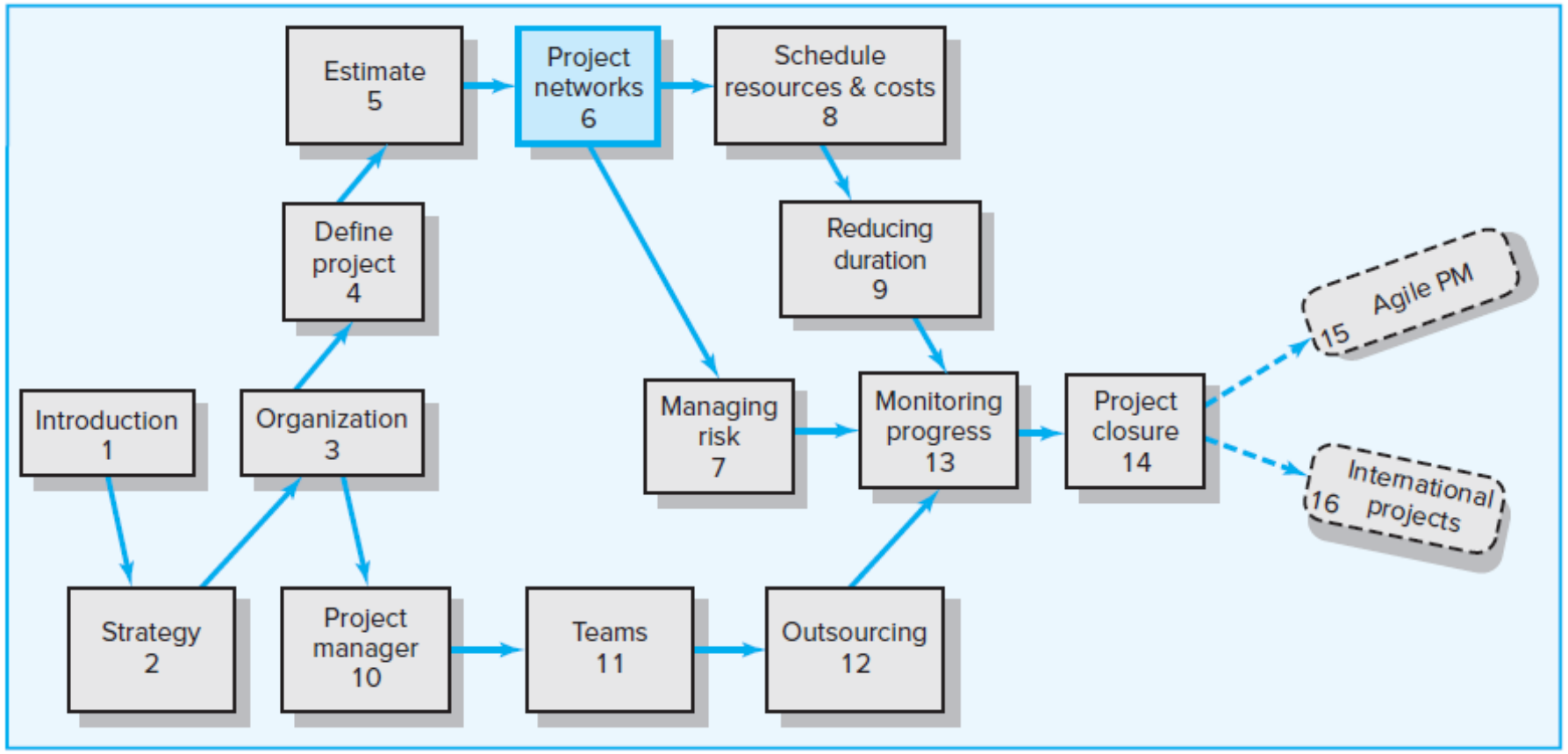
OntarioTech
Engineering
& Applied Science

Project Management for Engineers - ENGR 5410G
Fall 2024

Unit 4:
Developing a Project Schedule

Where We Are Now



Learning Objectives

06-01 Understand the linkage between WBS and the project network.

06-02 Diagram a project network using AON methods.

06-03 Calculate early, late, and slack activity times.

06-04 Identify and understand the importance of managing the critical path.

06-05 Distinguish free slack from total slack.

06-06 Demonstrate understanding and application of lags in compressing projects or constraining the start or finish of an activity.

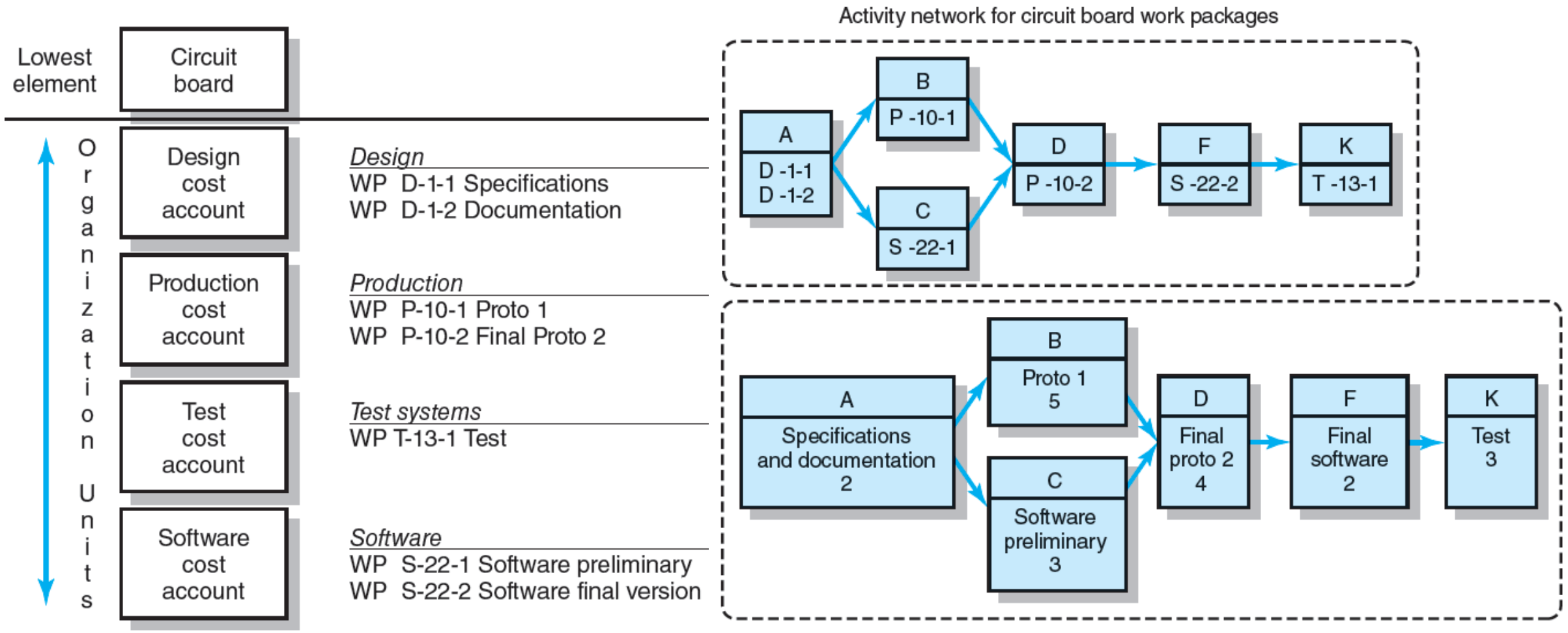
Chapter Outline

6.1 Developing the Project Network

The Project Network Defined

- Is a graphic flow chart depicting the project activities that must be completed, the logical sequences, the interdependencies of the activities to be completed, and the times for the activities to start and finish along with the longest path(s) through the network—the critical path.
- Provides the basis for scheduling labor and equipment.
- Enhances communication among project stakeholders.
- Provides an estimate of project duration.
- Provides the basis for budgeting the cash flow.
- Identifies which activities are “critical” and should not be delayed.
- Highlights which activities to consider for compressing the project duration.
- Helps managers get and stay on the project plan.

