PROJECT MANAGEMENT
THE MANAGERIAL PROCESS

Clifford F. Gray
Eric W. Larson
Third Edition

Chapter 6

Developing a Project Plan

PowerPoint Presentation by Charlie Cook

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Developing a Project Plan

- Developing the Project Network
- From Work Package to Network
- Constructing a Project Network
- Activity-on-Node (AON) Fundamentals
- Network Computation Process
- Using the Forward Pass and Backward Pass
- Level of Details for Activities
- Practical Considerations
- Extended Network Techniques to Come Closer to Reality
- Activity-on-Arrow Method
- Summary

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"I keep six honest serving-men (they taught me all I knew); their names are What and Why and When and How and Where and Who."

(Rudyard Kipling)

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Developing the Project Plan

• The Project Network
  – A flow chart that graphically depicts the sequence, interdependencies, and start and finish times of the project job plan of activities that is the *critical path* through the network.
    • Provides the basis for scheduling labor and equipment.
    • Enhances communication among project participants.
    • Provides an estimate of the project's duration.
    • Provides a basis for budgeting cash flow.
    • Identifies activities that are critical.
    • Highlights activities that are "critical" and can not be delayed.
    • Help managers get and stay on plan.

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From Work Package to Network

WBS/Work Packages to Network
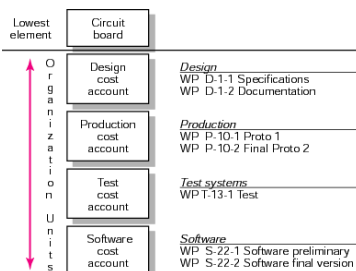
Lowest element	Circuit board	
Organization Units	Design cost account	*Design* WP D-1-1 Specifications WP D-1-2 Documentation
	Production cost account	*Production* WP P-10-1 Proto 1 WP P-10-2 Final Proto 2
	Test cost account	*Test systems* WP T-13-1 Test
	Software cost account	*Software* WP S-22-1 Software preliminary WP S-22-2 Software final version

FIGURE 6.1

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From Work Package to Network (cont'd)

WBS/Work Packages to Network (cont'd)
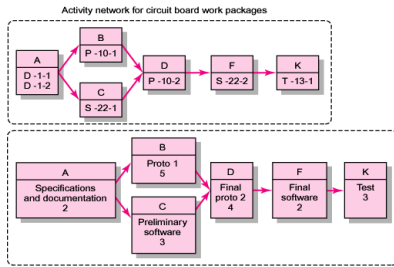
Activity network for circuit board work packages

FIGURE 6.1 (cont'd)

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Constructing a Project Network

- Terminology
  - **Activity:** an element of the project that requires time.
  - **Merge Activity:** an activity that has two or more preceding activities on which it depends.
  - **Parallel (Concurrent) Activities:** Activities that can occur independently and, if desired, not at the same time.
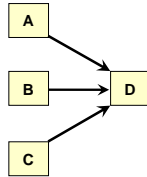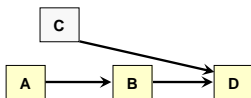

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Constructing a Project Network (cont'd)

- Terminology
  - **Path:** a sequence of connected, dependent activities.
  - **Critical path:** the longest path through the activity network that allows for the completion of all project-related activities; the shortest expected time in which the entire project can be completed. Delays on the critical path will delay completion of the entire project.

(Assumes that minimum of A + B > minimum of C in length of times to complete activities.)
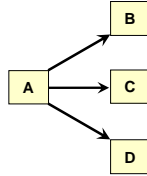McGraw-Hill/Irwin 6–9

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Constructing a Project Network (cont'd)

- Terminology
  - **Event:** a point in time when an activity is started or completed. It does not consume time.
  - **Burst Activity:** an activity that has more than one activity immediately following it (more than one dependency arrow flowing from it).
- Two Approaches
  - Activity-on-Node (AON)
    - Uses a node to depict an activity.
  - Activity-on-Arrow (AOA)
    - Uses an arrow to depict an activity.

