# Work Breakdown Structure (WBS)

# Project Schedule Management





# Time schedule

- 12:15-12:30 Presentation (1 and 12)
- 12:30-13:00: Lecture on WBS
- 13:00-13:45: Group work on WBS
- 13:45-14:00: Presentation (7 and 3)
- 14:00-14:45: Lecture on Gantt charts and network diagrams
- 14:45-15:45: Group work

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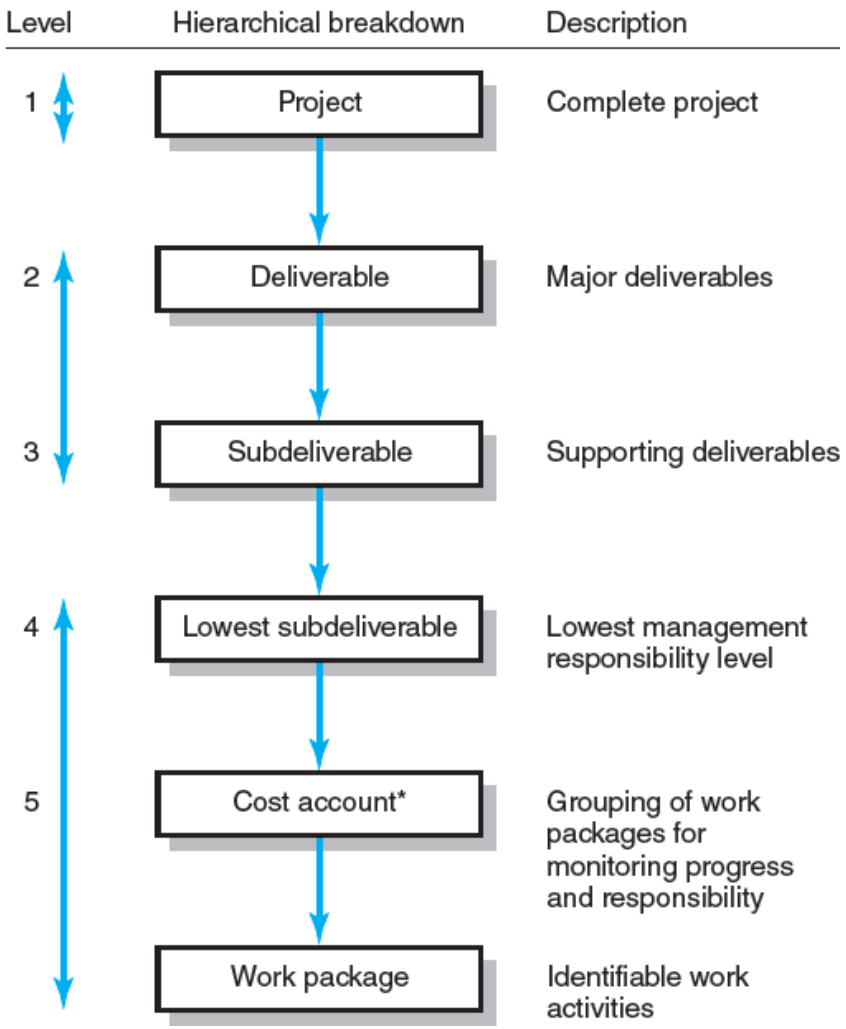
# What is a Work Breakdown Structure (WBS)?

WBS is a hierarchical breakdown of a project into manageable pieces, the smallest of which is called a work package and defines the scope of the project.

Packages are typically assigned to project team members.

This is structured in the way the work will be done and is used for scheduling.

Provides the basis for future planning, budgets, allows the tracking of performance and objectives.




# Hierarchical Breakdown of the WBS

This breakdown groups work packages by type of work within a deliverable and allows assignment of responsibility to an organizational unit. This extra step facilitates a system for monitoring project progress.

# How WBS Helps the Project Manager

- Assures project managers that all products and work elements are identified and to establish a basis for control.
- Facilitates the evaluation of cost, time, and technical performance at all levels in the organization over the life of the project.
- Helps project managers to plan, schedule, and budget the project.
- Helps in the development of the organization breakdown structure (OBS), which assigns project responsibilities to organization units and individuals.
- Defines communication channels and assists in understanding and coordinating many parts of the project.

# A work package:

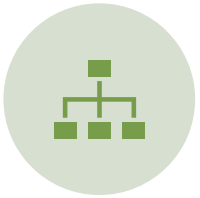
- Is the lowest level of the WBS.
- Is a short-duration task that has a definite start and stop point, consumes resources, and represents cost.
- As a rule of thumb, should not exceed 10 workdays or one reporting period.
- Is the basic unit used for planning, scheduling, and controlling the project.

# A work package - continued:

Defines the work (what).

Identifies time to complete a work package (how long).

Identifies a time-phased budget to complete a work package (cost).



Identifies resources needed to complete a work package (how much).

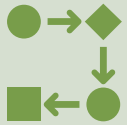
Identifies a single person responsible for of the work (who).

Identifies monitoring points for measuring progress (how well).

# Types of WBS

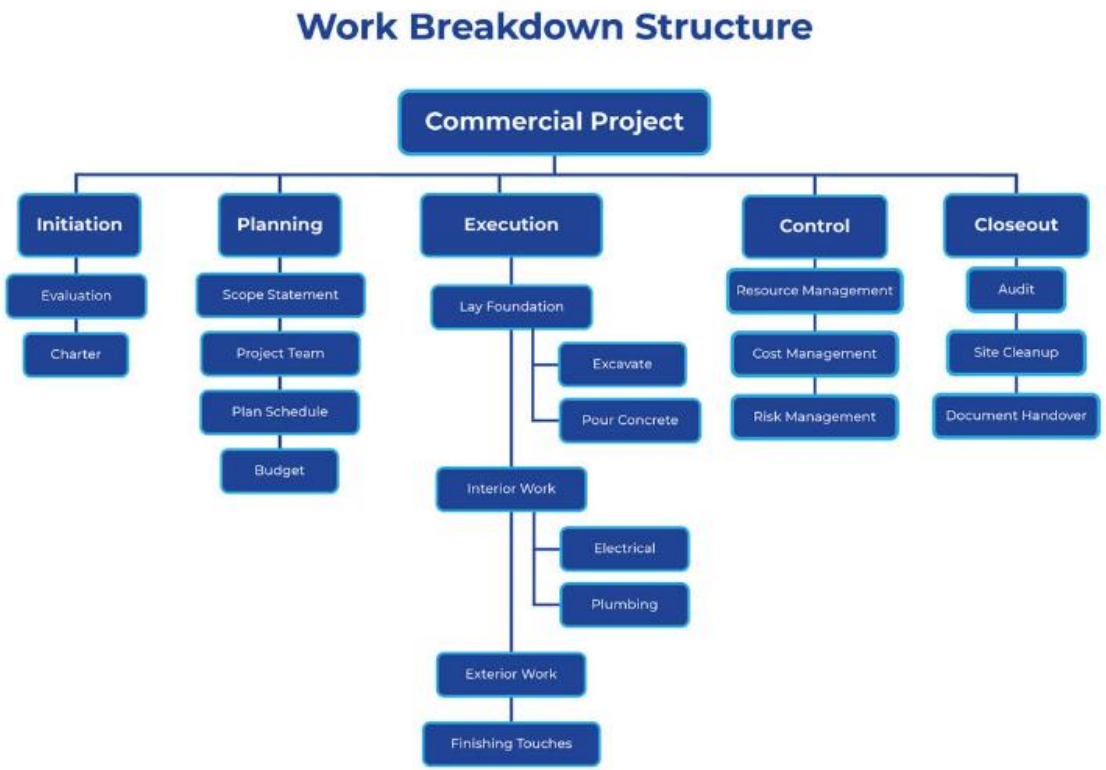
It's the key starting point for project scheduling.

There are two main types of WBS: deliverable-based, and phase-based.