6.2 From Work Package to Network



FIG

6.3 Constructing a Project Network

Terminology

- Activity: an element of the project that requires time but may not require resources
- Parallel activities: activities that can take place at the same time, if desired.
- Burst activity: an activity that has more than one activity immediately following it (more that one dependency arrow flowing from it)
- Merge activity: an activity that has more than one activity immediately preceding it (more than one dependency arrow flowing to it)
- Path: a sequence of connected, dependent activities
- Critical path: the path with the longest duration through the network

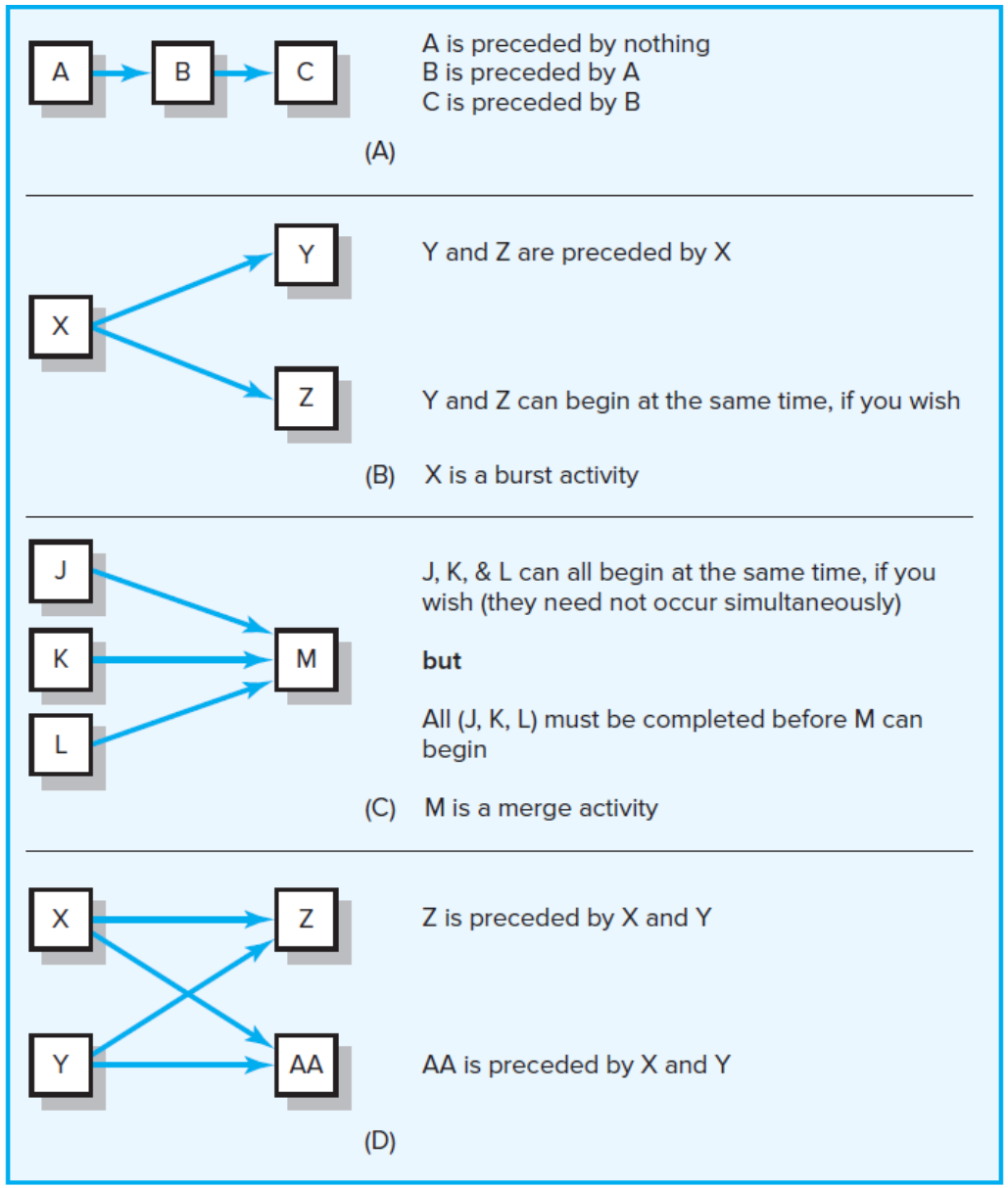
Two approaches

- Activity-on-Node (AON) uses a node to depict an activity.
- Activity-on-Arrow (AOA) uses an arrow to depict an activity.

Basic Rules to Follow in Developing Project Networks

1. Networks flow typically from left to right.
2. An activity cannot begin until all preceding connected activities have been completed.
3. Arrows on networks indicate precedent and flow and can cross over each other.
4. Each activity should have a unique identification number.
5. An activity identification number must be greater than that of any activities that precede it.
6. Looping is not allowed.
7. Conditional statements are not allowed.
8. Where there are multiple starts, a common start node can be used to indicate a clear project beginning on the network. Similarly, a single project end node can be used to indicate a clear ending.

6.4 Activity-on-Node (AON) Fundamentals



FIG

Network Information (Automated Warehouse)

AUTOMATED WAREHOUSE
Order Picking System

Activity	Description	Preceding Activity
A	Define Requirements	None
B	Assign Team	A
C	Design Hardware	A
D	Code Software	B
E	Build and Test Hardware	C
F	Develop Patent Request	C
G	Test Software	D
H	Integrate Systems	E, F, G

Automated Warehouse—Partial Network

AUTOMATED WAREHOUSE
Order Picking System

Activity	Description	Preceding Activity
A	Define Requirements	None
B	Assign Team	A
C	Design Hardware	A
D	Code Software	B
E	Build and Test Hardware	C
F	Develop Patent Request	C
G	Test Software	D
H	Integrate Systems	E, F, G

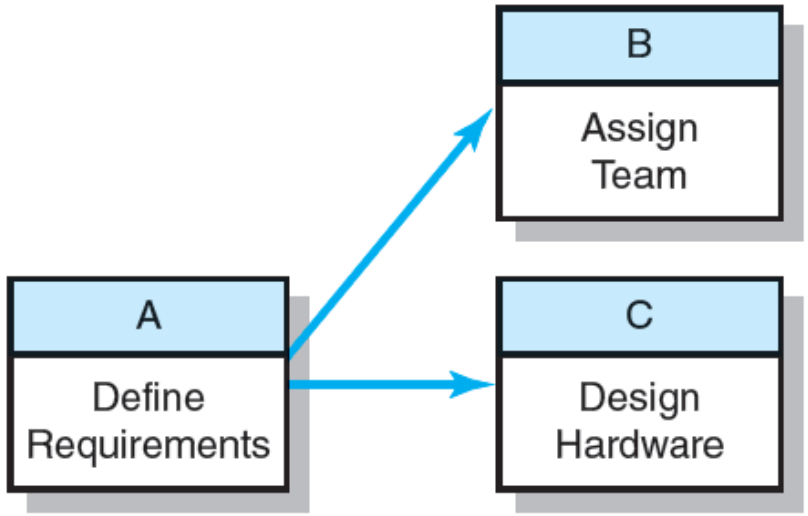
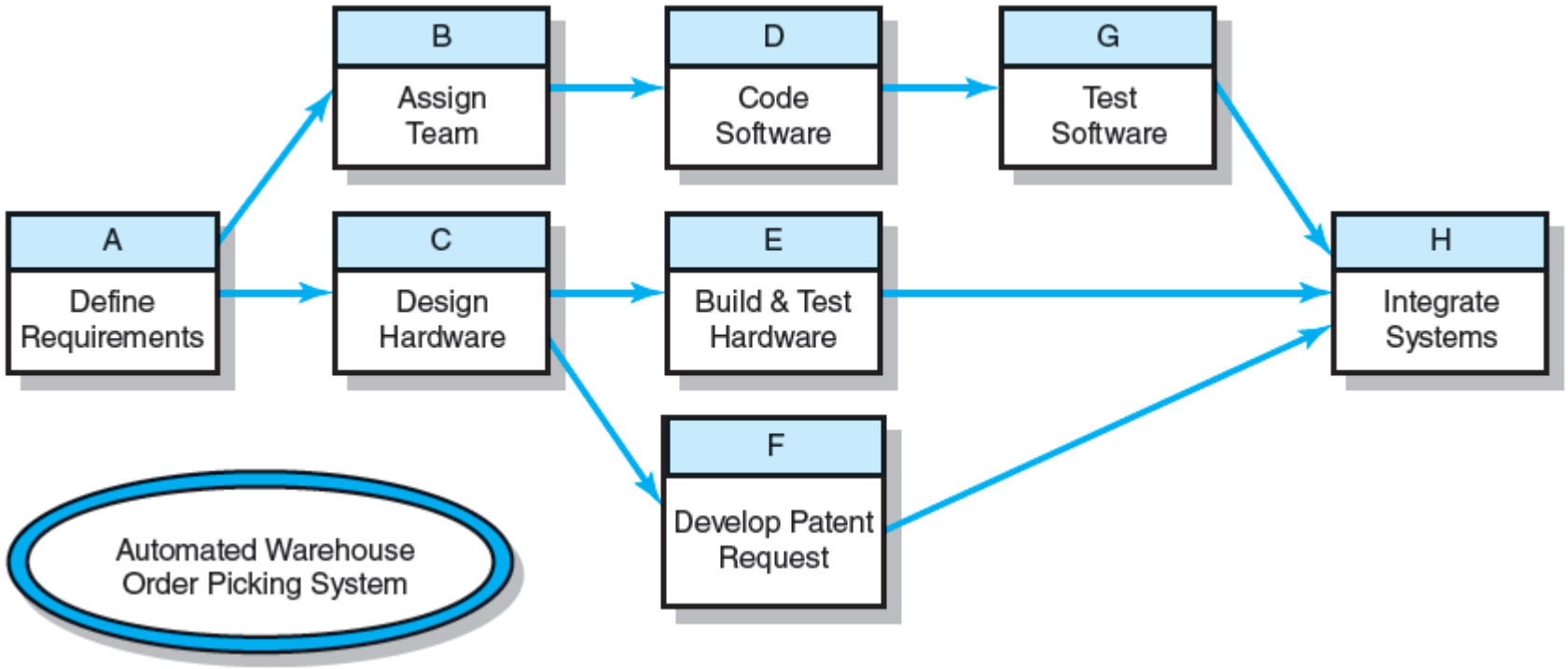