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Basic Rules to Follow in Developing Project Networks

- Networks typically flow from left to right.
- An activity cannot begin until all of its activities are complete.
- Arrows indicate precedence and flow and can cross over each other.
- Identify each activity with a unique number; this number must be greater than its predecessors.
- Looping is not allowed.
- Conditional statements are not allowed.
- Use common start and stop nodes.

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Relationships between activities

- Predecessor activities
  - Activities must be completed immediately before current activity
- Successor activities
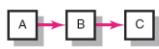 - Activities must immediately follow current activity
- Concurrent activities
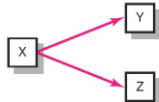 - Activities can occur while current activity is taking place

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Activity-on-Node Fundamentals

A is preceded by nothing
B is preceded by A
C is preceded by B

(A)

Y and Z are preceded by X

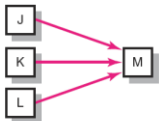Y and Z can begin at the same time, if you wish

(B)

FIGURE 6.2

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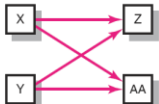## Activity-on-Node Fundamentals (cont'd)

J, K, & L can all begin at the same time, if you wish (they need not occur simultaneously)

but

All (J, K, L) must be completed before M can begin

(C)

Z is preceded by X and Y

AA is preceded by X and Y

(D)

FIGURE 6.2 (cont'd)

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Network Information

KOLL BUSINESS CENTER
County Engineers Design Department

Activity	Description	Preceding Activity
A	Application approval	None
B	Construction plans	A
C	Traffic study	A
D	Service availability check	A
E	Staff report	B, C
F	Commission approval	B, C, D
G	Wait for construction	F
H	Occupancy	E, G

TABLE 6.1

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5

Koll Business Center—Partial Network
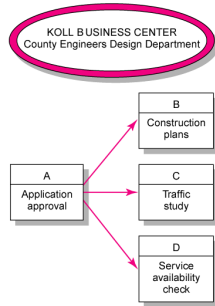
KOLL BUSINESS CENTER
County Engineers Design Department

B
Construction plans

A
Application approval

C
Traffic study

D
Service availability check

FIGURE 6.3

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Koll Business Center—Complete Network
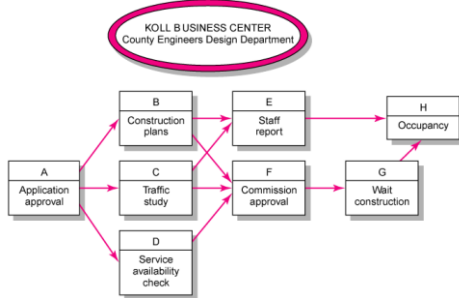
KOLL BUSINESS CENTER
County Engineers Design Department

B
Construction plans

E
Staff report

H
Occupancy

A
Application approval

C
Traffic study

F
Commission approval

G
Wait construction

D
Service availability check

FIGURE 6.4

McGraw-Hill/Irwin 6–17

Network Computation Process

• Forward Pass—Earliest Times
  –How soon can the activity start? (early start—ES)
  –How soon can the activity finish? (early finish—EF)
  –How soon can the project finish? (expected time—ET)
• Backward Pass—Latest Times
  –How late can the activity start? (late start—LS)
  –How late can the activity finish? (late finish—LF)
  –Which activities represent the critical path?
  –How long can it be delayed? (slack or float—SL)

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Network Information

KOLL BUSINESS CENTER
County Engineers Design Department

Activity	Description	Preceding Activity	Activity Time
A	Application approval	None	5
B	Construction plans	A	15
C	Traffic study	A	10
D	Service availability check	A	5
E	Staff report	B, C	15
F	Commission approval	B, C, D	10
G	Wait for construction	F	170
H	Occupancy	E, G	35

