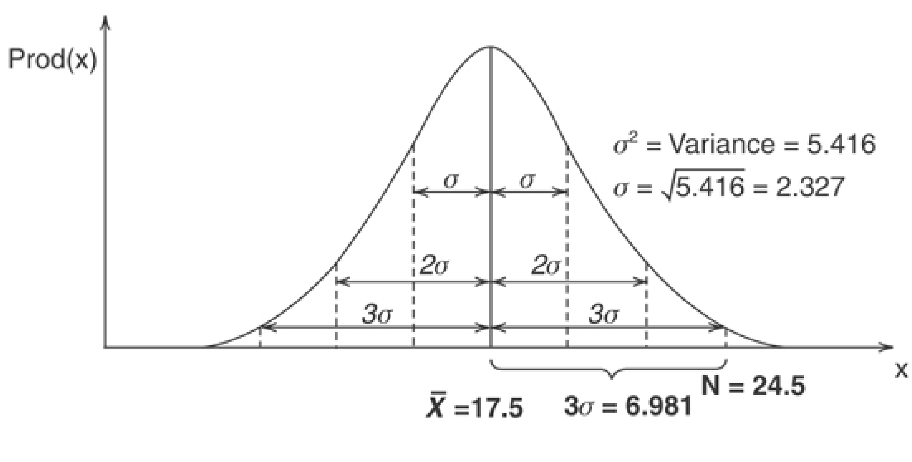


Figure 8.3 (p. 132)
Normal distribution of total project durations for small PERT network.

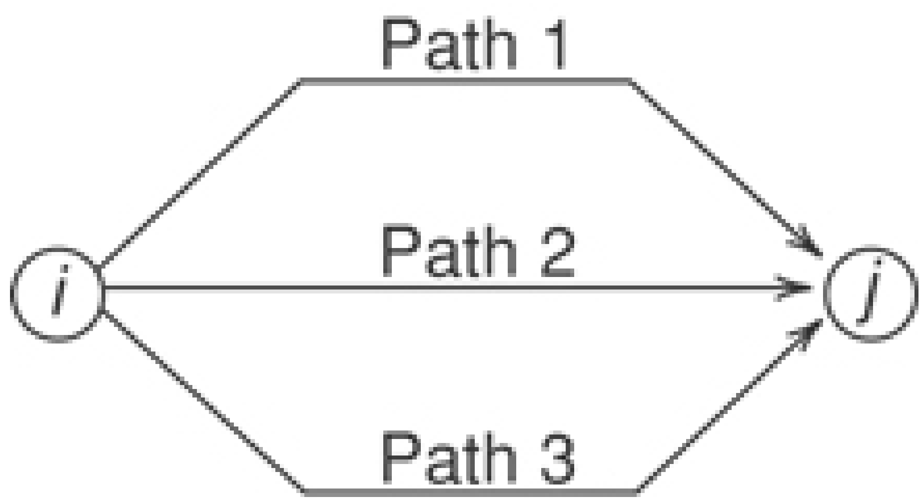


Figure 8.4 (p. 133)
Merge event bias.

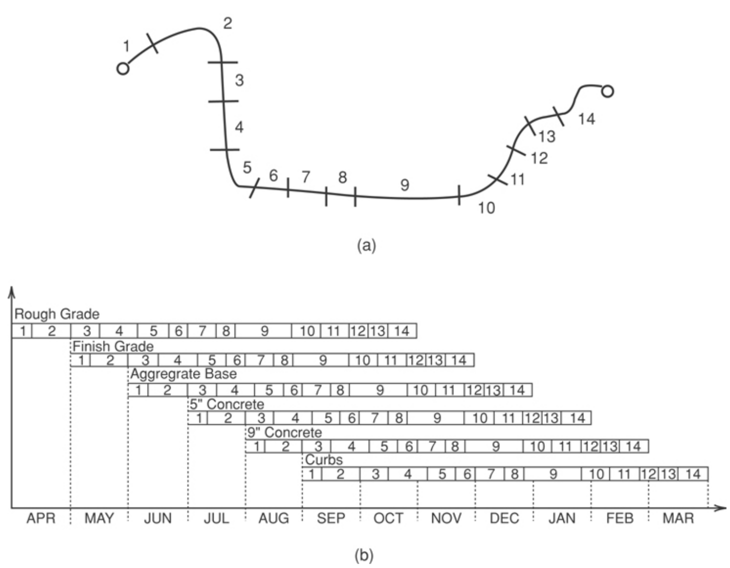


Figure 8.5 (p. 134)
Road project divided into 14 sections.

