Chapter 8. Project Management

Basic references:

- Heizer, J. & Render, B. (2009): Operations Management. New Jersey: Pearson Prentice Hall

Chapter 8. Project Management

8.1.- Project management and its phases

8.2.- Project planning and control techniques

8.3.- Limitations of the PERT-CPM technique

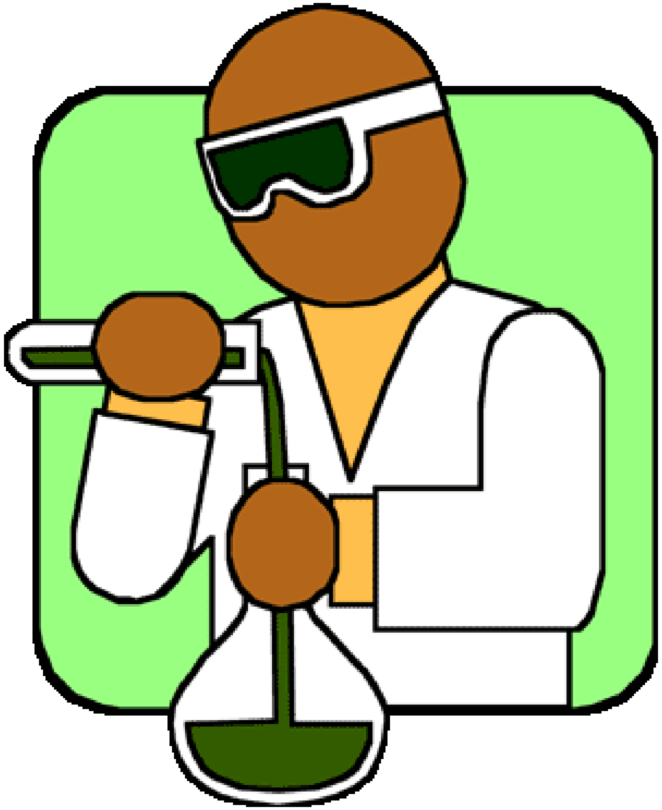
8.1.- Project management and its phases

Project characteristics

- ☑ Single unit
- ☑ Many related activities
- ☑ Difficult production planning and inventory control
- ☑ General purpose equipment
- ☑ High labour skills