FIGURE 6.3

Automated Warehouse—Completed Network

AUTOMATED WAREHOUSE
Order Picking System

Activity	Description	Preceding Activity
A	Define Requirements	None
B	Assign Team	A
C	Design Hardware	A
D	Code Software	B
E	Build and Test Hardware	C
F	Develop Patent Request	C
G	Test Software	D
H	Integrate Systems	E, F, G



FIG

6.5 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—TE)

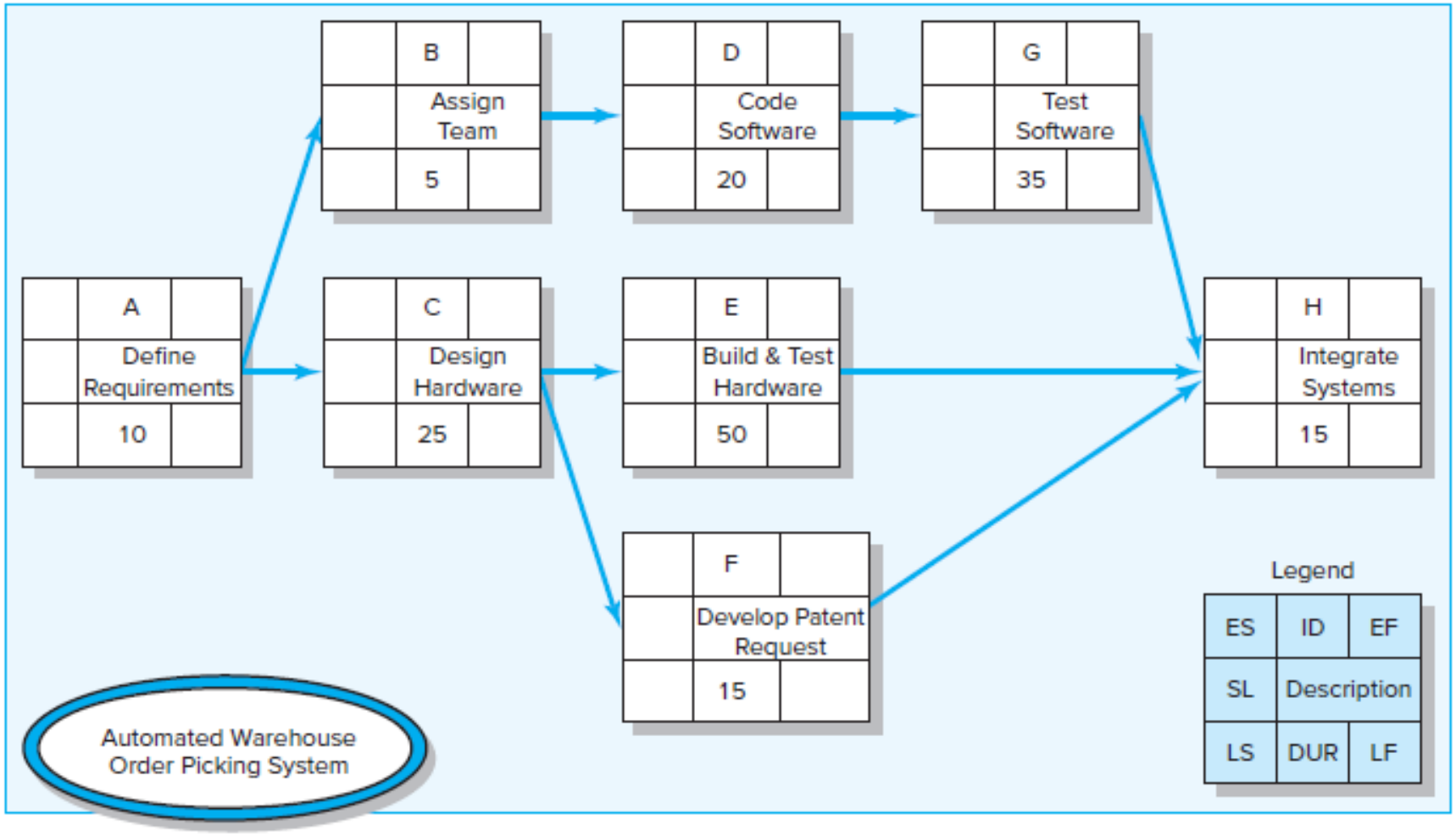
Backward Pass—Latest Times

- How late can the activity start? (late start—LS)
- How late can the activity finish? (late finish—LF)
- Which activities represent the critical path? (critical path—CP)
- How long can the activity be delayed? (slack or float—SL)

Network Information (Automated Warehouse)

AUTOMATED WAREHOUSE Order Picking System			
Activity	**Description**	**Preceding Activity**	**Activity Time**
A	Define Requirements	None	10 workdays
B	Assign Team	A	5
C	Design Hardware	A	25
D	Code Software	B	20
E	Build & Test Hardware	C	50
F	Develop Patent Request	C	15
G	Test Software	D	35
H	Integrate Systems	E, F, G	15