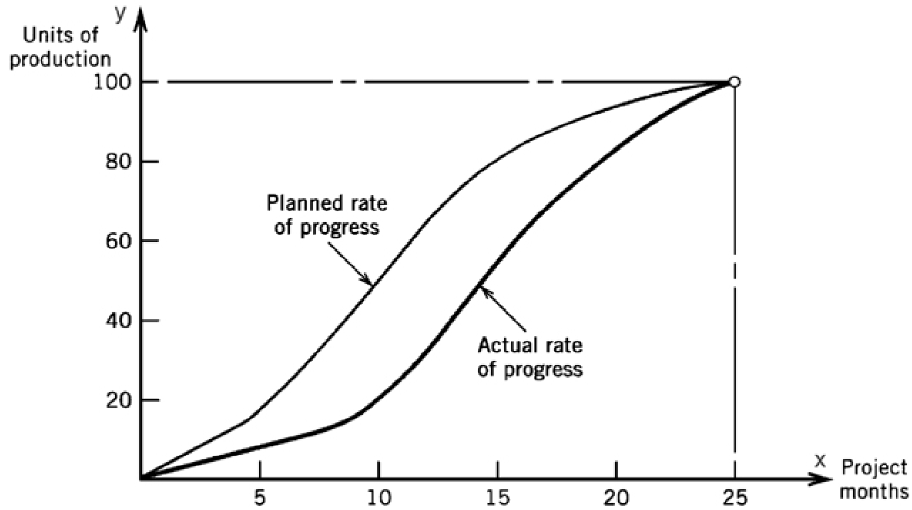


Figure 8.6 (p. 135)
Production curve.

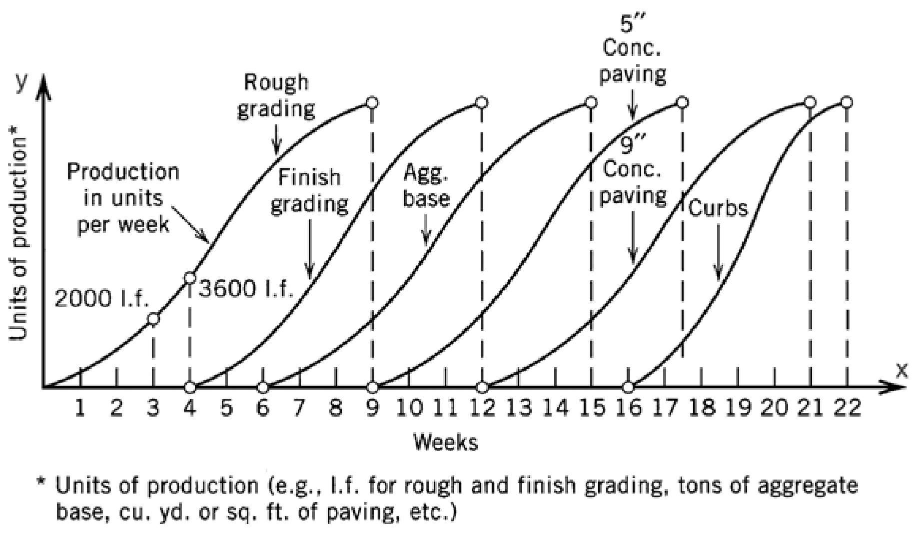


Figure 8.7 (p. 135)
Velocity diagrams for a road construction project.

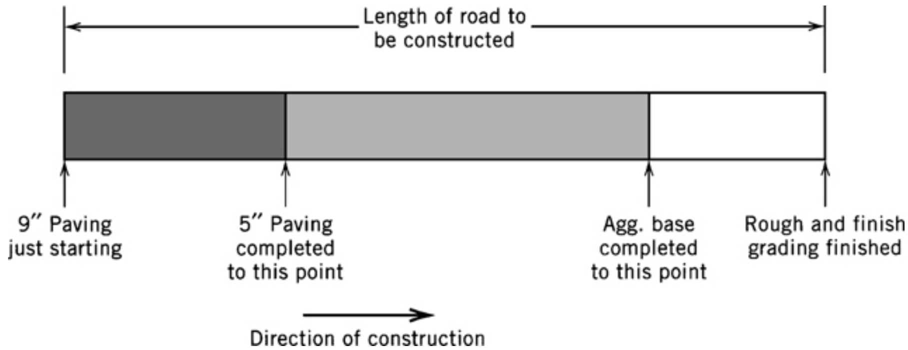


Figure 8.8 (p. 136)
Planned status of construction as of week 12.