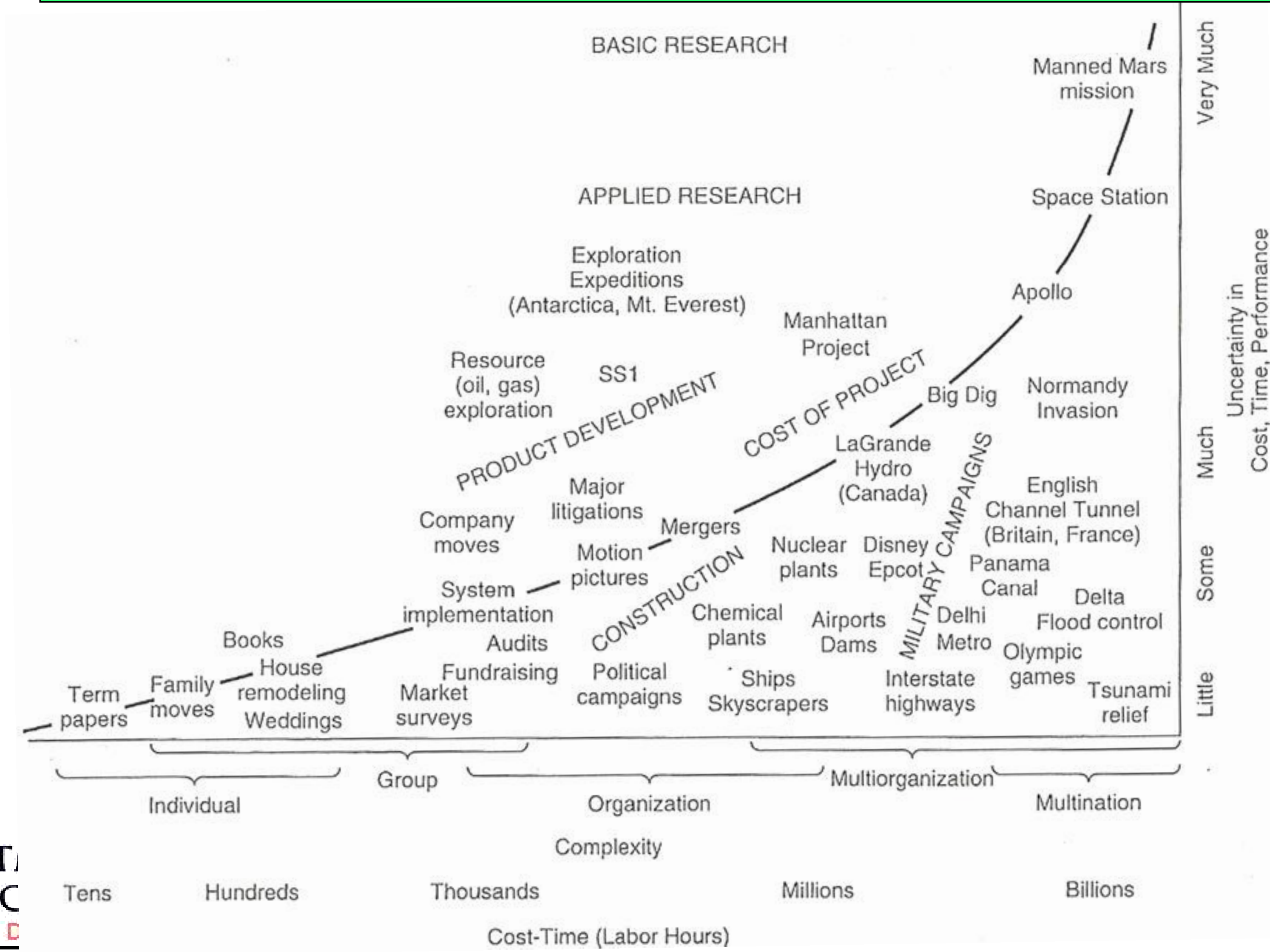
Examples of projects

☑ ***Building construction***



☑ ***Research project***