Activity-on-Node Network



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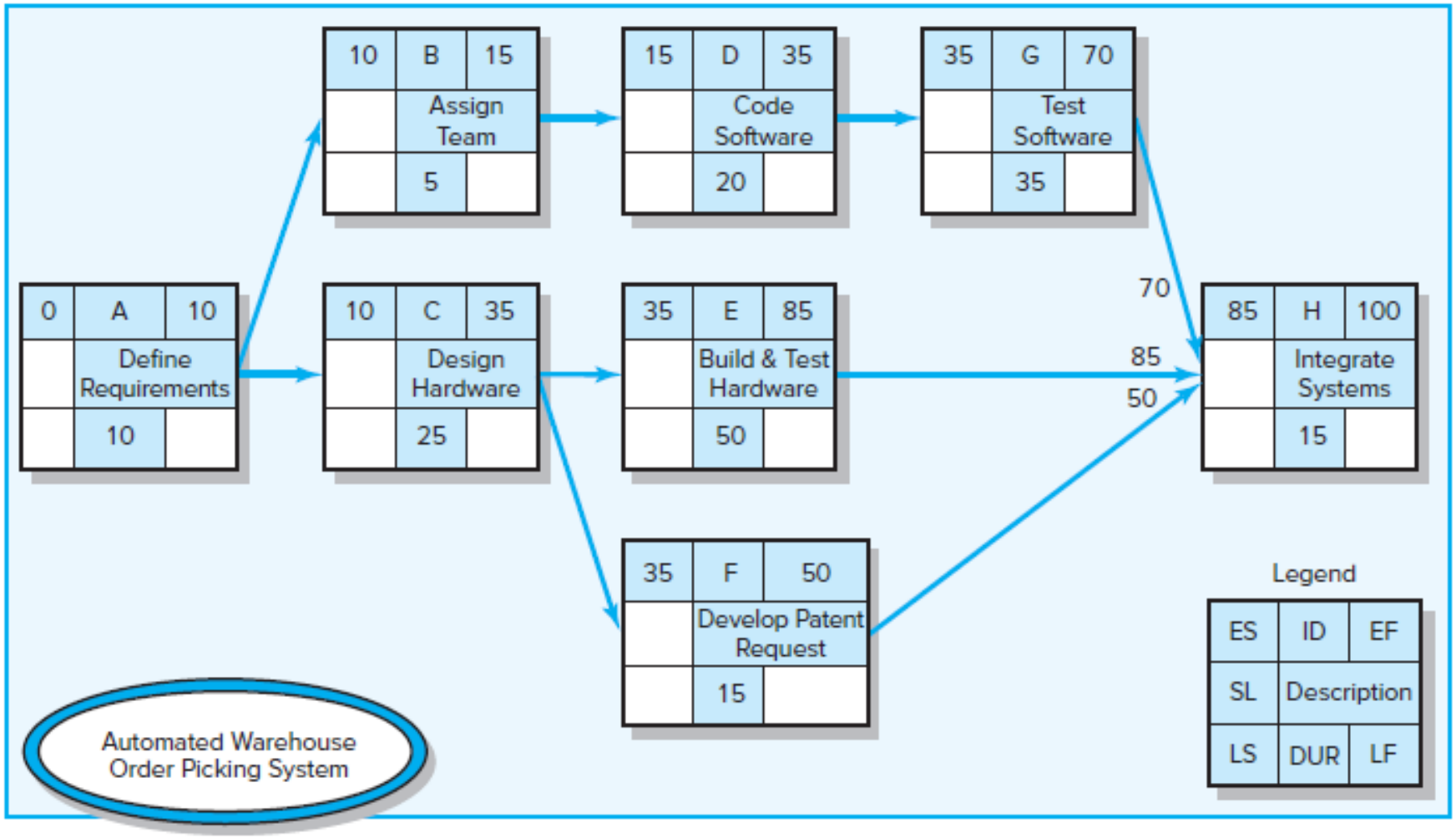
Activity-on-Node Network Forward Pass

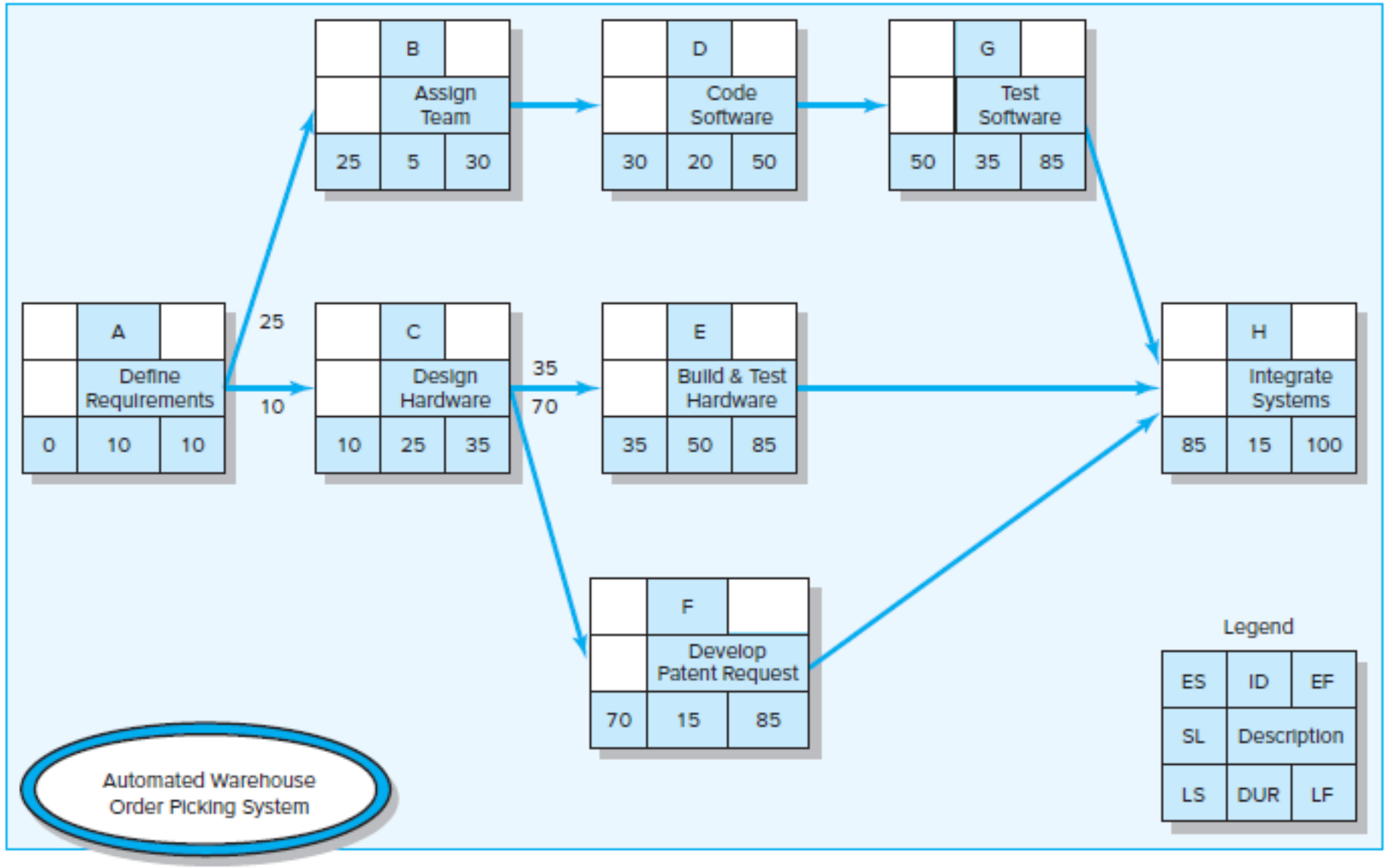


FIG

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 early finish (EF) number of all its immediate predecessor activities is selected.