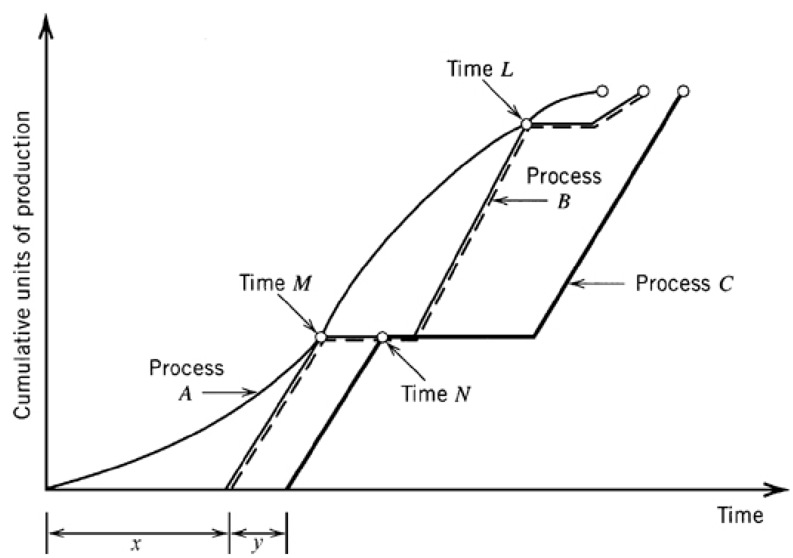


Figure 8.9 (p. 137)
Unbalanced process production rates.

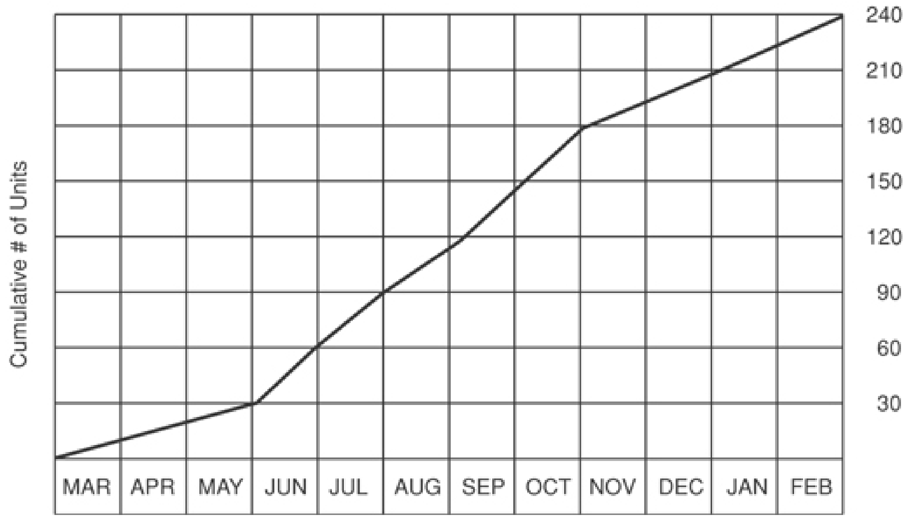


Figure 8.10 (p. 137)
Objective chart.