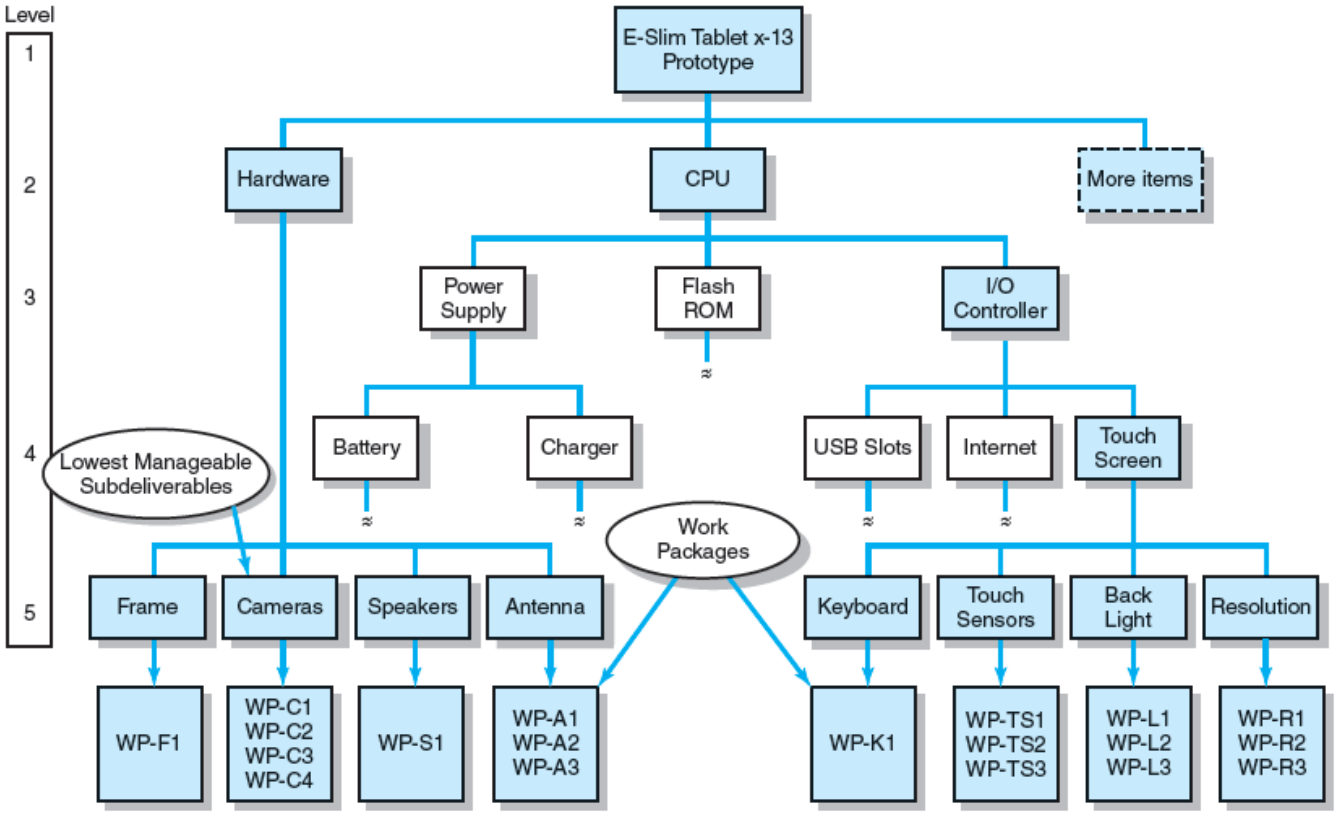


They depend on whether you want to divide your project in terms of time or scope.

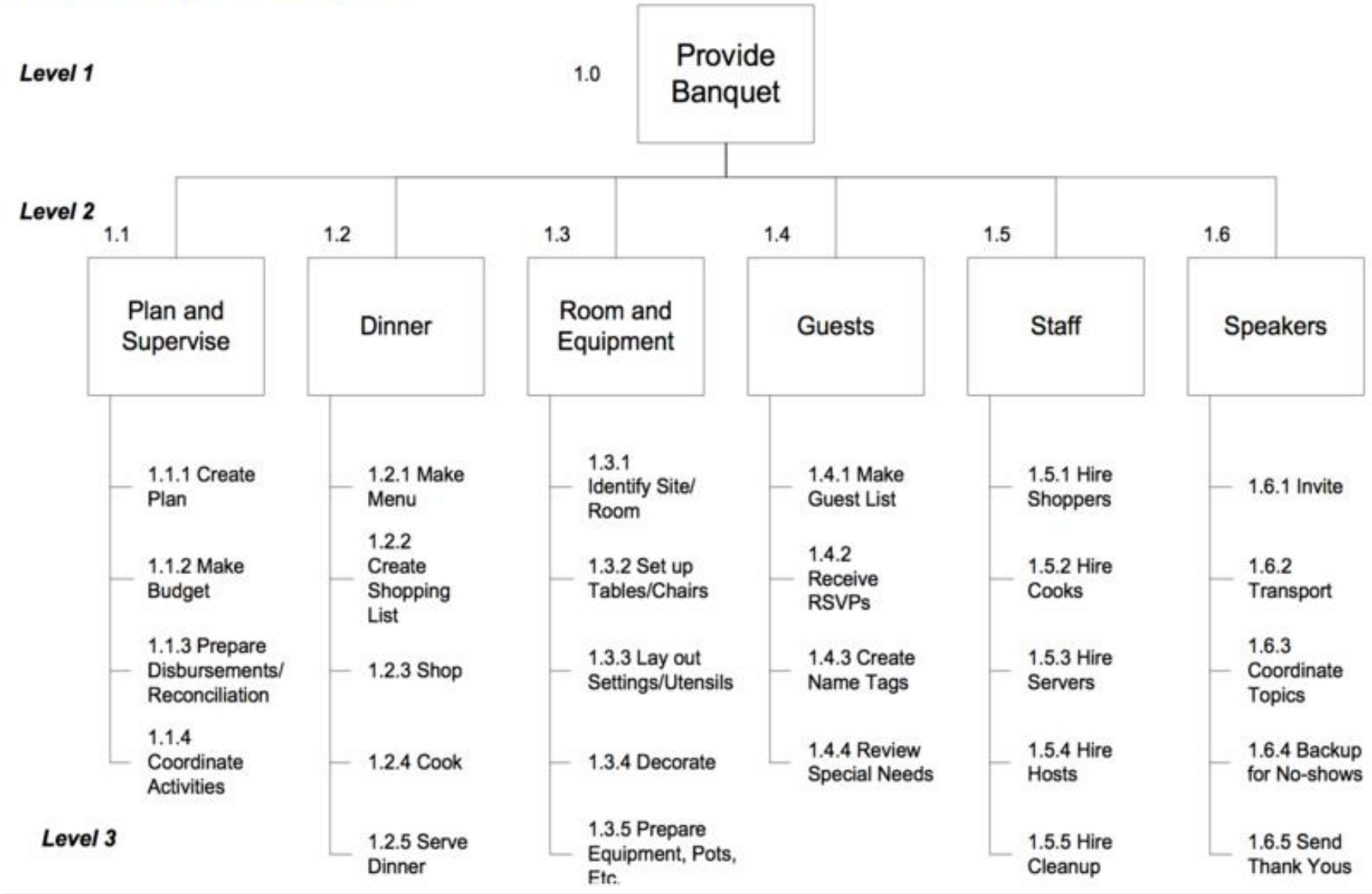
# WBS for Construction Project (Phase-based)



# Work Breakdown Structure (Deliverable-based)



# WBS Example - Banquet




# Responsibility Matrix

- Is also called a linear responsibility chart.
- Summarizes the tasks to be accomplished and who is responsible for what on the project.
- Lists all the project activities and the participants responsible for each activity.
- Provides a mean for all participants in a project to view their responsibilities and agree on their assignments.
- Clarifies the extent or type of authority exercised by each participant.

# Responsibility Matrix for a Market Research Project

| | Project Team | | | | |
|---|---|---|---|---|---|
| Task | Richard | Dan | Dave | Linda | Elizabeth |
| Identify target customers | R | S | | S | |
| Develop draft questionnaire | R | S | S | | |
| Pilot-test questionnaire | | R | | S | |
| Finalize questionnaire | R | S | S | S | |
| Print questionnaire | | | | | R |
| Prepare mailing labels | | | | | R |
| Mail questionnaires | | | | | R |
| Receive and monitor returned questionnaires | | | | R | S |
| Input response data | | | R | | |
| Analyze results | | R | S | S | |
| Prepare draft of report | S | R | S | S | |
| Prepare final report | R | | S | | |

R = Responsible
S = Supports/assists

# WBS build-up example: Develop an Electric Car

First create a list of tasks such as:

- Raise Funds
- System Design
- Event
- Purchase Material
- Engage Stakeholders
- Rent Equipment
- Engagement Specialist
- Reconcile Accounts and Finalize Payments
- Develop Scope and Plan
- Complete Assembly
- Disassemble Car
- System Design
- Component Testing
- Track Testing
- Travel

# WBS build-up Electric Car example: Mix of Deliverables and Phase based

| 1. Initiating | 2. Planning | 3. Construction | 4. Testing | 5. Competition | 6. Close Out |
|---|---|---|---|---|---|
| 1.1 Develop Scope and Plan | 2.1 System Design | 3.1 Purchase Material | 4.1 Component Testing | 5.1 Travel | 6.1 Disassemble Car |
| 1.2 Engage Stakeholders | 2.2 Cost Estimate | 3.2 Rent Equipment | 4.2 Track Testing | 5.2 Event | 6.2 Reconcile Accounts and Finalize Payments |
| 1.3 Raise Funds | 2.3 Approvals | 3.3 Engagement Specialist | | | |
| | | 3.4 Complete Assembly | | | |

# WBS dictionary

The WBS dictionary provides detailed information about each element in the WBS so people are in agreement about the different elements and no misunderstanding occurs. The dictionary can include:

- → **Descriptions of work.**
- → Assumptions and constraints.
- → Schedules and milestones.
- → Resources required.
- → Cost estimates.
- → Quality requirements.
- → Technical references.