Activity-on-Node Network Backward Pass

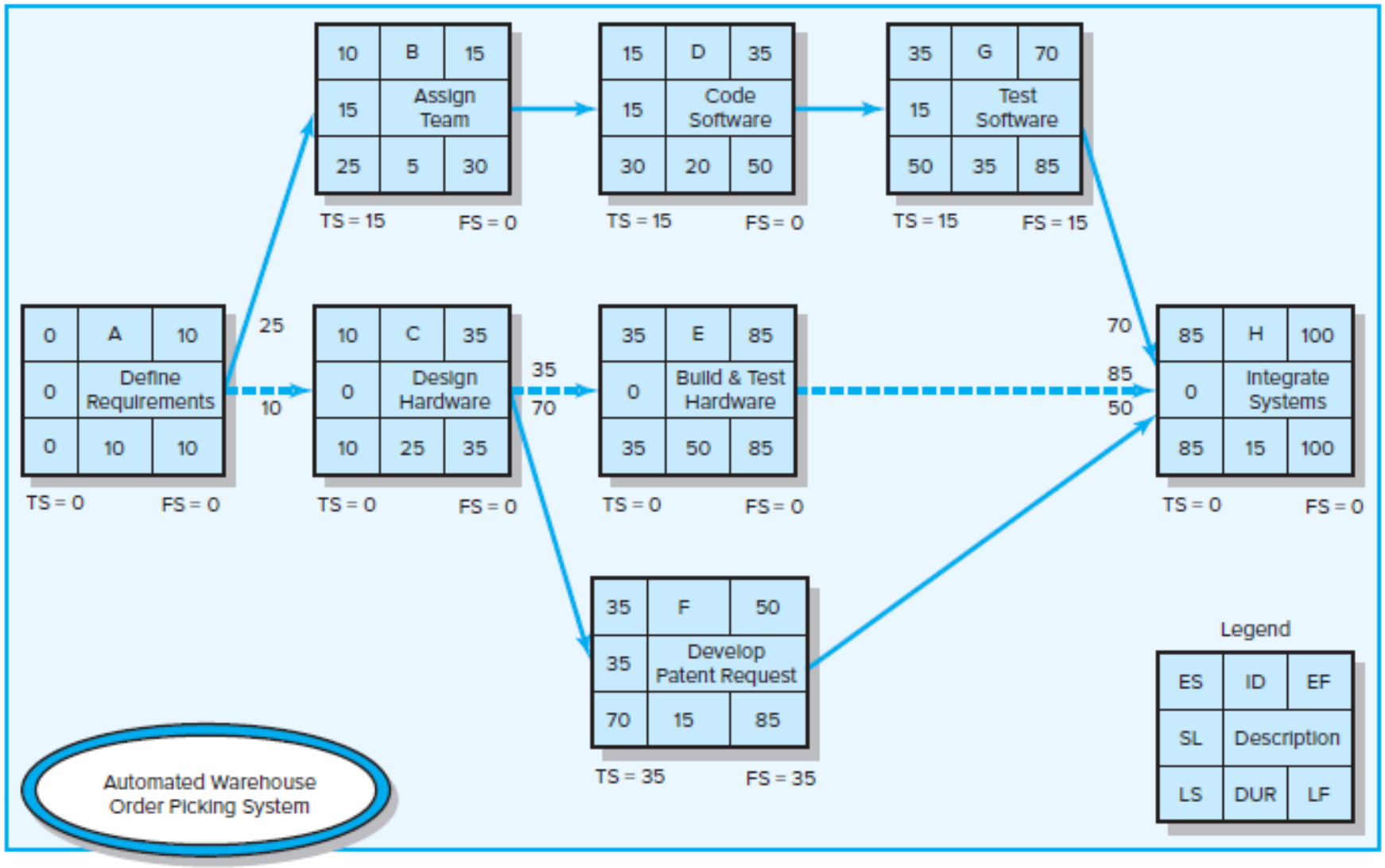


FIG

Backward Pass Computation

- Subtract activity times along each path starting with the project end activity (LF – Duration = LS).
- Carry the late start (LS) to the next preceding activity where it becomes its late finish (LF) unless…
- The next succeeding activity is a burst activity, in which case the smallest late start (LS) number of all its immediate successor activities is selected.

Forward and Backward Pass Completed with Slack Times



FIG

Determining Slack (or Float) Times

Total Slack

- Tells us the amount of time an activity can be delayed and not delayed the project.
- Is how long an activity can exceed its early finish date without affecting the project end date or an imposed completion date.
- Is simply the difference between the LS and ES (LS – ES = SL) or between LF and EF (LF – EF = SL).

Free Slack

- Is the amount of time an activity can be delayed without delaying any immediately following (successor) activity.
- Is how long an activity can exceed its early finish date without affecting the early start dates of any successor(s).
- Allows flexibility in scheduling scarce resources.
- Occurs only activity at the end of a chain of activities, where you have a merge activity.

The Critical Path

- Is the network path(s) that has (have) the least slack in common.
- Is the longest path through the activity network.
- Is the shortest expected time in which the entire project can be completed.
- Is important because it impacts completion time.
- Is where you put best people on.
- Is where you pay extra attention when doing risk assessment.
- Is where you don’t look when other managers are asking to ‘borrow’ people or equipment.
- Is where you look when you don’t have time to monitor all activities.

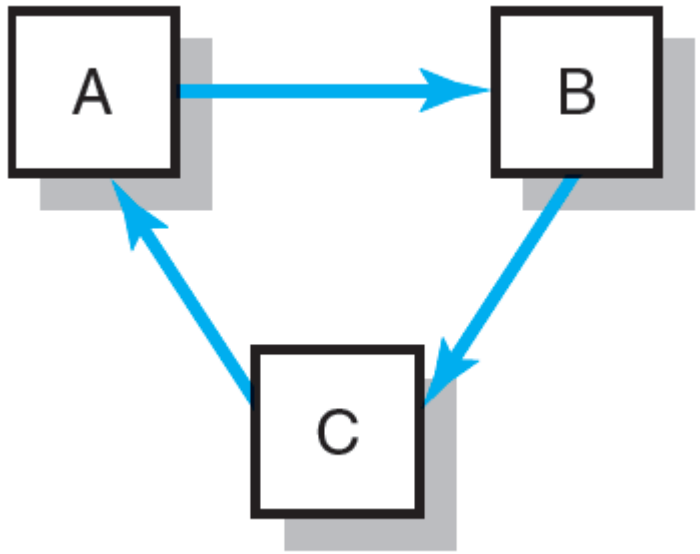
Sensitivity

- Network sensitivity is the likelihood the original critical path(s) will change once the project is initiated.
- A network schedule that has only one critical path and noncritical activities that enjoy significant slack would be labeled ‘insensitive’.

6.8 Practical Considerations

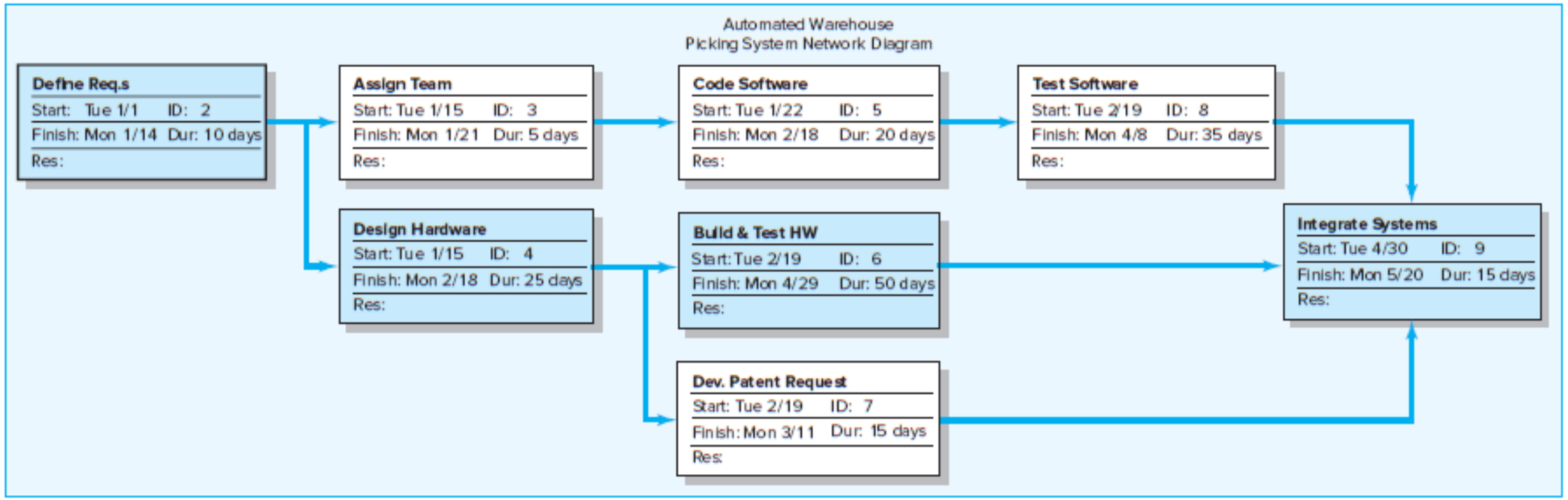
- Network Logic Errors
- Activity Numbering
- Use of Computers to Develop Networks (and Gantt Chart)
- Calendar Dates
- Multiple Starts and Multiple Projects