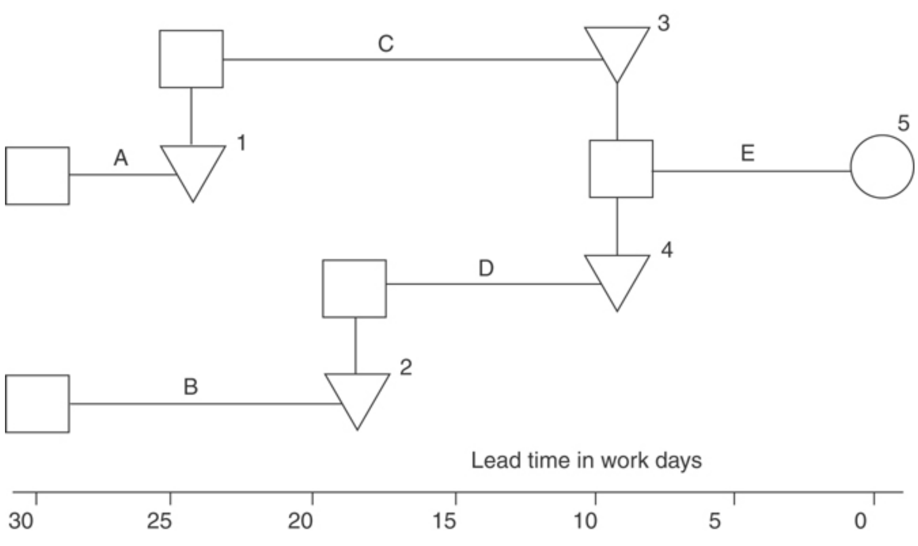


Figure 8.11 (p. 138)
Program chart with lead time in workdays.

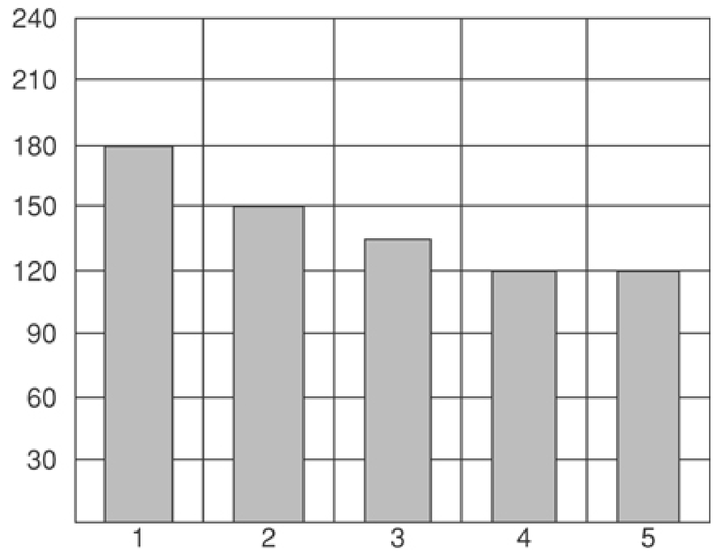


Figure 8.12 (p. 139)
Progress Chart.

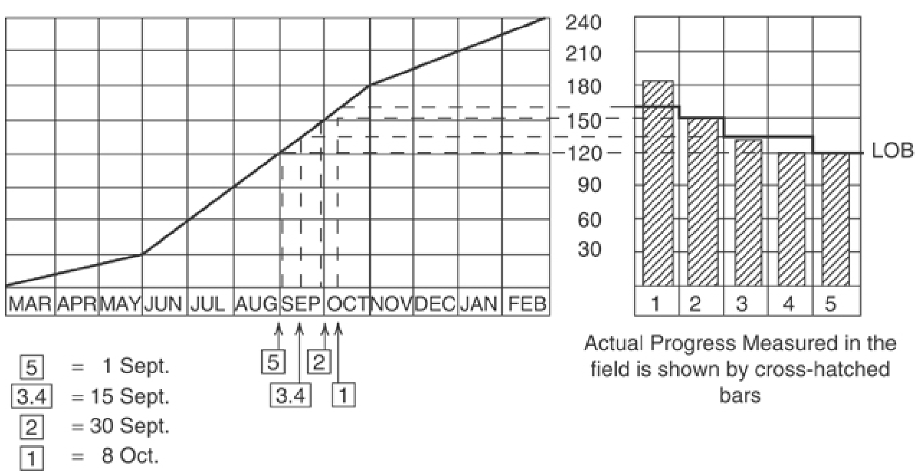
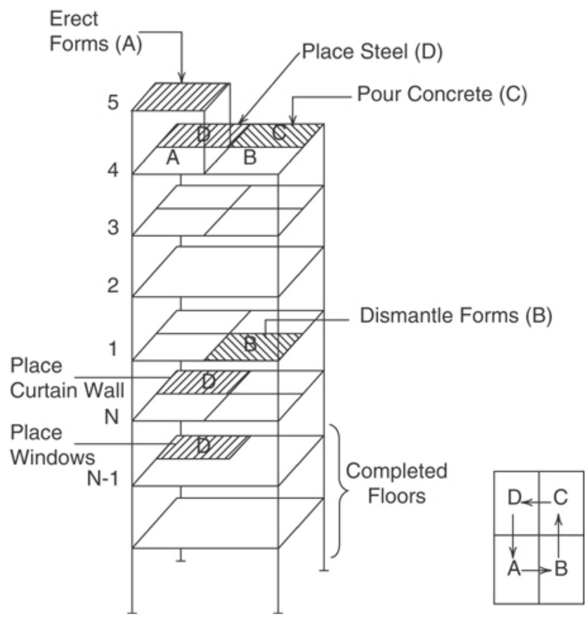


Figure 8.13 (p. 139)
Progress Chart with Line of Balance.