Examples of projects



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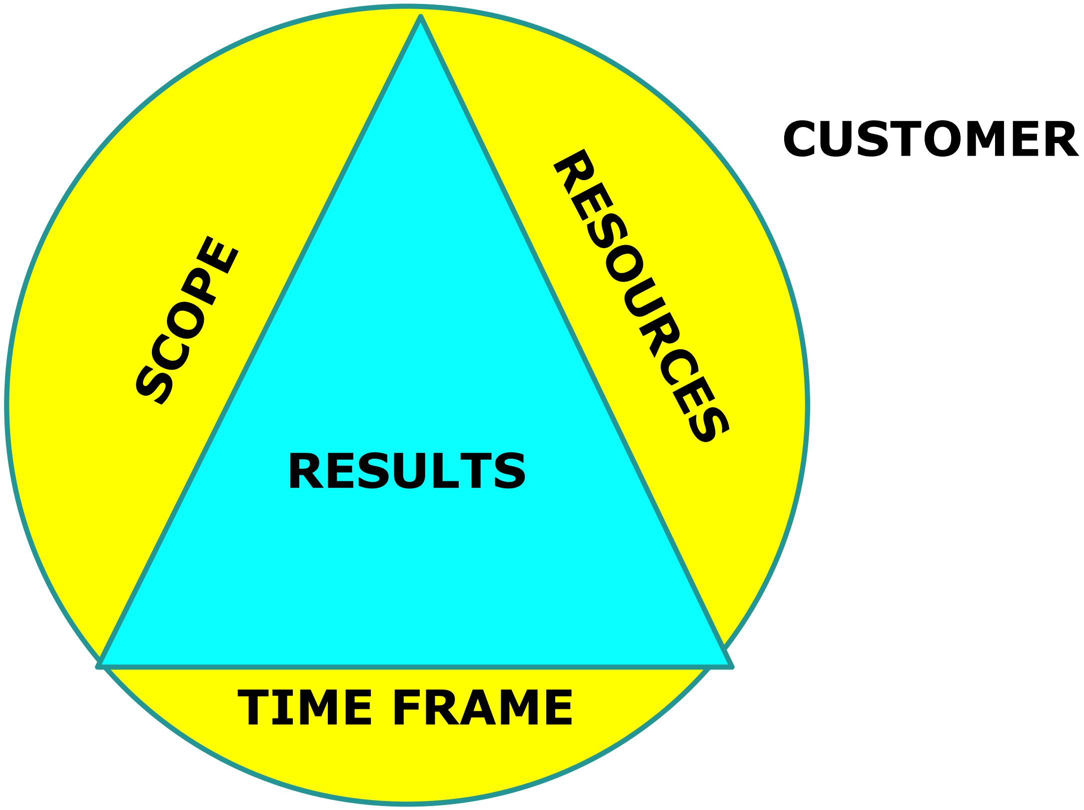
The triple constraint