Network Logic Errors—Illogical Loop



FIG

Automated Warehouse Picking System Network

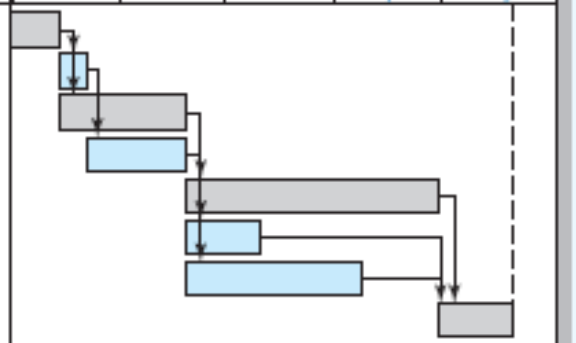


FIGU

Automated Warehouse Picking System Gantt Chart

Automated Warehouse Picking System Schedule Table

ID	Duration	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
2	10	Define Req.s	Tue 1/1	Mon 1/14	Tue 1/1	Tue 1/15	0 days	0 days
3	5	Assign Team	Tue 1/15	Mon 1/21	Tue 2/5	Mon 2/11	0 days	15 days
4	25	Design Hardware	Tue 1/15	Mon 2/18	Tue 1/15	Mon 2/18	0 days	0 days
5	20	Code Software	Tue 1/22	Mon 2/18	Tue 2/12	Mon 3/11	0 days	15 days
6	50	Build and Test HW	Tue 2/19	Mon 4/29	Tue 2/19	Mon 4/29	0 days	0 days
7	15	Dev. Patent Request	Tue 2/19	Mon 3/11	Tue 4/9	Mon 4/29	35 days	35 days
8	35	Test Software	Tue 2/19	Mon 4/8	Tue 3/12	Mon 4/29	15 days	15 days
9	15	Integrate Systems	Tue 4/30	Mon 5/20	Tue 4/30	Mon 5/20	0 days	0 days



FIGU

6.9 Extended Network Techniques to Come Closer to Reality

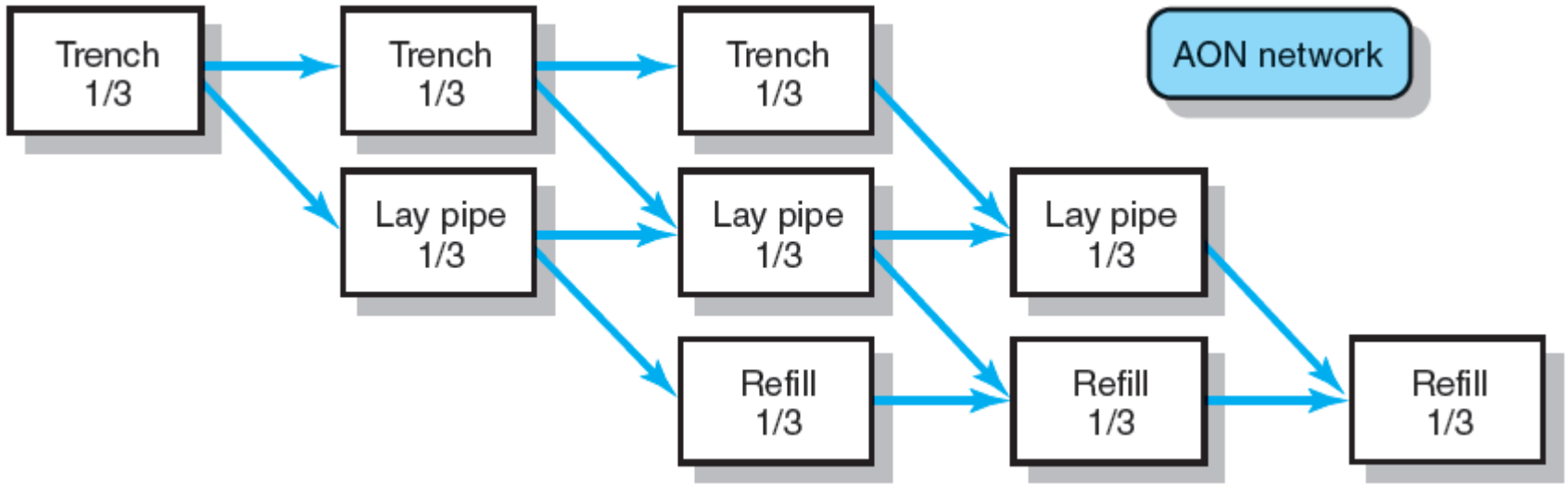
Laddering

- Activities are broken into segments so the following activity can begin sooner and not delay the work.

Use of Lags to Reduce Schedule Detail and Project Duration

- A lag is 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.

Example of Laddering Using Finish-to-Start Relationship



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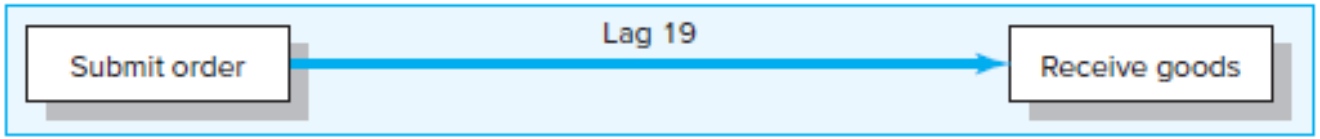
Use of Lags

Finish-to-Start Relationship



Start-to-Start Relationship

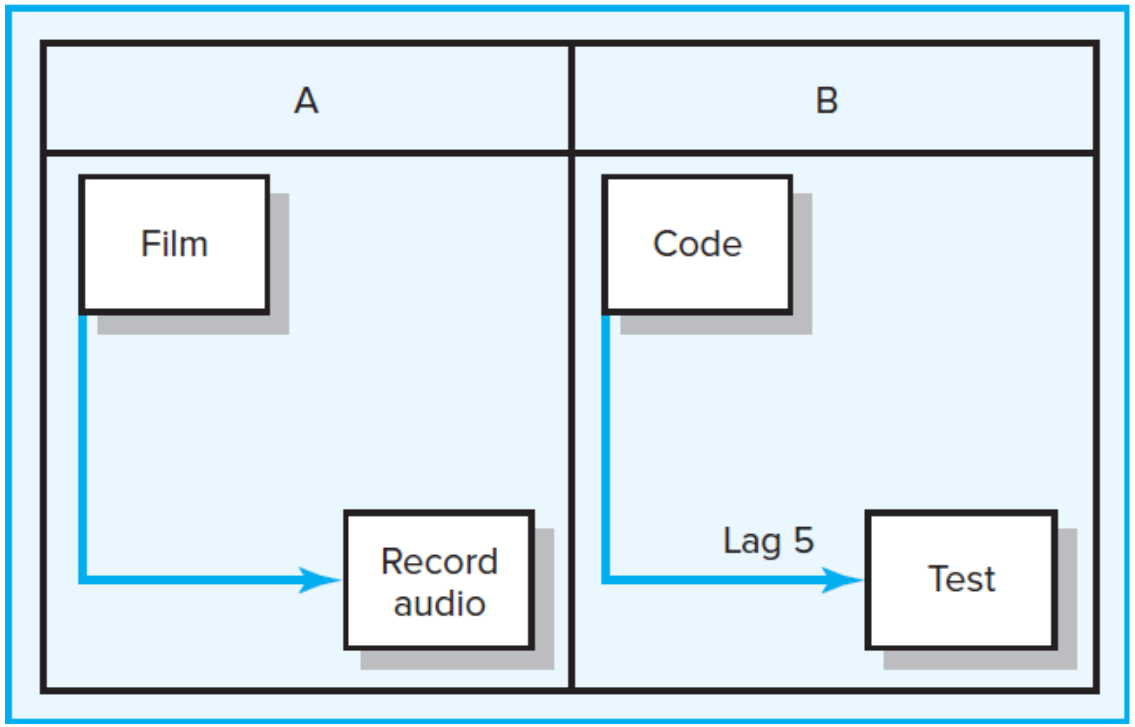
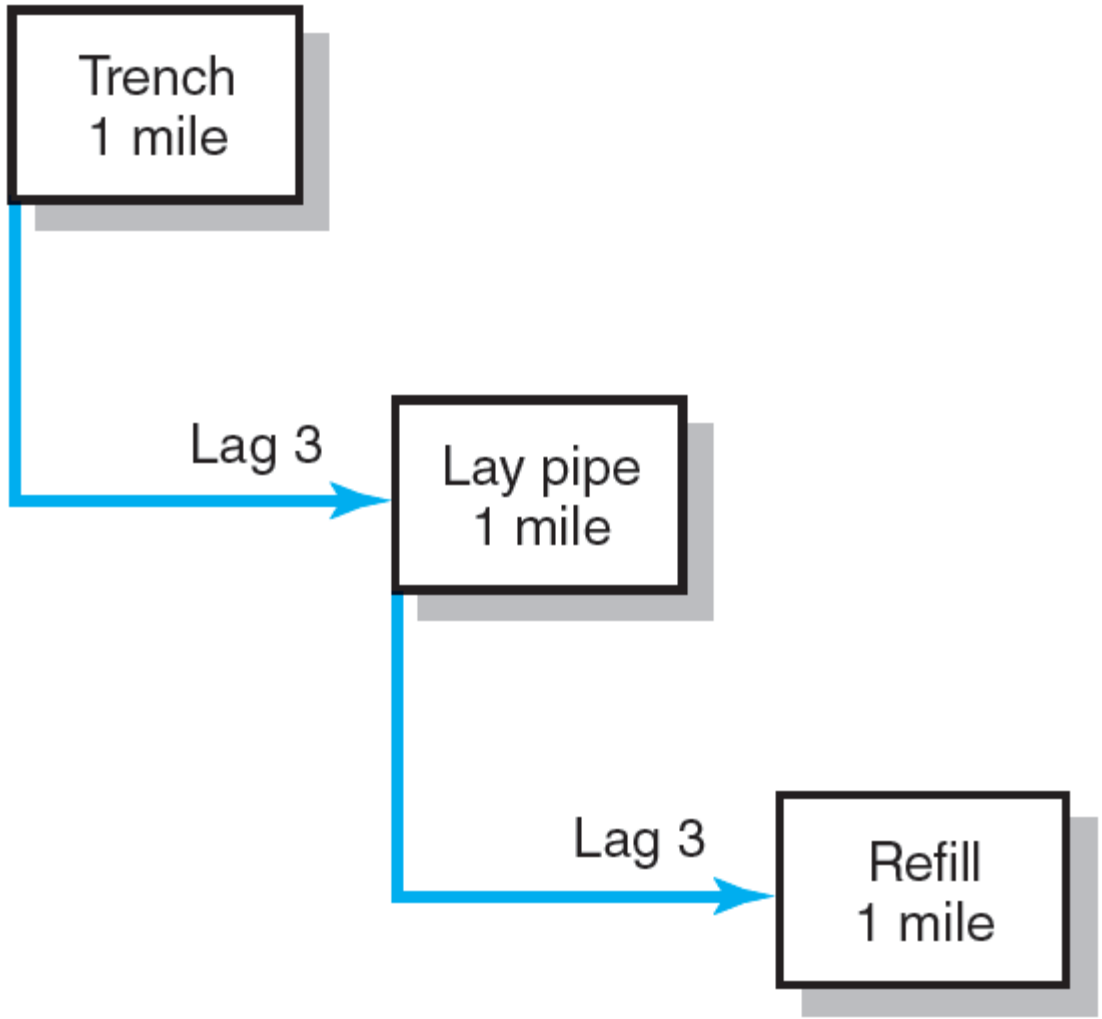