TABLE 6.2
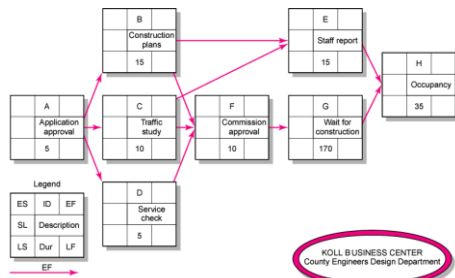
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Activity-on-Node Network
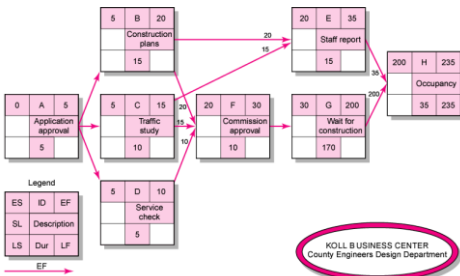
FIGURE 6.5

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Activity-on-Node Network Forward Pass

FIGURE 6.6

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Forward Pass Computation

- Add activity times along each path in the network (ES + Duration = EF).

- Carry the early finish (EF) to the next activity where it becomes its early start (ES) *unless…*

- The next succeeding activity is a merge activity, in which case the largest EF of all preceding activities is selected.
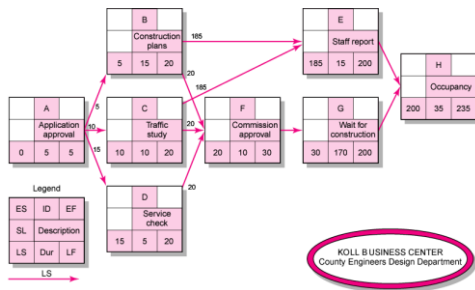
Activity-on-Node Network Backward Pass

FIGURE 6.7

Backward Pass Computation

- Subtract activity times along each path in the network (LF - Duration = LS).

- Carry the late start (LS) to the next activity where it becomes its late finish (LF) *unless*

- The next succeeding activity is a burst activity, in which case the smallest LF of all preceding activities is selected.

Determining Slack (or Float)

- Slack (or Float)
  - The amount of time an activity can be delayed after the start of a longer parallel activity or activities.
- Total slack
  - The amount of time an activity can be delayed without delaying the entire project.
- The critical path is the network path(s) that has (have) the least slack in common.

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Activity-on-Node Network with Slack
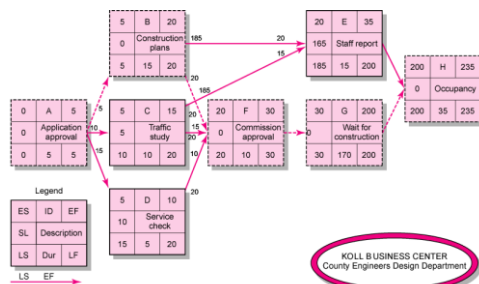
FIGURE 6.8

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Practical Considerations

- Network Logic Errors
- Activity Numbering
- Use of Computers to Develop Networks
- Calendar Dates
- Multiple Starts and Multiple Projects

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Illogical Loop

A → B → C → A

FIGURE 6.9

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Air Control Project

FIGURE 6.10

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Air Control Project (cont'd)