The triple constraint

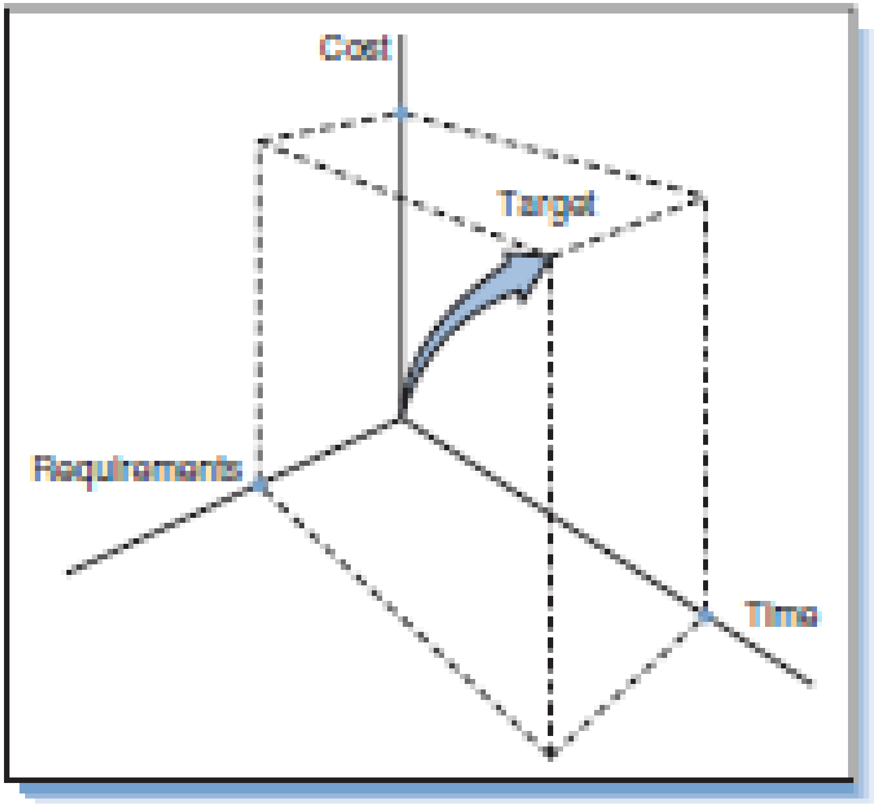
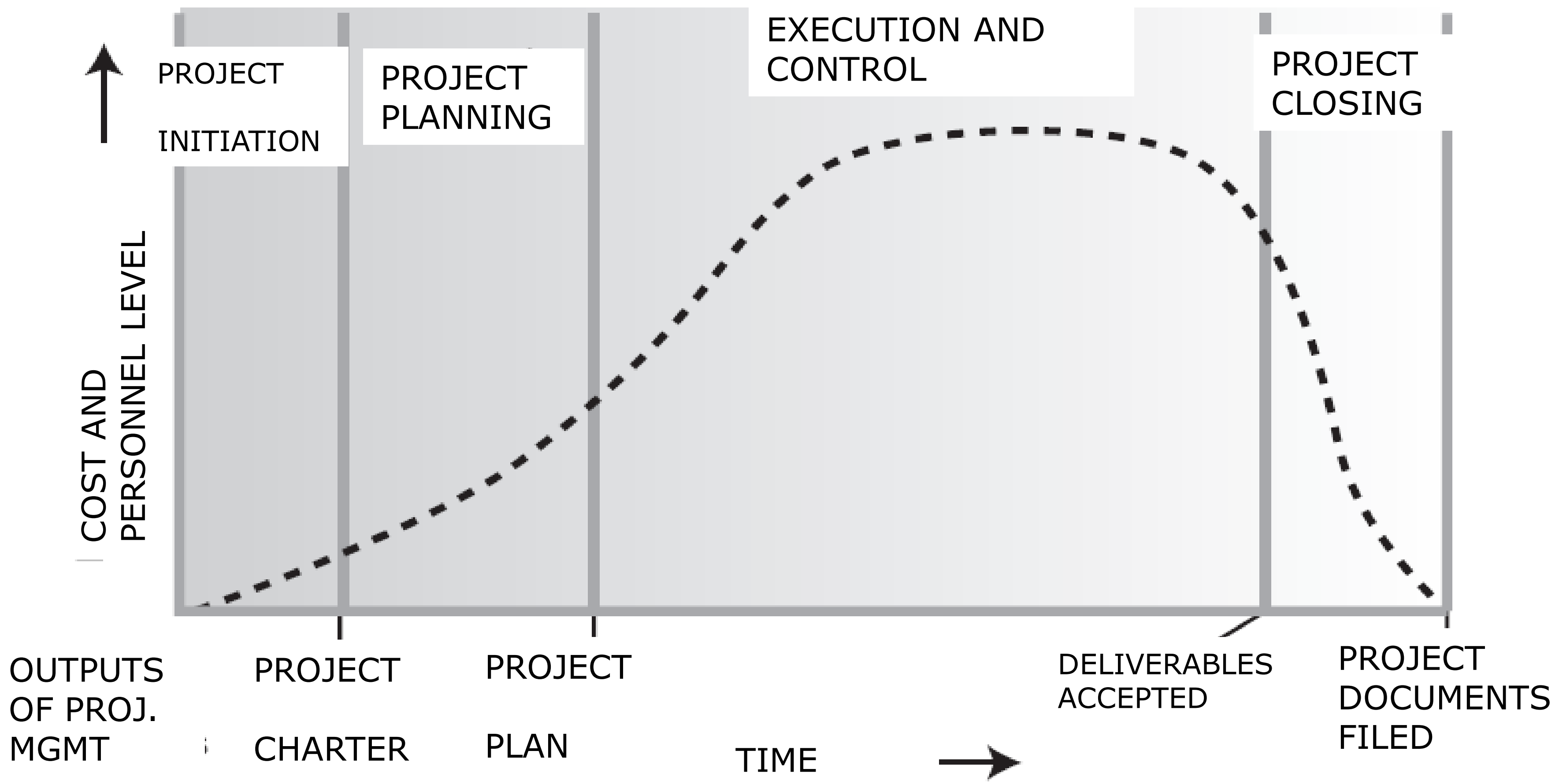


Figure I.4
Three-dimensional project goal. Adapted from Milton Rosenau, *Successful Project Management*. Belmont, CA: Lifetime Learning Publications; 1981. p. 16.