# Electric Car WBS Dictonary example

| **Develop Electric Car Project** | |
|---|---|
| | |
| **Work Breakdown Structure (WBS)** | WBS Dictionary |
| | |
| WBS Activity | |
| | |
| 1.0 Develop Electric Car | Overall Project |
| | |
| 1.1 Initiating | |
| 1.1.1 Develop Scope and Plan | Prepare the Statement of Work, Project Cost Estimate, Schedule and other Baseline Documents |
| 1.1.2 Engage Stakeholders | Communication with Project Stakeholders including status reports, discussions on scope, etc. |
| 1.1.3 Raise Funds | All activities associated with fund raising not covered in Engage Stakeholders. This includes meeting with prospective contributors, preparation of brochures, preparation of mail outs and related activities |
| | |
| 1.2 Planning | |
| 1.2.1 Systems Design | Engineering and other activities to design the solar car structure and systems including specifying the equipment and materials. Preparation of related documents for approval. |
| 1.2.2 Cost Estimate | Preparation of a detailed cost estimate for the procurement and construction of the car based on the Systems Design. |
| 1.2.3 Approvals | Activities related to gaining approval of the budget internally and the design with the Design Judge. |
| | |
| 1.3 Construction | |
| 1.3.1 Purchase Materials | Cost of labor associated with purchasing material for the car and the cost of the permanent material in the car including all components and delivery. |
| 1.3.2 Rent Equipment | Cost of special equipment that must be rented to support construction. This may include welding machines, grinders, etc. |
| 1.3.3 Engage Specialist | The cost of a Power Systems specialist to review the design and perform specialty installation tasks for the Power Systems. |
| 1.3.4 Complete Assembly | Labor associated with the assembly of the car from the purchased materials. |
| | |
| 1.4 Testing | |
| 1.4.1 Component Testing | Activities associated with individual system testing including any repairs or remediation. May included additional material that is damaged in testing. |
| 1.4.2 Track Testing | Activities associated with live testing of the completed car including any adjustments and remediation. Includes cost of the test track plus any additional material that is damaged in testing. |





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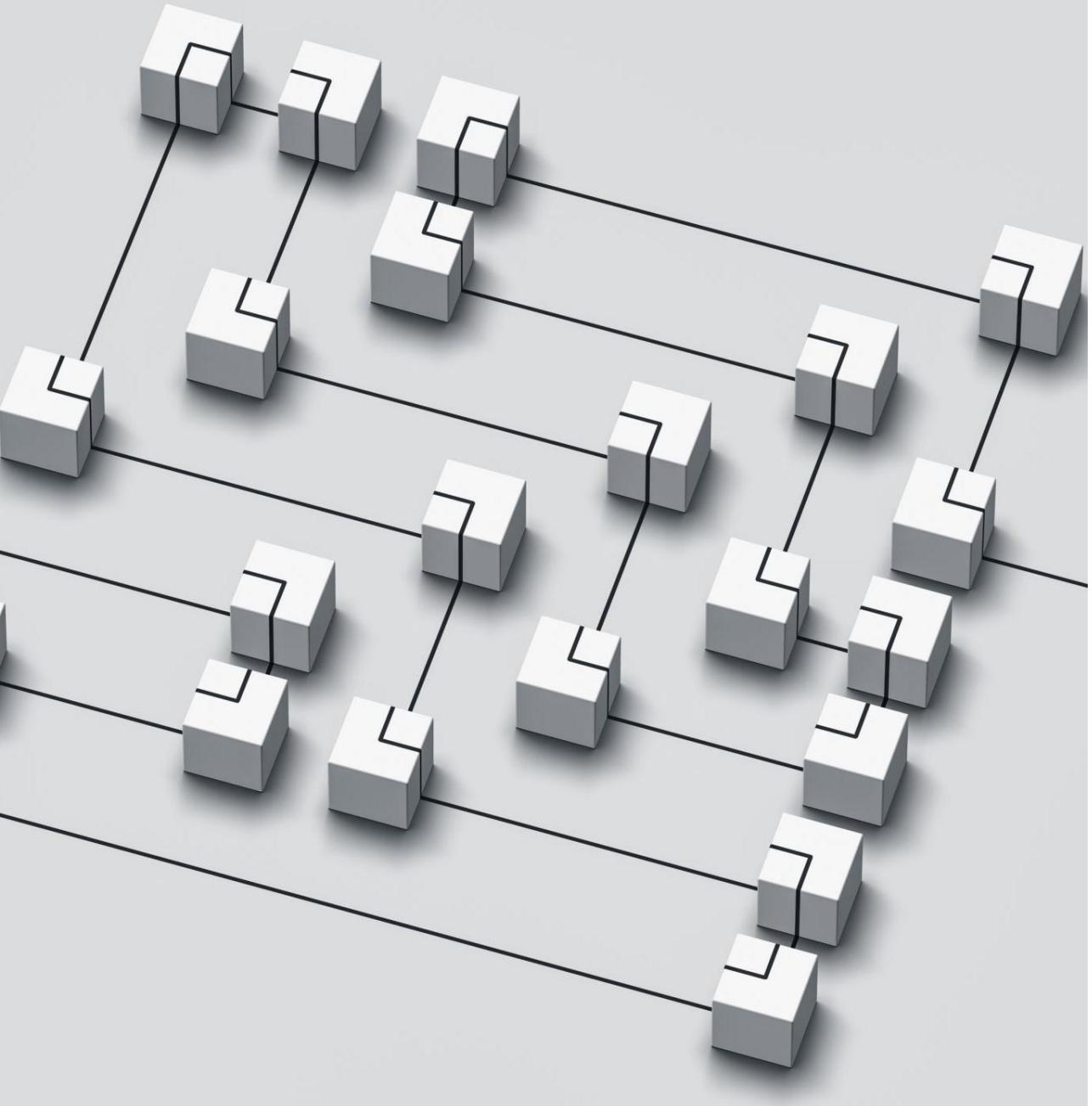





# Group work

- → Identify relevant work packages, sub deliverables and deliverables
- → Create a phase- or deliverables-based WBS structure
- → Think about a responsibility matrix
- → Think about a WBS dictionary

- → Meet here again at 13:45

# Project Schedule Management

# Project Schedule Management overall

→ Scheduling the project provides a detailed plan that represents how and when the project will deliver the deliverables that constitute the product or service based on the project scope.

→ Part of planning

→ Schedule management also serves as a tool for communication, managing stakeholders' expectations, and a baseline for performance.

→ The focus in this lecture is on the network diagram along with the critical path and the Gantt chart - the same as you must deliver in your project.

# The Project Schedule Management processes is mainly in the planning phase of the project

Initiating | Planning | Executing | Monitoring and controlling | Closing

- Plan schedule management
- Define activities
- Sequence activities
- Estimate activity durations
- Develop schedule

- Control schedule

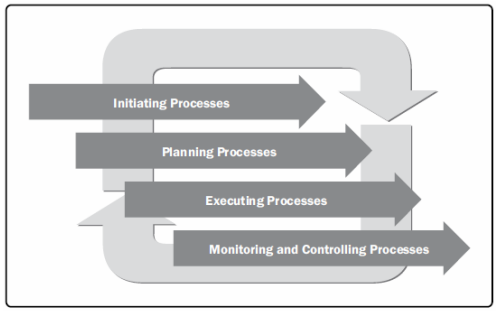


Figure X3-3. Relationship of Process Groups in Continuous Phases





# The schedule management plan

- The schedule management plan establishes the criteria and the activities for developing, monitoring, and controlling the schedule. It usually contains some of the following:
  - Unit of measure – establishes the unit of measure, e.g., hours, days, weeks or grams, kilograms, tons.
  - Level of accuracy – defines the acceptable range of duration on an activity.
  - Control thresholds – follows up on the level of accuracy and defines when actions are required on the outer boundaries.
  - Reporting formats – establishes the format and frequency of the schedule reports.