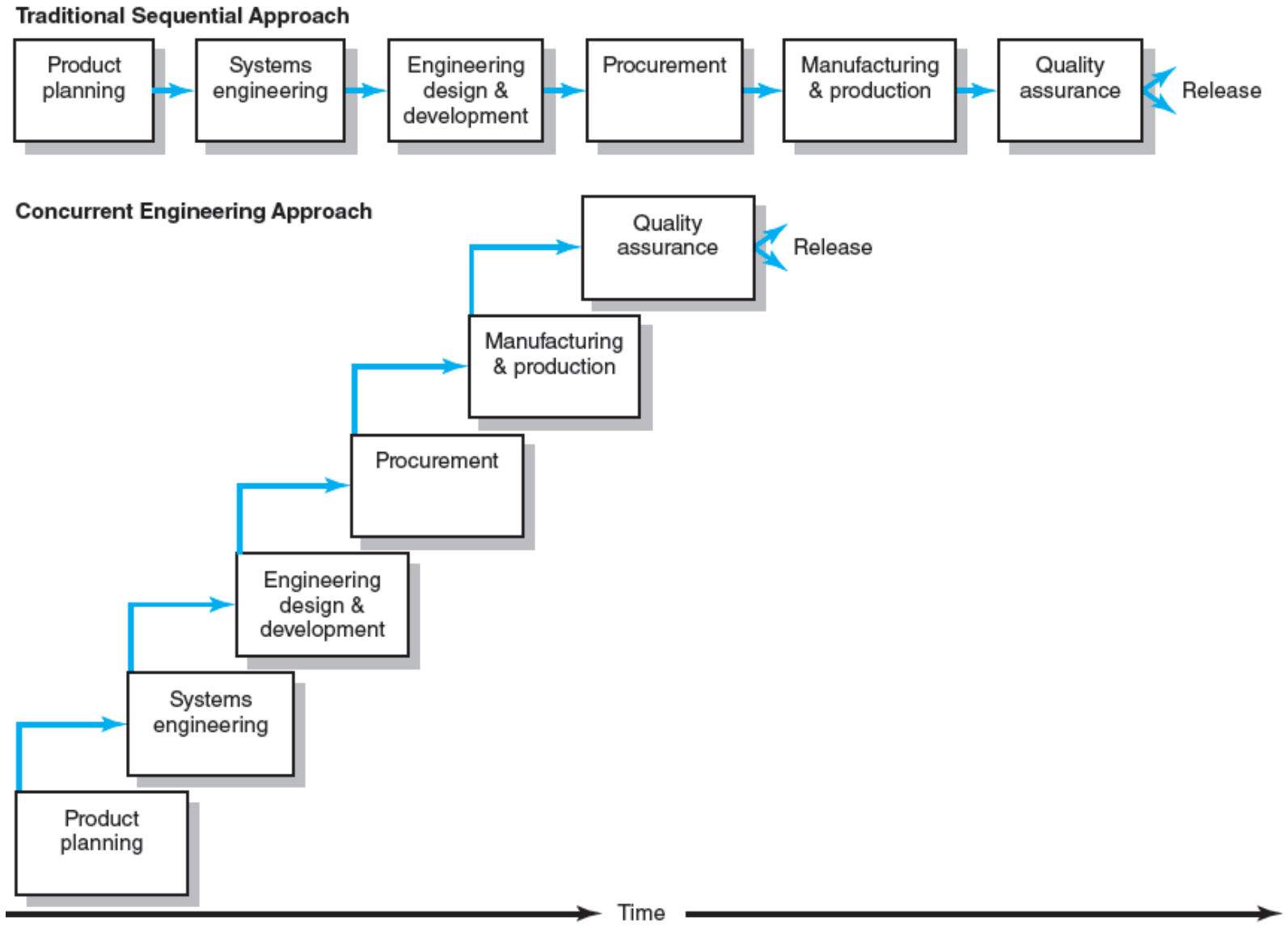
FIGURE 6.13 and Figure 6.14

Use of Lags to Reduce Project Duration



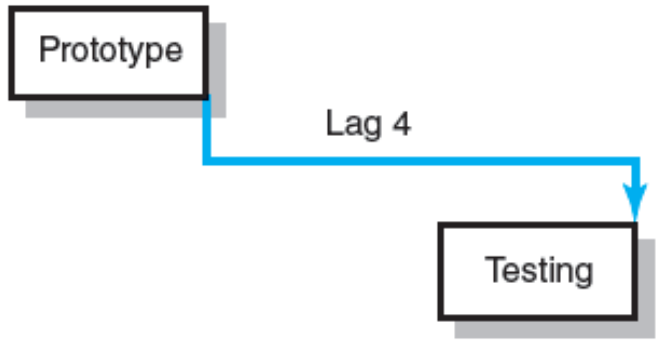
FIGU

New Product Development Process

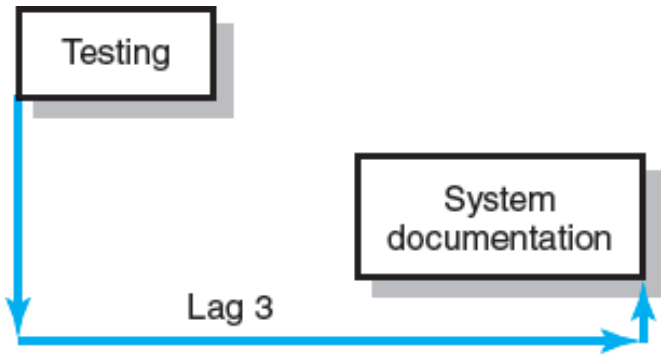


FIGU

Use of Lags (Continued)