The project phases



The triple constraint

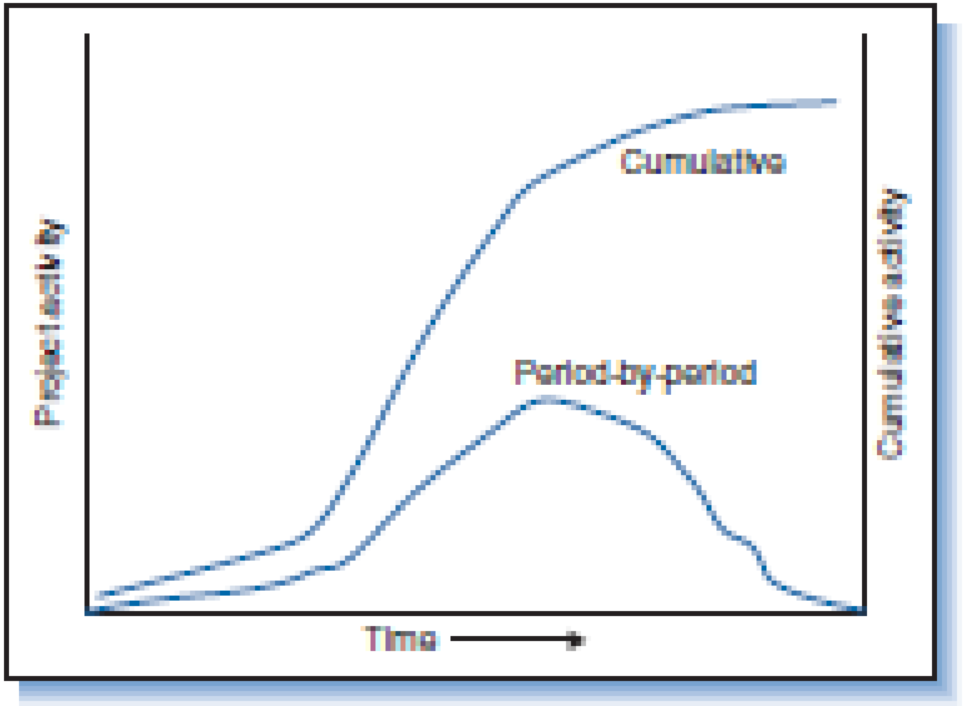
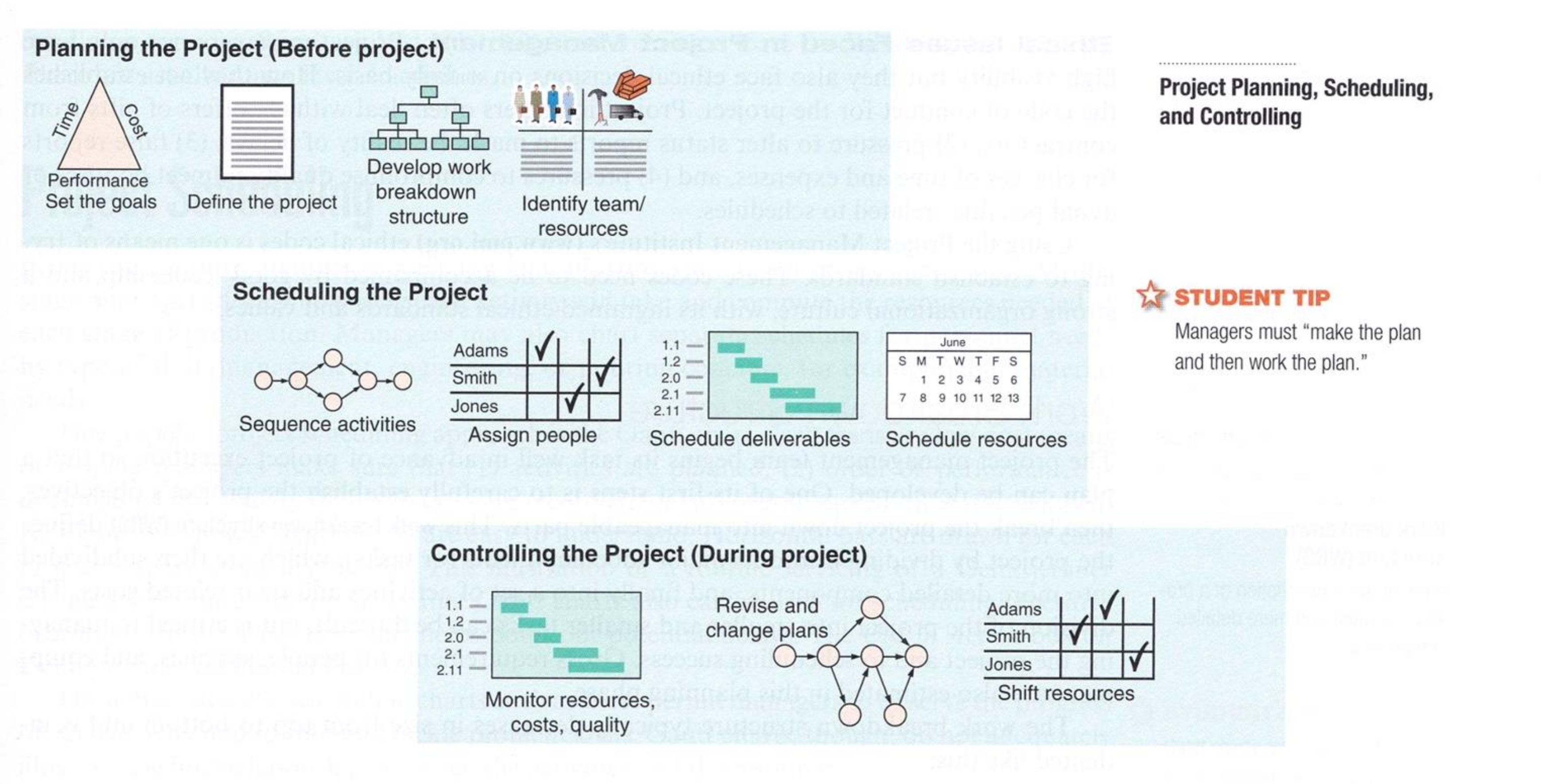