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



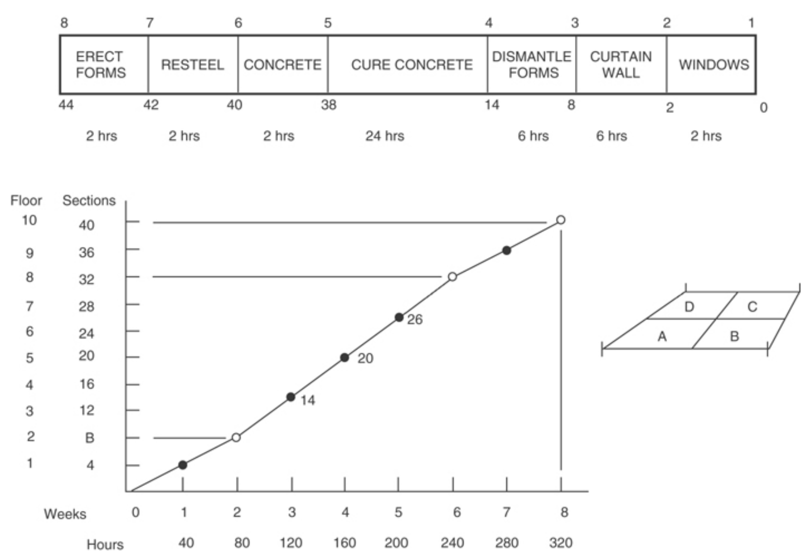
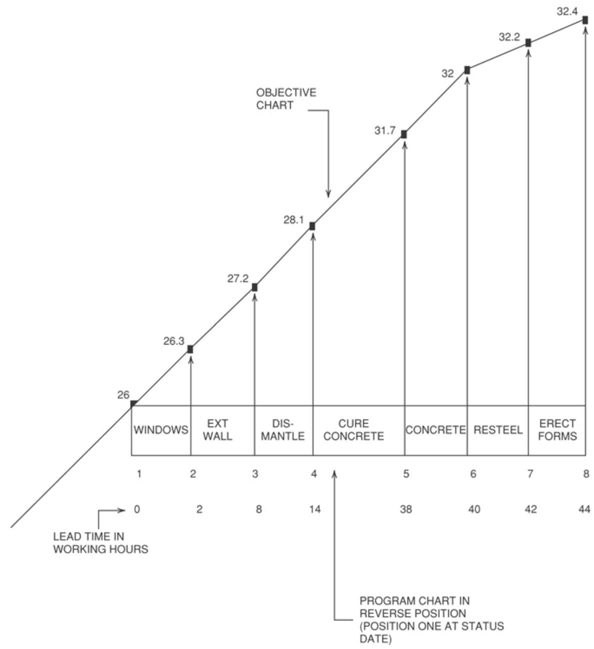


Figure 8.15 (p. 141)
Program chart and objective.

Figure 8.16 (p. 142)
Enlarged projection of program chart onto objective chart.