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# Milestone list



After the scope is defined, the milestones for the project can be established. The WBS can be used as guidance for selecting the milestones.



Milestones are not a task with a duration but represent a significant point or event in the project.



The milestones can be both very broad and very detailed. However, try to make only the most significant events as the milestones.



As an example, for a construction project (house).

The foundation is built.
The walls are raised.
The roof is set.

# Network diagram

A project network diagram is a graphic flow chart that is depicting:

- The project activities that must be completed.
- The logical sequences.
- The interdependencies of the activities to be completed.
- The time for the activities to start and finish along with the longest path(s) through the network (aka. the critical path).

The network diagram is helpful for the project manager since it provides an excellent overview that can be used:

- As the basis for scheduling labor and equipment.
- As the baseline for controlling the project.
- To identify which activities that are critical or a bottleneck and should not be delayed.



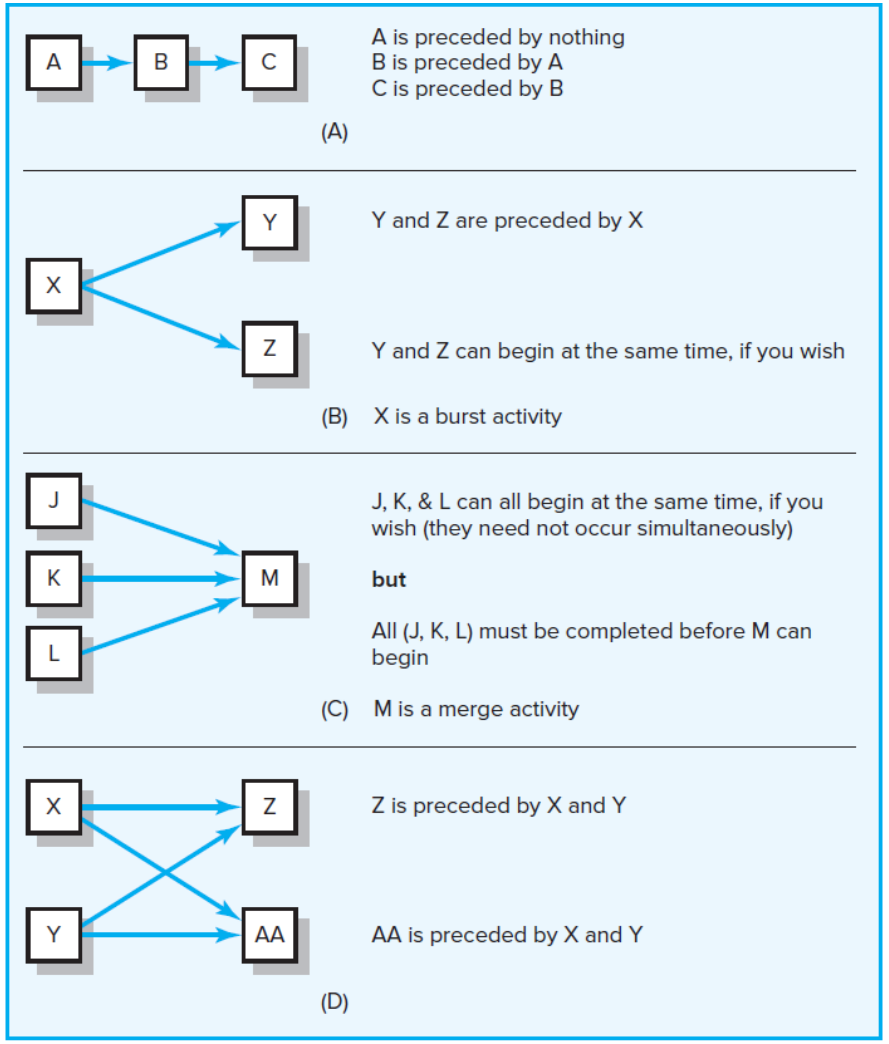


# Constructing a Project Network Diagram

## Terminology

- Activity: an element of the project that requires time and usually 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