Figure 3.1
Level of activity during the project life cycle.

Project management

1. Planning - goal setting, defining the project, team organisation
2. Scheduling - relates people, money, and supplies to specific activities and activities to each other
3. Controlling - monitors resources, costs, quality, and budgets; revises plans and shifts resources to meet time and cost demands

Project management



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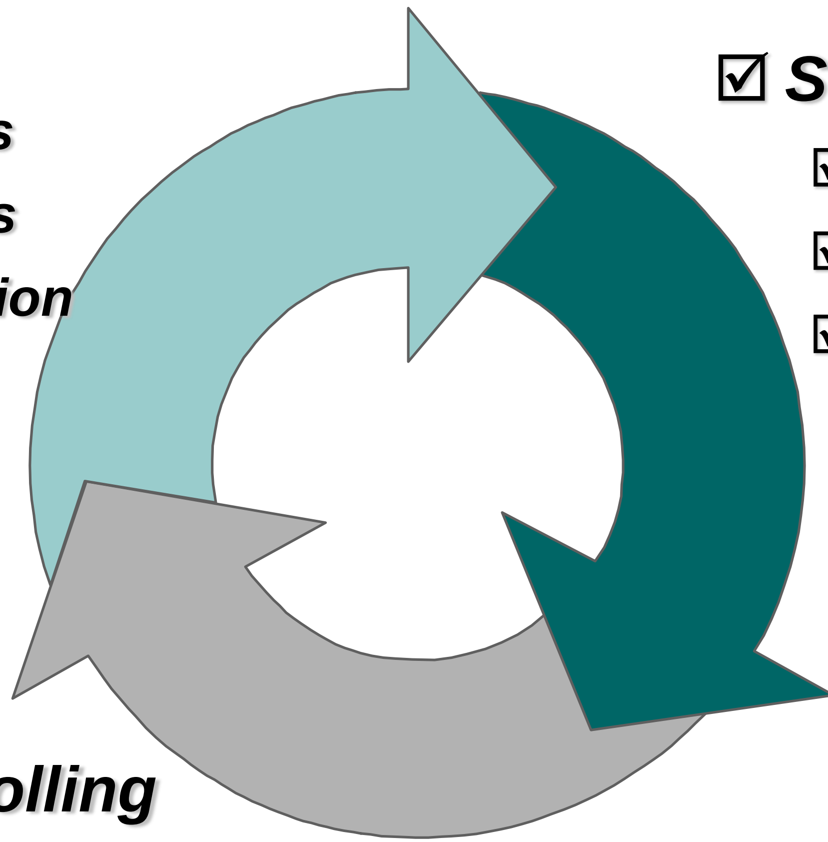
Project management activities