ID	Duration	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	2 days	Order review	Tue 1/1/05	Wed 1/2/05	Tue 1/1/05	Wed 1/2/05	0 days	0 days
2	15 days	Order vendor parts	Thu 1/3/05	Thu 1/17/05	Wed 1/16/05	Wed 1/30/05	13 days	13 days
3	10 days	Produce other standard parts	Thu 1/3/05	Sat 1/12/05	Mon 1/21/05	Wed 1/30/05	18 days	18 days
4	13 days	Design custom parts	Thu 1/3/05	Tue 1/15/05	Thu 1/3/05	Tue 1/15/05	0 days	0 days
5	18 days	Software development	Thu 1/3/05	Sun 1/20/05	Wed 1/23/05	Sat 2/9/05	20 days	20 days
6	15 days	Manufacture custom hardware	Wed 1/16/05	Wed 1/30/05	Wed 1/16/05	Wed 1/30/05	0 days	0 days
7	10 days	Assemble	Thu 1/31/05	Sat 2/6/05	Thu 1/31/05	Sat 2/9/05	0 days	0 days
8	5 days	Test	Sun 2/10/05	Thu 2/14/05	Sun 2/10/05	Thu 2/14/05	0 days	0 days

FIGURE 6.11

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Extended Network Techniques to Come Close to Reality

- Laddering
  - Activities are broken into segments so the following activity can begin sooner and not delay the work.
- Lags
  - The minimum amount of time a dependent activity must be delayed to begin or end.
    - Lengthy activities are broken down to reduce the delay in the start of successor activities.
    - Lags can be used to constrain finish-to-start, start-to-start, finish-to-finish, start-to-finish, or combination relationships.

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Example of Laddering Using Finish-to-Start Relationship

Trench 1/3	Trench 1/3	Trench 1/3	AON network
Lay pipe 1/3	Lay pipe 1/3	Lay pipe 1/3	
Refill 1/3	Refill 1/3	Refill 1/3	

FIGURE 6.12

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Use of Lags

Finish-to-Start Relationship

X — Lag 2 → Y

FIGURE 6.13

Start-to-Start Relationship

A — Activity M → Activity N

B — Activity P — Lag 5 → Activity Q

FIGURE 6.14

McGraw-Hill/Irwin 6–33

Use of Lags Cont'd

Use of Lags to Reduce Detail

Trench 1 mile

Lag 3

Lay pipe 1 mile

Lag 3

Refill 1 mile

FIGURE 6.15

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Traditional Sequential Approach

Product planning → Systems engineering → Engineering design & development → Procurement → Manufacturing & production → Quality assurance → Release

Concurrent Engineering Approach

Quality assurance → Release

Manufacturing & production

Procurement

Engineering design & development

Systems engineering

Product planning

New Product Development Process

FIGURE 6.16

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Use of Lags (cont'd)

Prototype

Lag 4

Testing

Finish-to-Finish Relationship

FIGURE 6.17

Testing

System documentation

Lag 3

Start-to-Finish Relationship

FIGURE 6.18

Lag 4

Code

Lag 2

Debug

Combination Relationship

FIGURE 6.19

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Network Using Lags

0	A	5
0	Design system	5
0	5	10

5	F	20
12	System documentation	0
17	3	20

Lag 2

12	E	18
4	Test system	0
16	2	18

Lag 2

Lag 3

3	B	4
0	Order hardware	0
3	1	4

Lag 4

8	C	10
0	Install hardware	0
8	2	10

10	D	16
0	Install hardware	0
10	6	16

Lag 2

Legend

ES	ID	EF
SL	Description	SL
LS	Duration	LF

FIGURE 6.20

Hammock Activities

- Hammock Activity
  - An activity that spans over a segment of a project.
  - Duration of hammock activities is determined after the network plan is drawn.
  - Hammock activities are used to aggregate sections of the project to facilitate getting the right amount of detail for specific sections of a project.