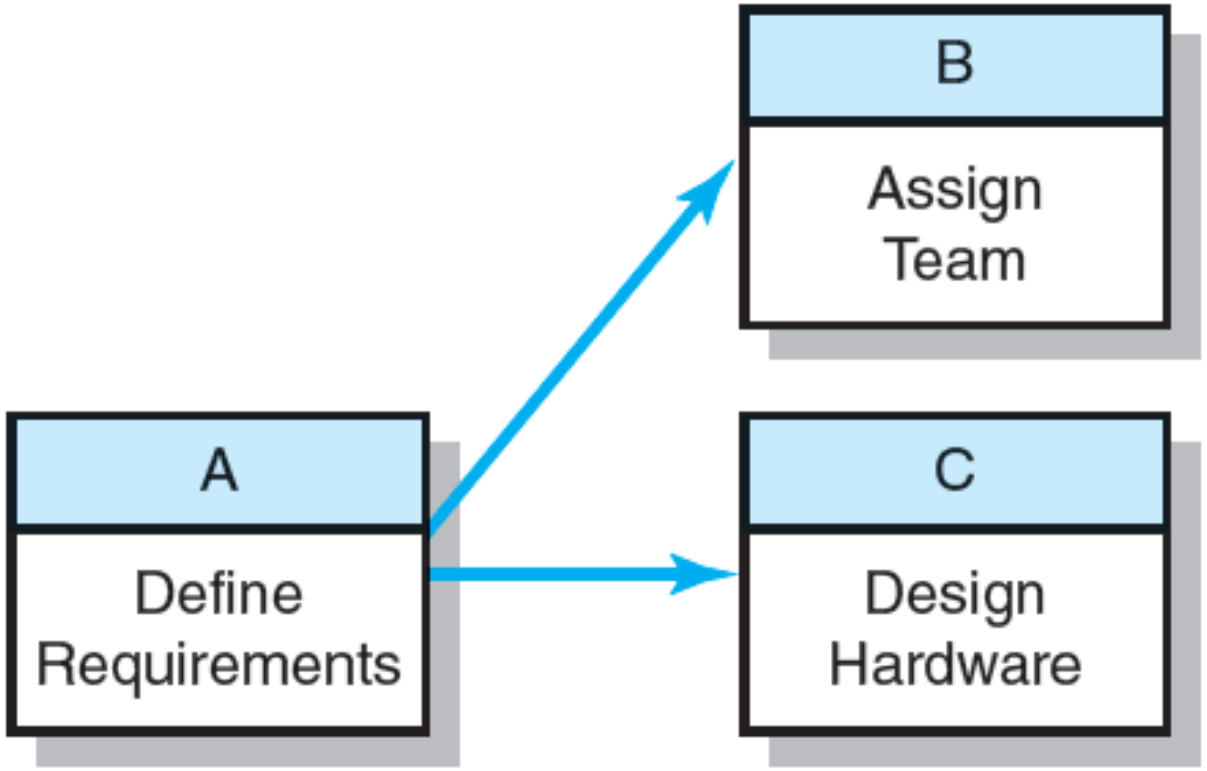
# Activity-on-Node (AON) Fundamentals



# Network Information (Automated Warehouse)

| AUTOMATED WAREHOUSE<br>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





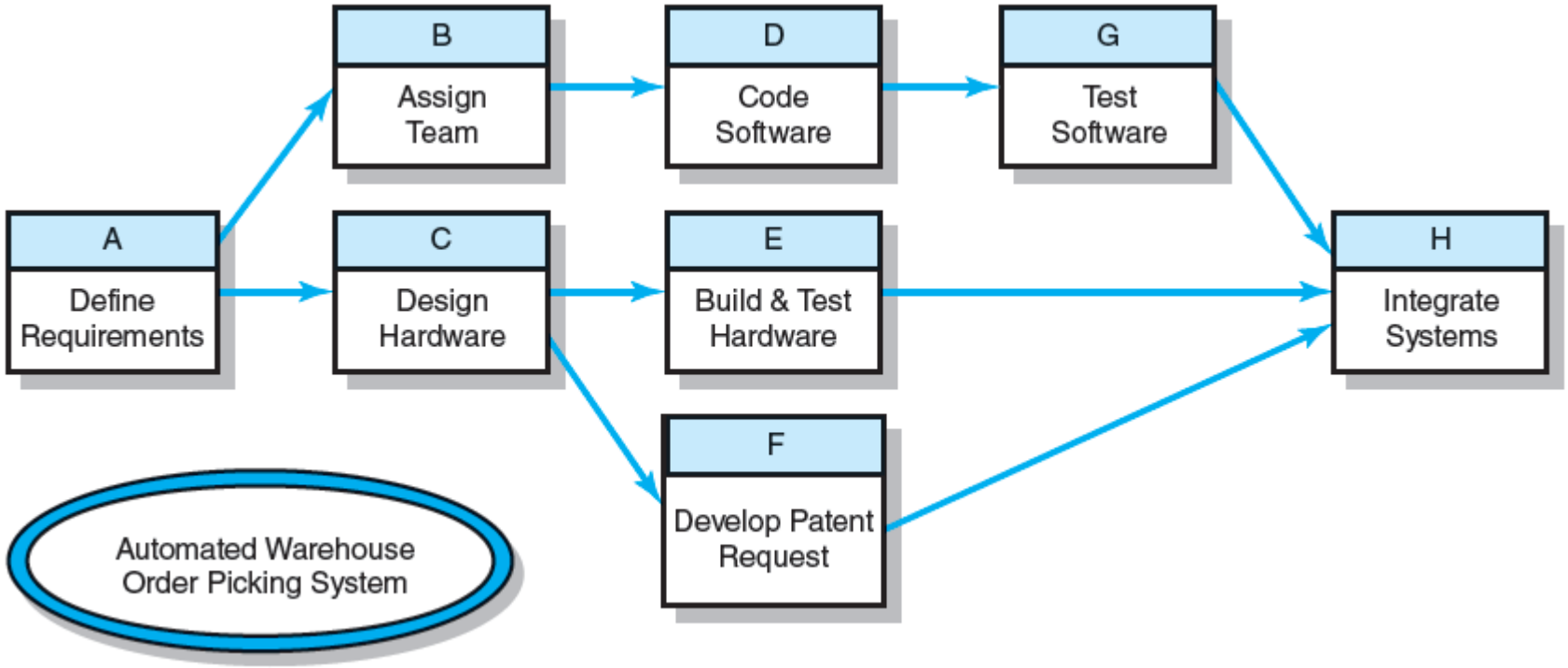
**AUTOMATED WAREHOUSE**
**Order Picking System**

| 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 |

# 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 |



# 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

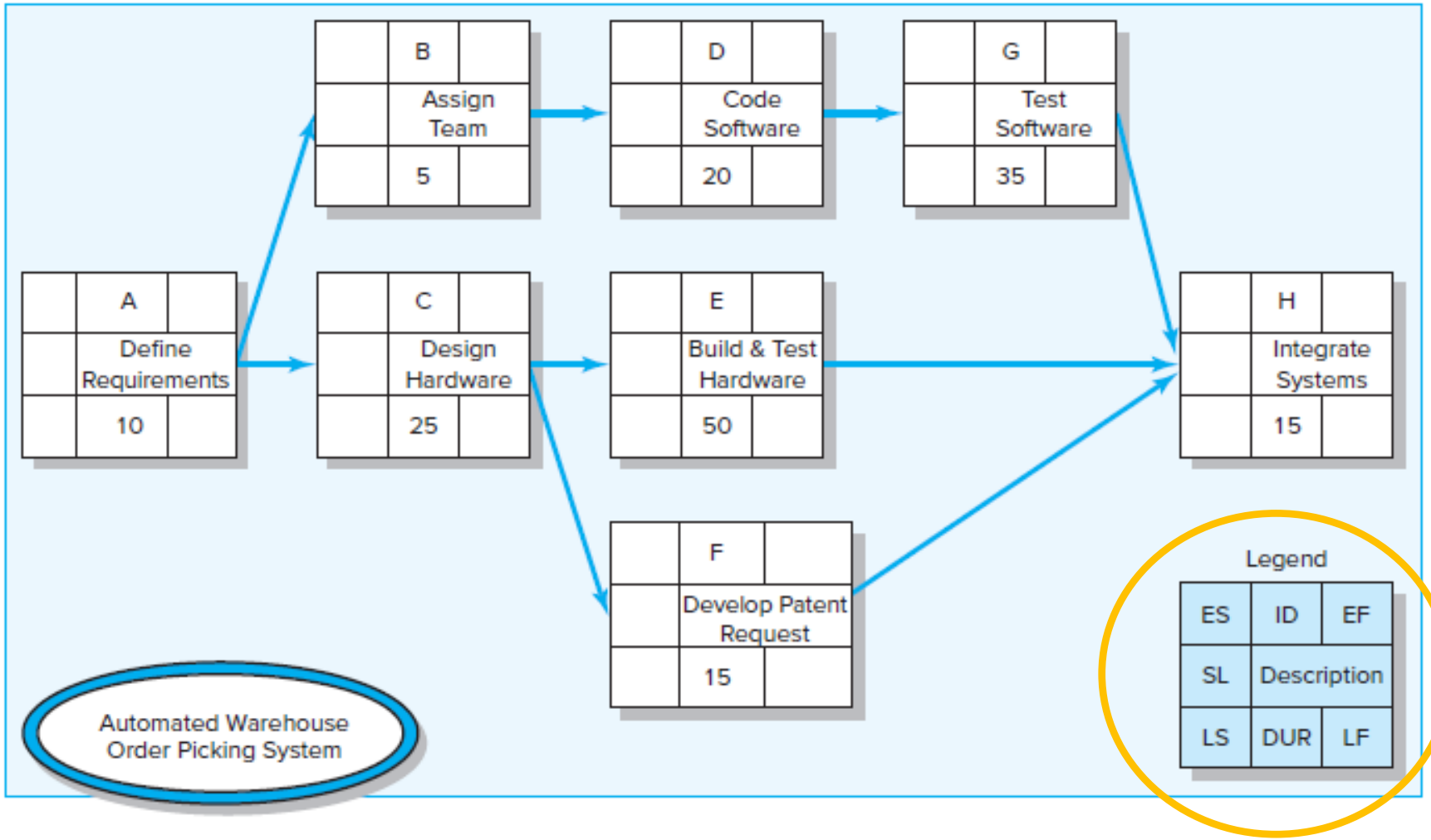
- How late can the activity start? (late start—LS)
- How late can the activity finish? (late finish—LF)
- Which activities represent the critical path? (critical path—CP)
- How long can the activity be delayed? (slack or float—SL)