- ☑ ***Planning***
  - ☑ ***Objectives***
  - ☑ ***Resources***
  - ☑ ***Organisation***

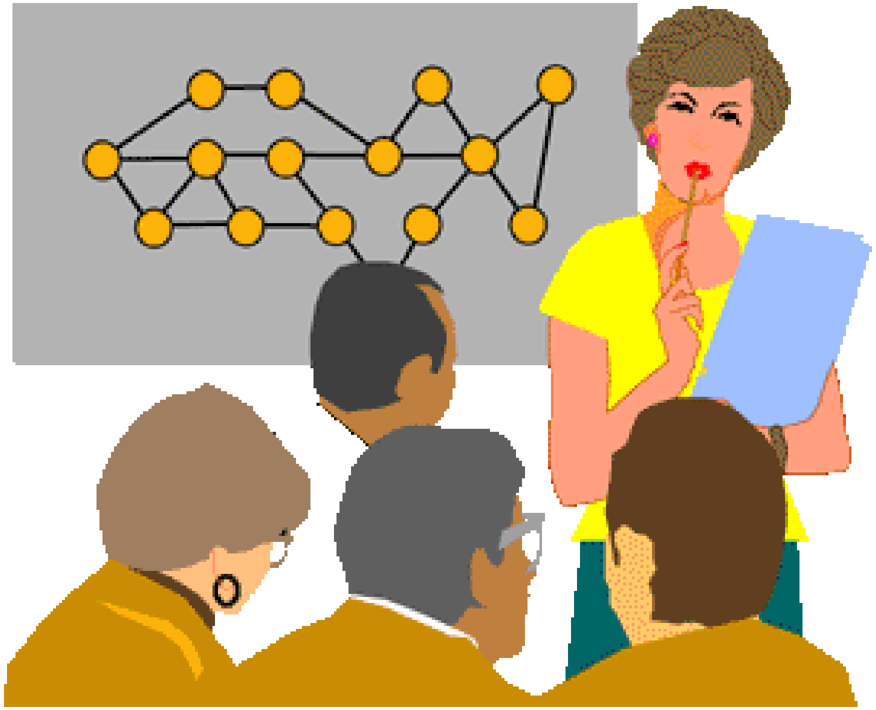


- ☑ ***Scheduling***
  - ☑ ***Project activities***
  - ☑ ***Start & end times***
  - ☑ ***Network***