Finish-to-Finish Relationship

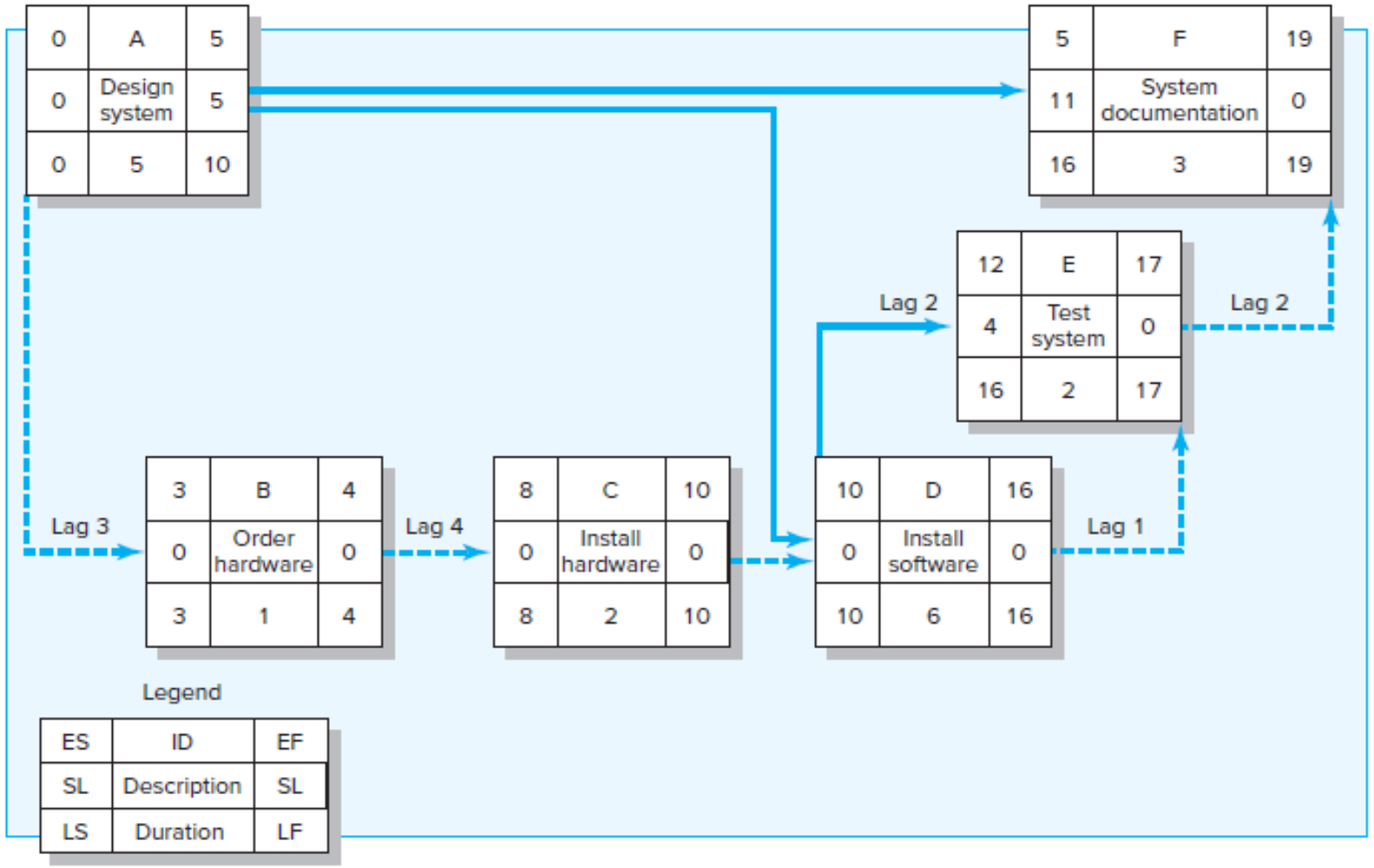


Start-to-Finish Relationship

Combination Relationships

FIGURE 6.17, Figure 6.18 and Figure 6.19

Network Using Lags

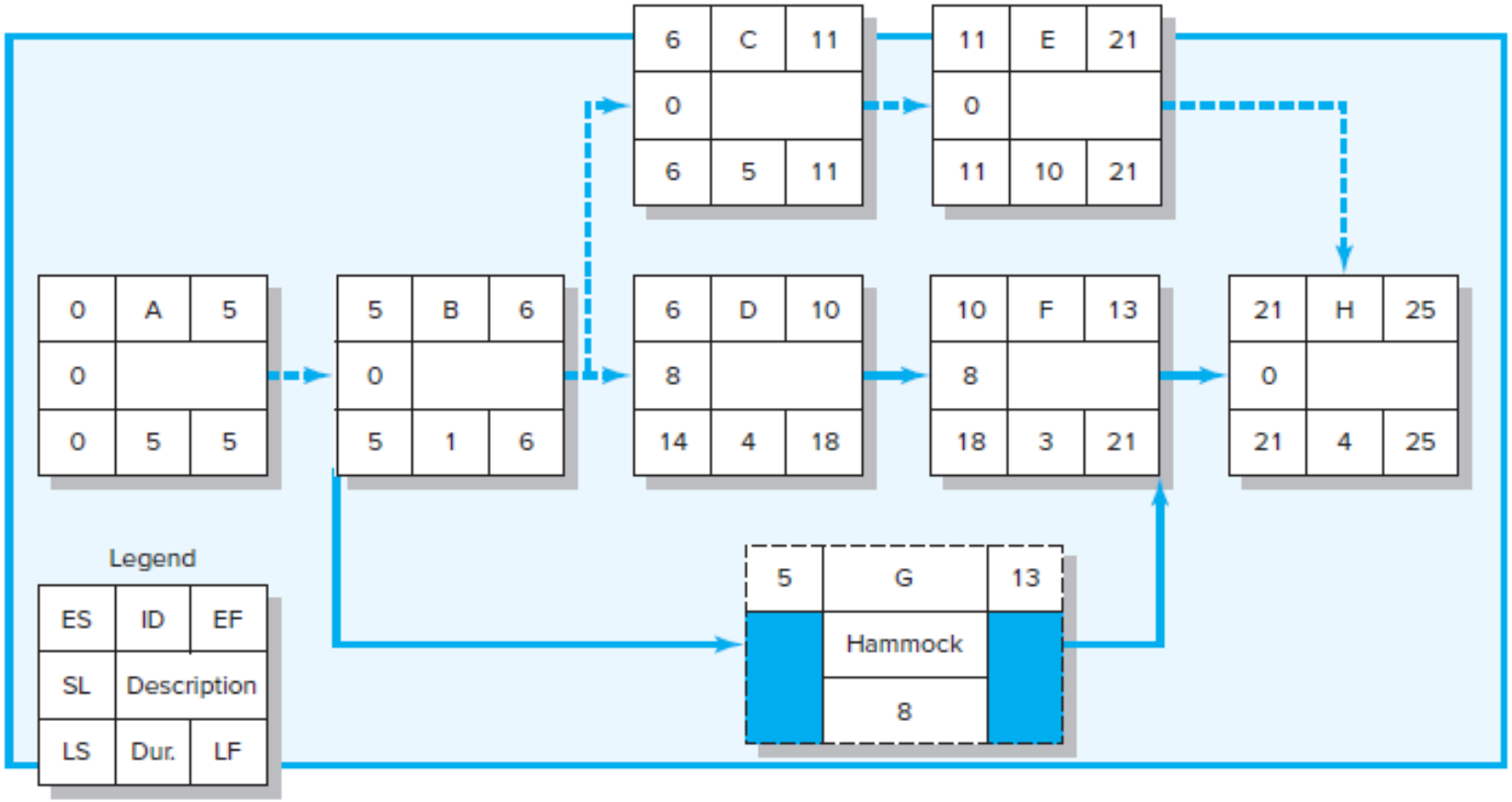


FIGU

Hammock Activity

- Spans over a segment of a project.
- Has a duration that is determined after the network plan is drawn.
- Is very useful in assigning and controlling indirect project costs.
- Is used to aggregate sections of the project to facilitate getting the right level of detail for specific sections of a project.

Hammock Activity Example



FIGU

Key Terms

Activity
Activity-on-arrow (AOA)
Activity-on-node (AON)
Burst activity
Concurrent engineering
Critical path
Early time
Free slack (FS)
Gantt chart
Hammock activity
Lag relationship
Late time
Merge activity
Parallel activities
Path
Sensitivity
Total slack

Any Questions!