# 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



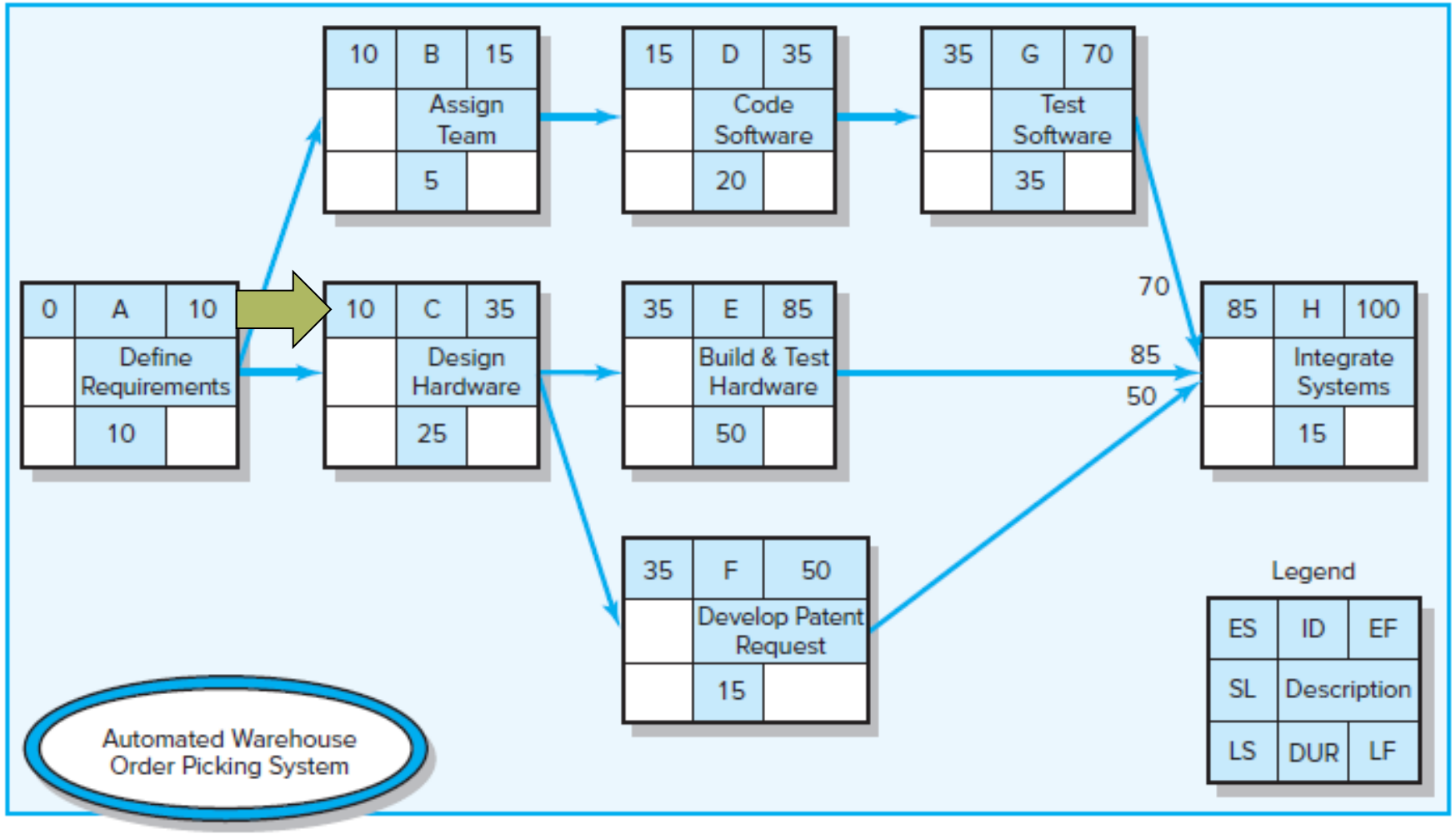
# Forward Pass Computation

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 Forward Pass




ES = early start
EF = early finish
LS = late start
LF = late finish
SL = slack or float

For instance:
Assign team:
DUR = 5
ES = A's EF
EF = ES + DUR

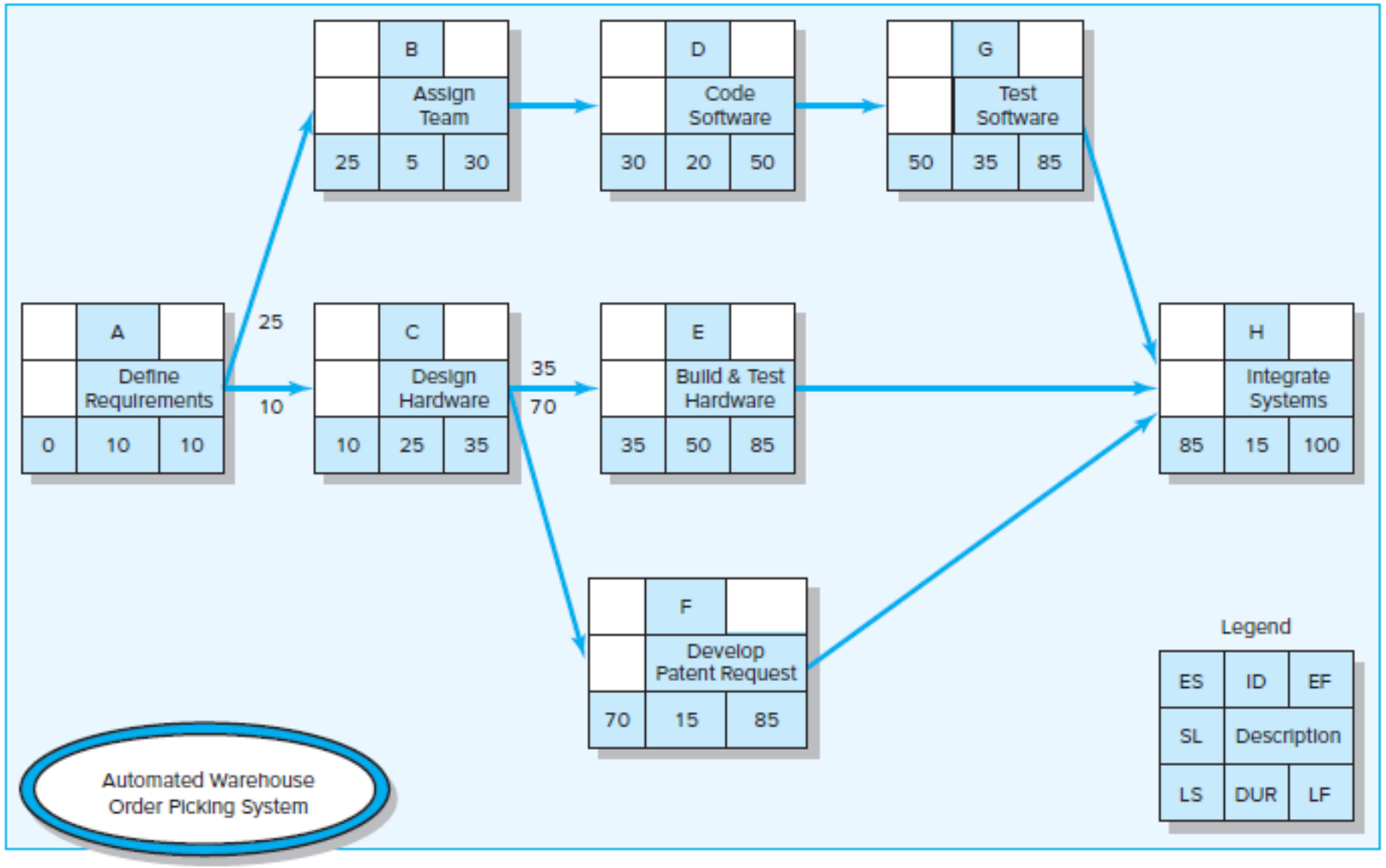
# Backward Pass Computation

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.

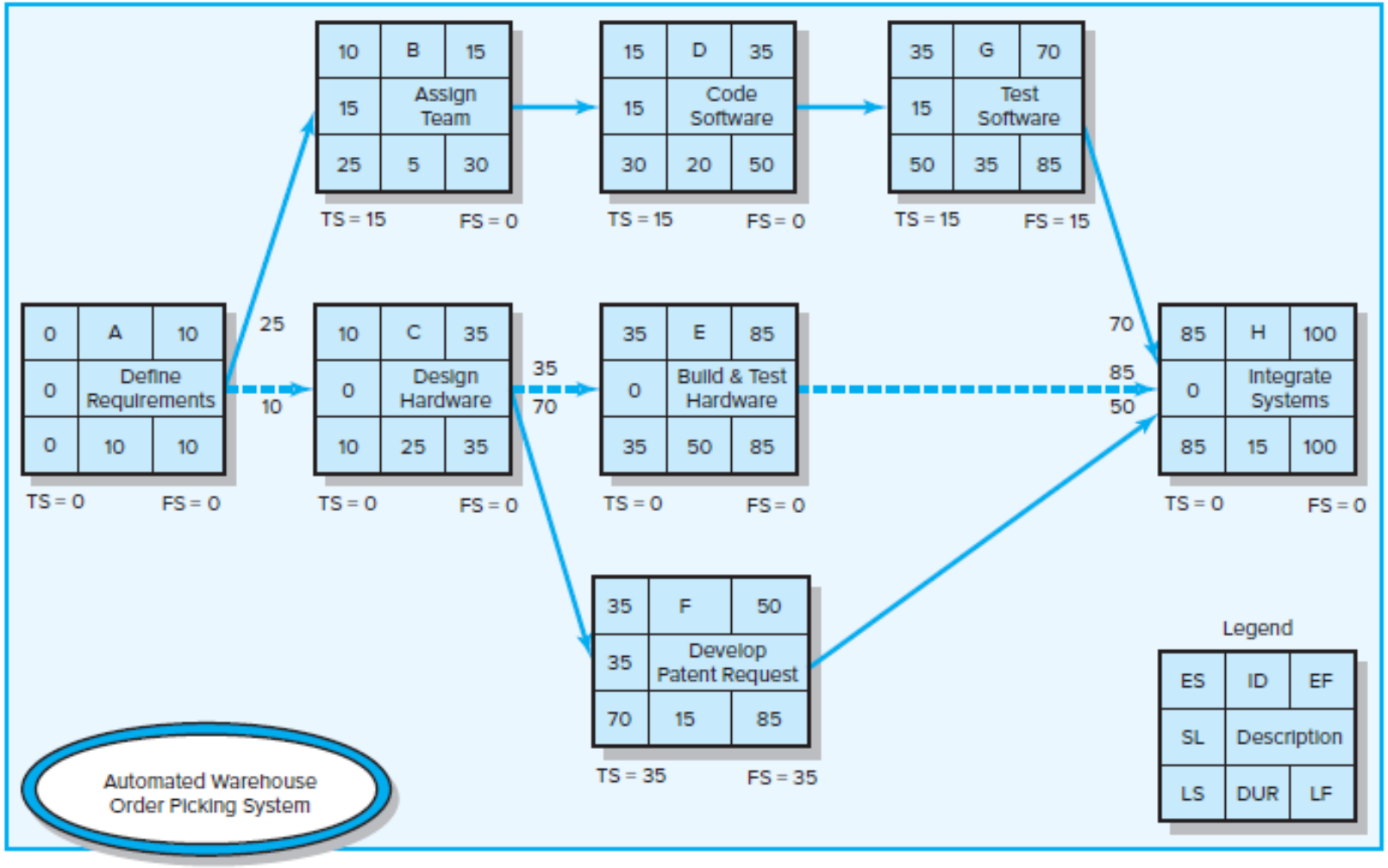
# Activity-on-Node Network Backward Pass