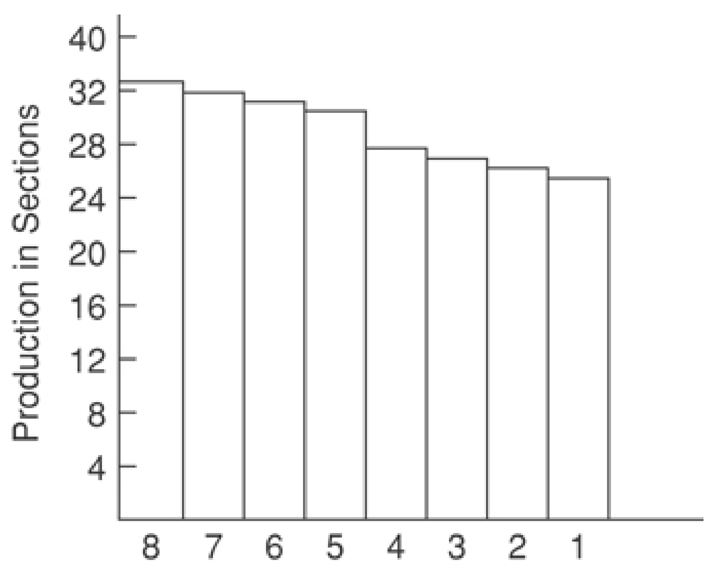


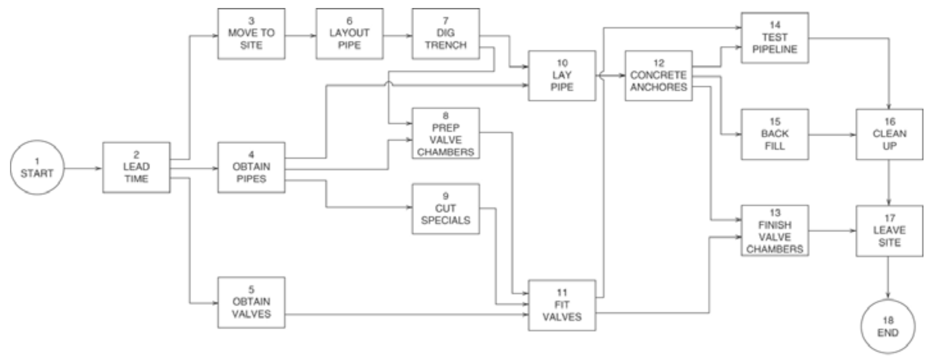
Figure 8.17 (p. 142)
Line of balance for week 5.

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_a, 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_a, t_m, t_b	6, 7, 8	80, 90, 100
60	Rough-in Plumbing	t_a, t_m, t_b	5, 7, 10	110
70	Install Conduit	t_a, 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_a, 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)

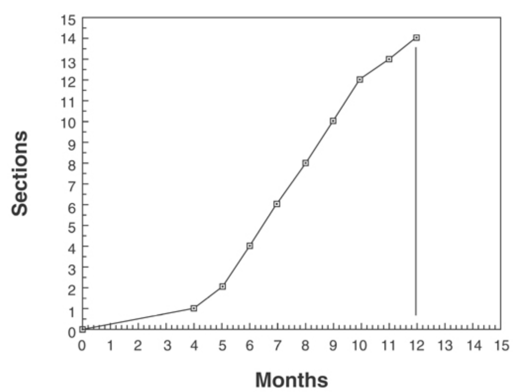
Activity	Description	t_a	t_m	t_b	Followed by Activity
1	Start	0	0	0	2
2	Lead Time	10	10	10	3, 4, 5
3	Move to Site	18	20	22	6
4	Obtain Pipes	20	30	100	8, 9, 10
5	Obtain Valves	18	20	70	11
6	Lay Out Pipeline	6	7	14	7
7	Dig Trench	20	25	60	8, 10
8	Prepare Valve Chambers	17	18	31	11
9	Cut Specials	7	9	17	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)



Network For Problem 8.2

Problem 8.2b (p. 144)



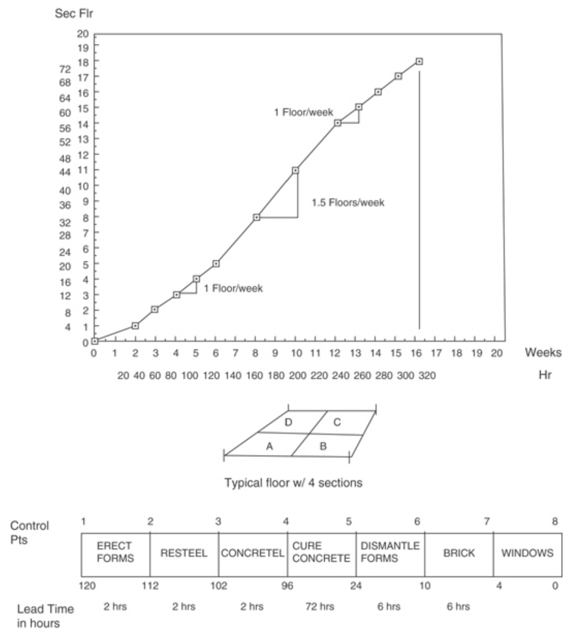
Rough Grade	Finish Grade	Agg. Base	5" Concrete	9" Concrete	Curbs
25	20	15	7	8	5

Lead Time in working days: 80, 55, 35, 20, 30, 5, 0

Program Chart

Problem 8.3 (p. 145)

Problem 8.4 (p. 145)



Problem 8.5 (p. 146)