Hammock Activity Example

6	C	11
0		
6	5	11

11	E	21
0		
11	10	21

0	A	5
0		
0	5	5

5	B	6
0		
5	1	6

6	D	10
8		
14	4	18

10	F	13
8		
18	3	21

21	F	25
0		
21	4	25

Legend

ES	ID	EF
SL	Description	
LS	Dur.	LF

5	G	13
	Hammock	
	8	

FIGURE 6.21
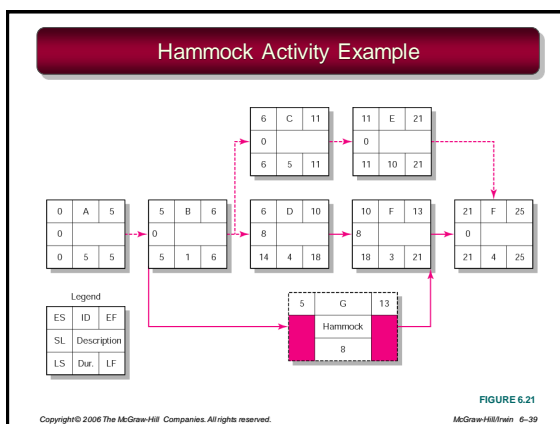
Key Terms

Activity	Gantt chart
Activity-on-arrow (AOA)	Hammock activity
Activity-on-node (AON)	Lag relationship
Burst activity	Merge activity
Concurrent engineering	Network sensitivity
Critical path	Parallel activity
Early and late times	Slack/float—total and free

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Activity-on-Arrow Network Building Blocks

FIGURE A6.1

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Activity-on-Arrow Network Fundamentals
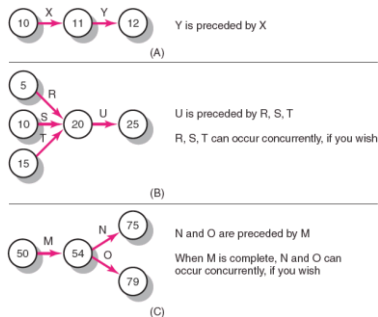
FIGURE A6.2

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Activity-on-Arrow Network Fundamentals
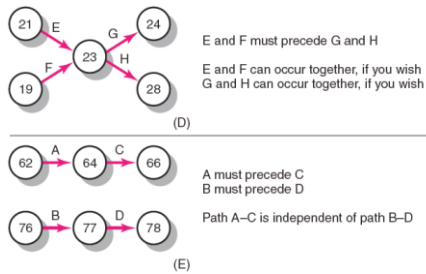
E and F must precede G and H

E and F can occur together, if you wish
G and H can occur together, if you wish

(D)

A must precede C
B must precede D

Path A–C is independent of path B–D

(E)

Koll Center Project: Network Information

KOLL BUSINESS CENTER
County Engineers Design Department

Activity	Description	Preceding Activity	Activity Time
A	Application approval	None	5
B	Construction plans	A	15
C	Traffic study	A	10
D	Service availability check	A	5
E	Staff report	B, C	15
F	Commission approval	B, C, D	10
G	Wait for construction	F	170
H	Occupancy	E, G	35

Partial Koll Business Center AOA Network
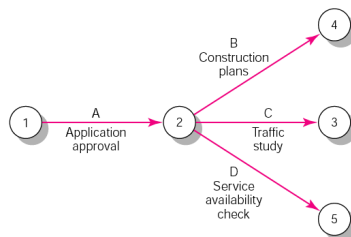
15
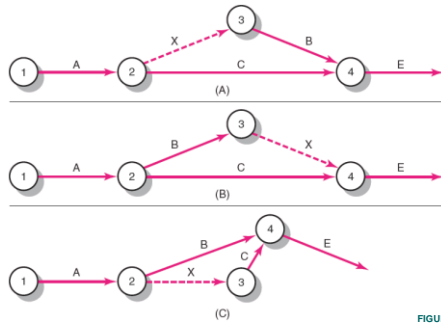
Partial AOA Koll Network

FIGURE A6.4

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Partial AOA Koll Network (cont'd)
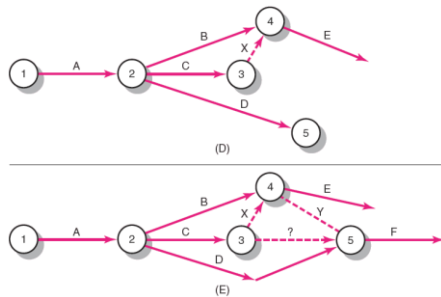
FIGURE A6.4 (cont'd)