ES = early start
EF = early finish
LS = late start
LF = late finish
SL = slack or float

Now we move backwards!
H: integrate system
LF = 100
DUR = 15
LS = LF – DUR

# Forward and Backward Pass Completed with Slack Times



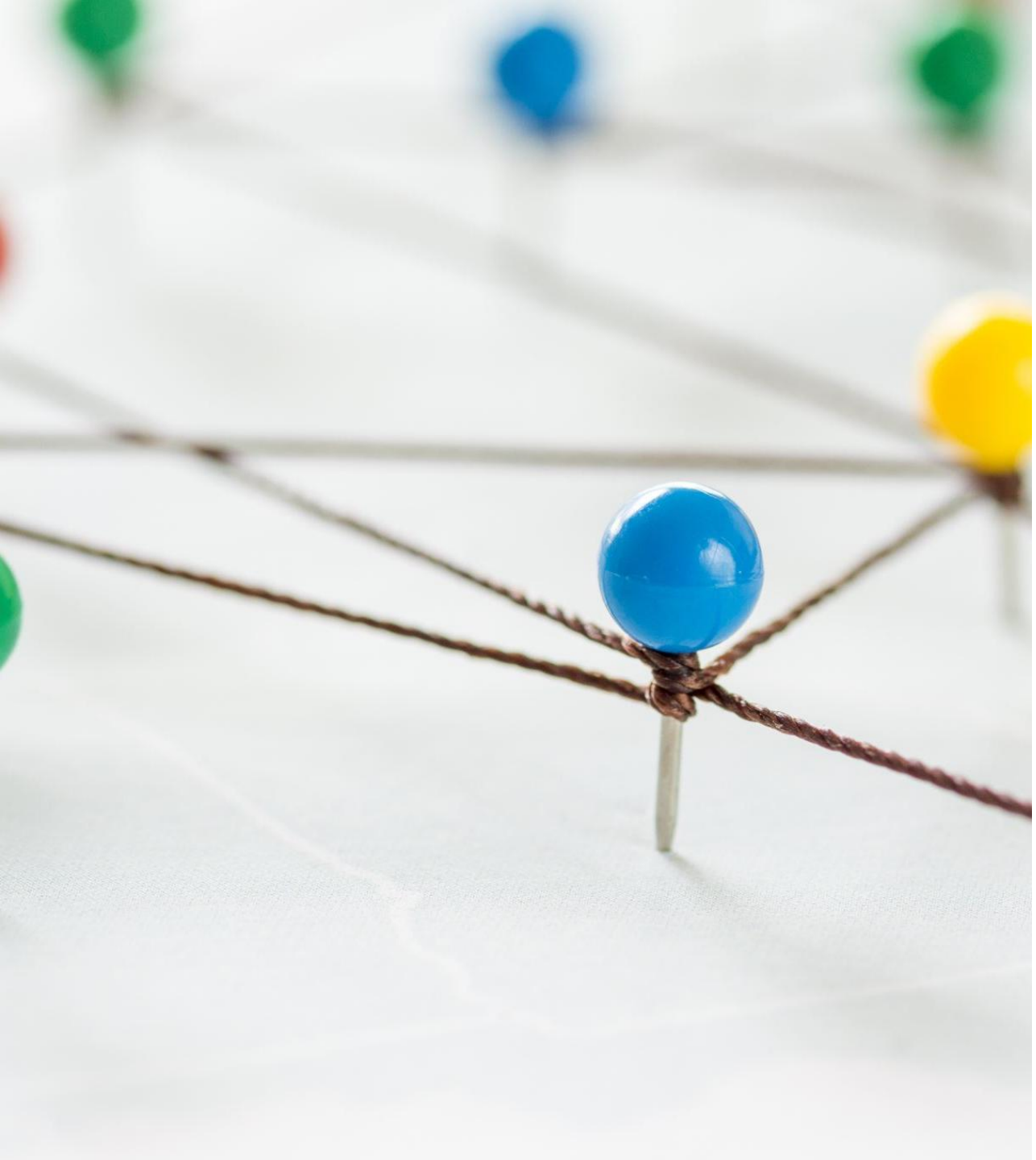
# Determining Slack (or Float) Times

## Total Slack

- Tells us the amount of time an activity can be delayed and without delaying 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 at the end of a chain of activities, where you have a merge activity.







# The Critical Path

→ Is the longest path through the activity network.

→ Once you've identified which activities are on the longest path, or critical path, you can more easily discern which activities have float times and could be delayed without making the project longer.

# Estimating the number of work periods needed to complete the activities

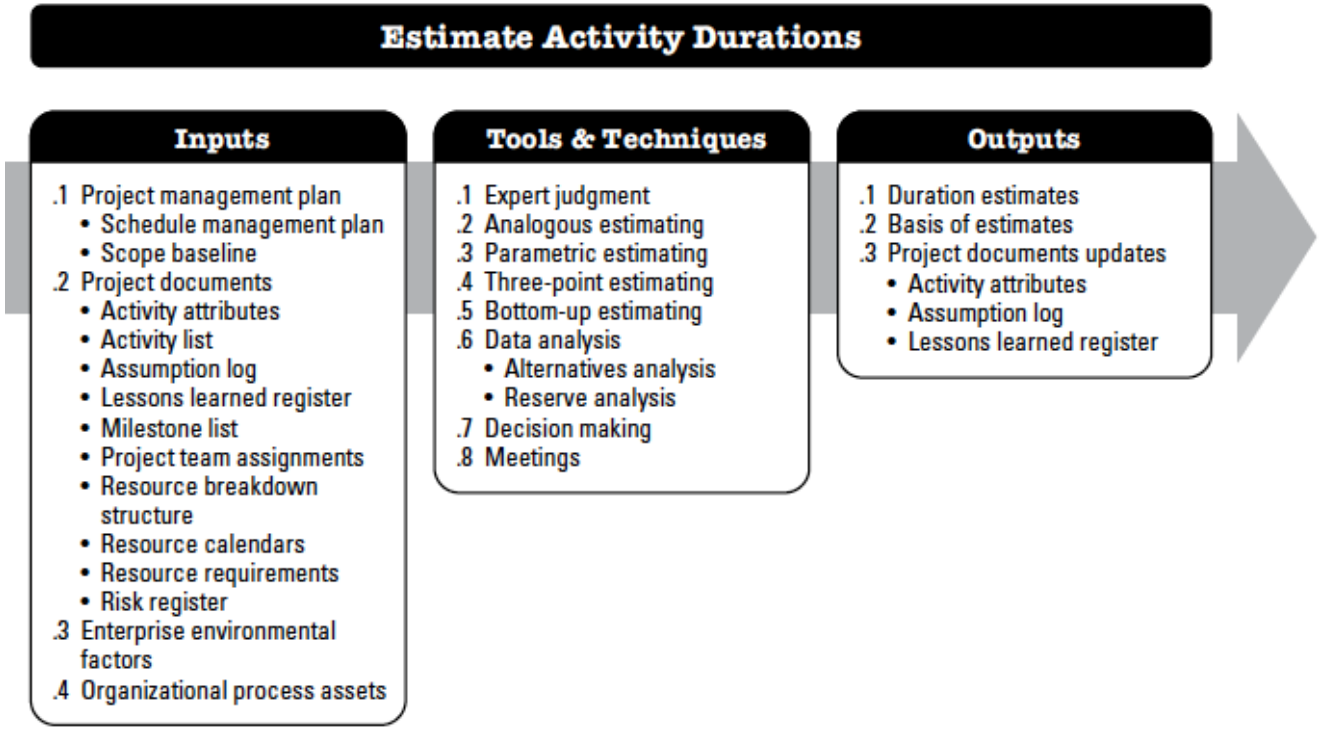



Figure 6-12. Estimate Activity Durations: Inputs, Tools & Techniques, and Outputs

# Methods of estimating

→ There are a lot of different options that can assist in estimating durations. Remember to account for your assumptions and reasoning for the estimates.