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Activity-on-Arrow Network
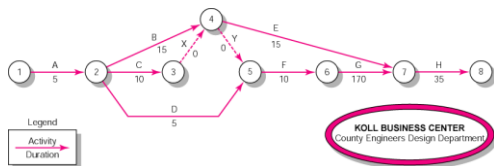
KOLL BUSINESS CENTER
County Engineers Design Department

FIGURE A6.5

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Activity-on-Arrow Network Forward Pass
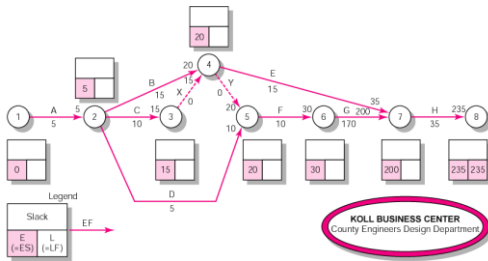
FIGURE A6.6
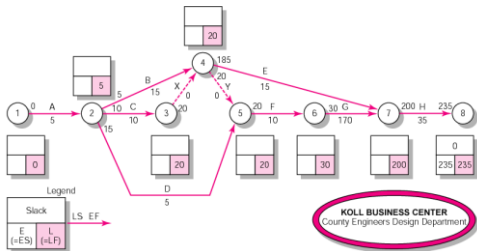
Activity-on-Arrow Network Backward Pass

FIGURE A6.7

Activity-on-Arrow Network Backward Pass, Forward Pass, and Slack
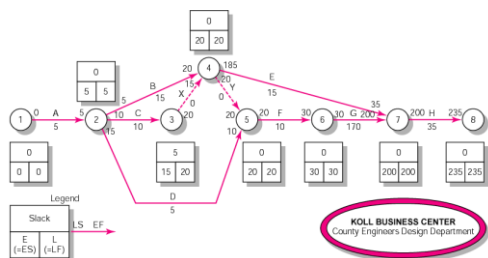
FIGURE A6.8

Air Control Inc. Custom Order Project— AOA Network Diagram
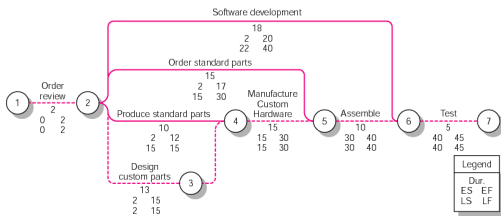
Software development
18
2   20
22   40

Order standard parts
15
2   17
15   30

Order review
2
0   2
0   2

Manufacture Custom Hardware

Produce standard parts
10
2   12
15   15

Assemble
10
30   40
30   40

Test
5
40   45
40   45

15
15   30
15   30

Design custom parts
13
2   15
2   15

Legend
Dur.
ES   EF
LS   LF

FIGURE A6.9

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AON Method

Comparison of AON and AOA Methods

Advantages
1. No dummy activities are used.
2. Events are not used.
3. AON is easy to draw if dependencies are not intense.
4. Activity emphasis is easily understood by first-level managers.
5. The CPM approach uses deterministic times to construct networks.

Disadvantages
1. Path tracing by activity number is difficult. If the network is not available, computer outputs must list the predecessor and successor activities for each activity.
2. Network drawing and understanding are more difficult when dependencies are numerous.

AOA Method

Advantages
1. Path tracing is simplified by activity/event numbering scheme.
2. AOA is easier to draw if dependencies are intense.
3. Key events or milestones can easily be flagged.

Disadvantages
1. Use of dummy activities increases data requirements.
2. Emphasis on events can detract from activities. Activity delays cause events and projects to be late.

TABLE A6.2

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