→ Experts and past projects (experience) are the main source of estimation. This will paint a fairly accurate picture of what to expect in the different phases of the project.

- → As an example, the construction of a house can be used. If it took 4 months to construct a 1 plan house with 4 bedrooms and 2 restrooms it will most likely take the same amount of time to build a similar house ”next door”.
- → The past delays can also be taken into considerations. Perhaps the house was estimated to 3,5 months, but the drying phase of both the foundation and walls took a combined 2 weeks more. If there are no seasonal changes or obvious reason for the delay, this delay should be included in the next phase.

# Methods of estimating - continued

- → The duration can also be estimated using mathematical formulars and algorithm, either by testing or based on experience.
  - → A rough estimate can be used. For example, if it takes 15 minutes to paint 1 square meters ($m^2$) of wall in the newly build house, and there is 150 square meters it will take ($150m^2$*15min)/60= 37,5hours to paint the whole house.
  - → However, the painting consisting of covering the floor, contacts etc., (2) painting first layer, (3) drying, (4) painting second layer, and (5) remove the covering (the last drying is not included). Therefore, there are a lot of uncertainties. Some of the square meters will only take 10 minutes and others will take 30 minutes. The estimate will be more accurate by estimating how many of the 10-, 15-, and 30-minutes cycles there are.

# Methods of estimating - continued

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  - → Alternatively, three-point estimating can be used. The formular consist of the most likely time (tM), optimistic time (tO), and the pessimistic time (tP). If we assess the painting of a $m^2$ wall tM to 15 min, tO to 10 min, and tP to 30 the result would be (15+10+30)/3= 18,3 min

# Gantt chart

→ The Gantt chart is one of the easiest, most used, and oldest tools to manage a project.

→ It was developed in 1917 (Henry Gantt) and used for building ships and aircrafts during WWI

→ The Gantt chart presents the project in a graphical form by showing the duration of the different tasks in a sequenced order – but only to a certain extent. It does not explicitly show the relationship behind the tasks.

→ Strength: Easy to understand, easy to use, and provide an excellent overview.

→ Weakness: Lacks detail so the usage can only be on the overall level in complicated projects.

# The setup of the Gantt chart:

- Each task is assigned a job number or a letter.
- Each task has a description.
- Each task has a precedent task (i.e., the task needs to be finished before starting the next task).
- Each task is assigned an amount of time for its completion.

# Gantt chart – example (building a house)

| Job # | Description | Immediate predecessors | Time (week) |
|---|---|---|---|
| A | Start | - | 0 |
| B | Building the foundation | A | 6 |
| C | The walls are raised | B | 3 |
| D | The roof is set | C | 2 |
| E | Doors and windows are installed | D | 1 |
| F | Installing kitchen | E | 2 |
| G | Installing bathroom | E | 2 |
| H | Installing electric | E | 4 |
| I | Finish | F,G,H | 0 |

# Gantt chart – example (building a house)

You may add a coloumn with:
Responsible and workload

**Develop schedule**

| Job # | Description | Immediate predecessors | Time in weeks | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| A | Start | - | | | | | | | | | | | | | | | | | | | |
| B | Building the foundation | A | | | | | | | | | | | | | | | | | | | |
| C | The walls are raised | B | | | | | | | | | | | | | | | | | | | |
| D | The roof is set | C | | | | | | | | | | | | | | | | | | | |
| E | Doors and windows are installed | D | | | | | | | | | | | | | | | | | | | |
| F | Installing kitchen | E | | | | | | | | | | | | | | | | | | | |
| G | Installing bathroom | E | | | | | | | | | | | | | | | | | | | |
| H | Installing electric | E | | | | | | | | | | | | | | | | | | | |
| I | Finish | F,G,H | | | | | | | | | | | | | | | | | | | |

# How to control the schedule

The Gantt chart is the baseline and will provide a good visual tool to “control” the schedule and assess if there are delays or not.

If the network diagram is created it will provide an even better baseline because of the variations included.

The most important things is that when a delay is encountered, the consequences (í.e., the added time) is estimated and the plan is adjusted accordingly. If the added time can be absorbed it is not that critical, but if not, alternatives must be deployed ASAP (alternatively through the change request).





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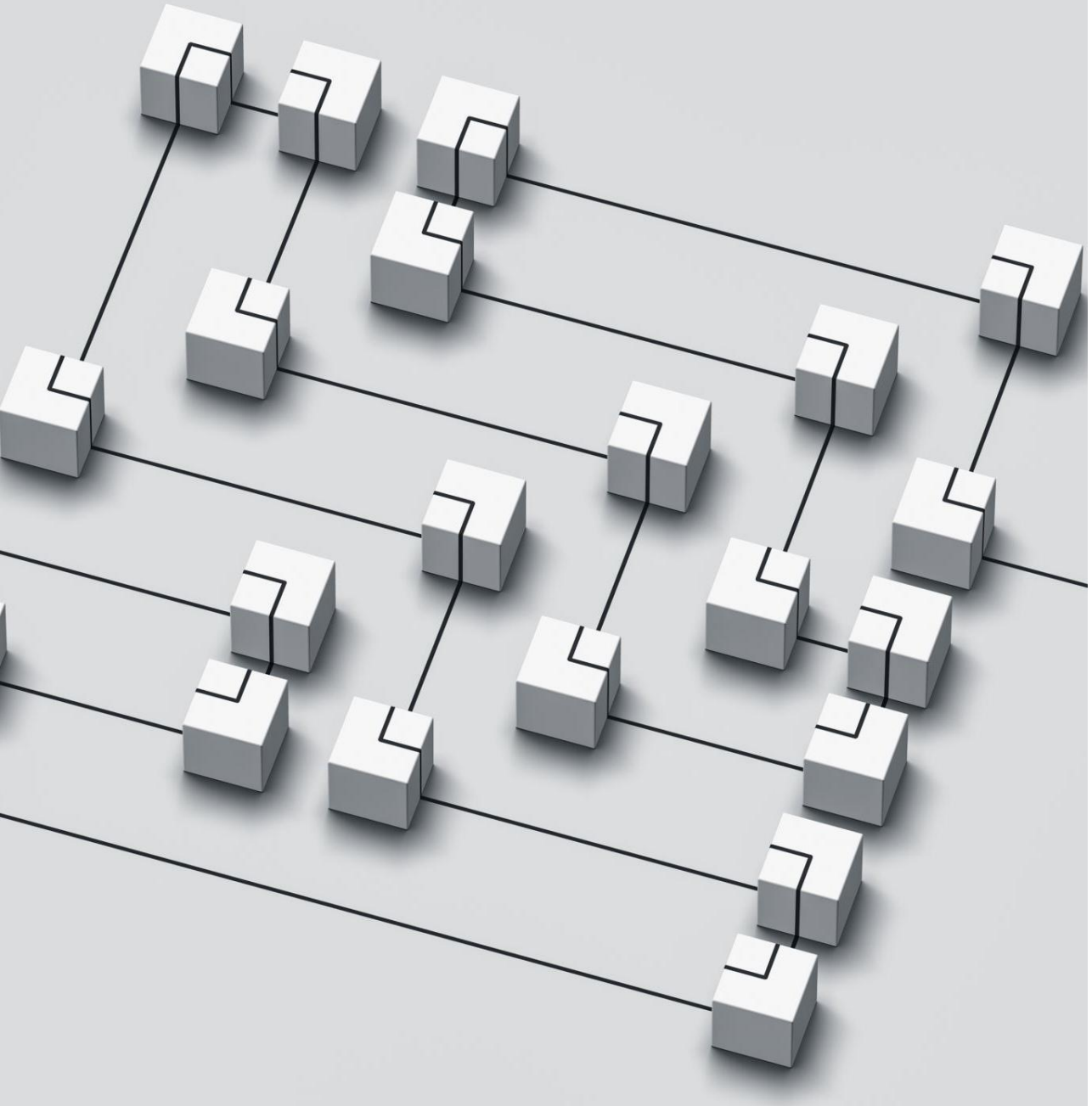
- 14:00-14:45: Lecture on Gantt charts and network diagrams
- 14:45-15:45: Group work







# Group work

→ Create a Gantt chart for your project and reflect on its feasibility

→ Create a critical path (Activity on node)

→ Use PMBOK for guidance or ask me