- ☑ ***Controlling***
  - ☑ ***Monitor, compare, revise, action***

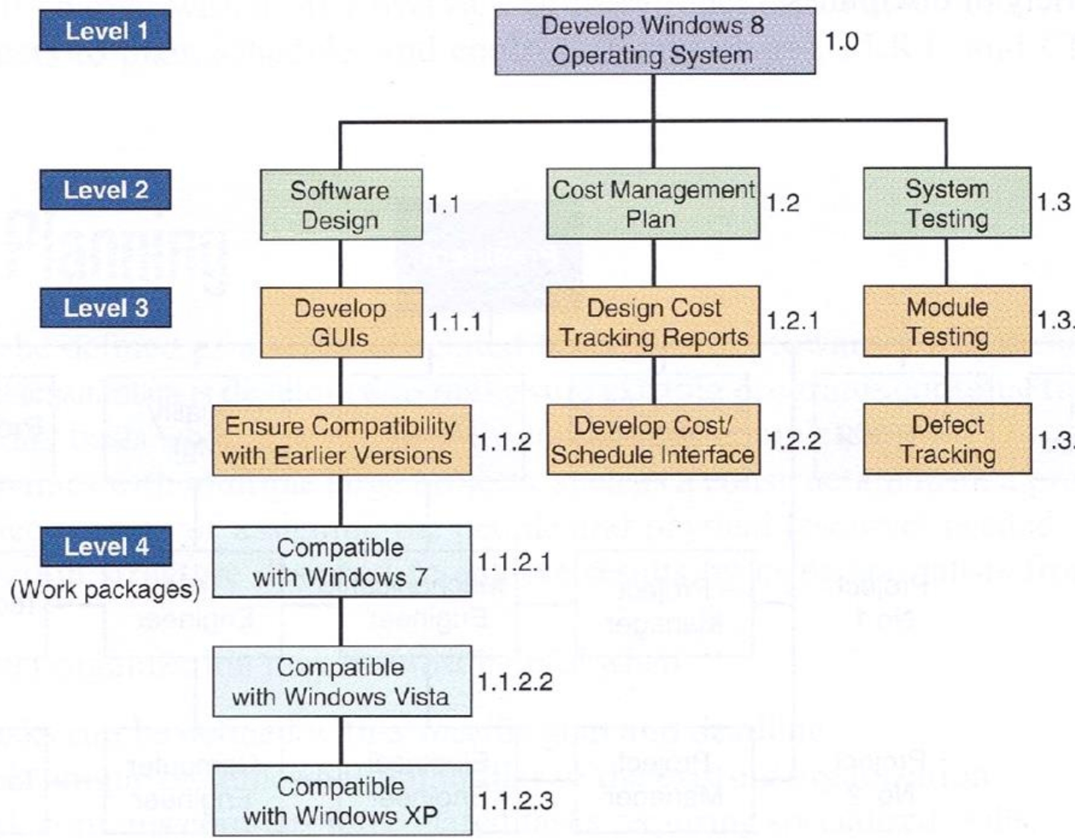
Project planning

- ☑ Establishing objectives
- ☑ Defining project
- ☑ Creating work breakdown structure
- ☑ Determining resources
- ☑ Forming organisation



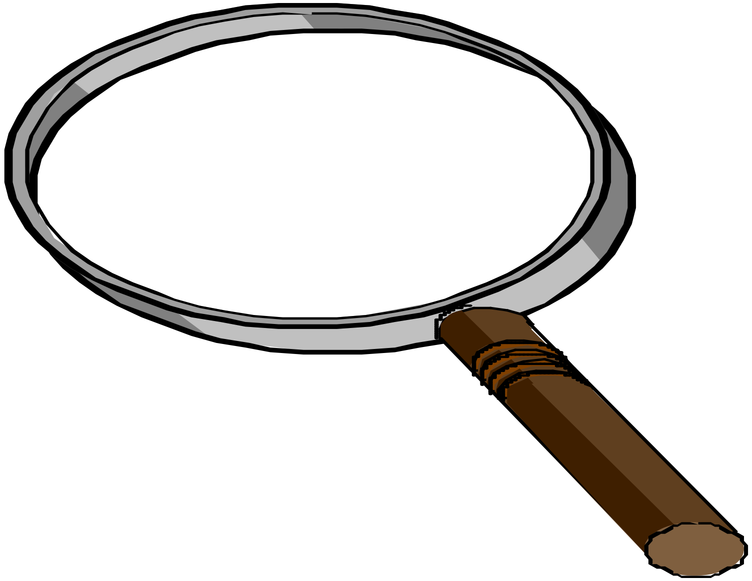
Project planning

Work Breakdown Structure

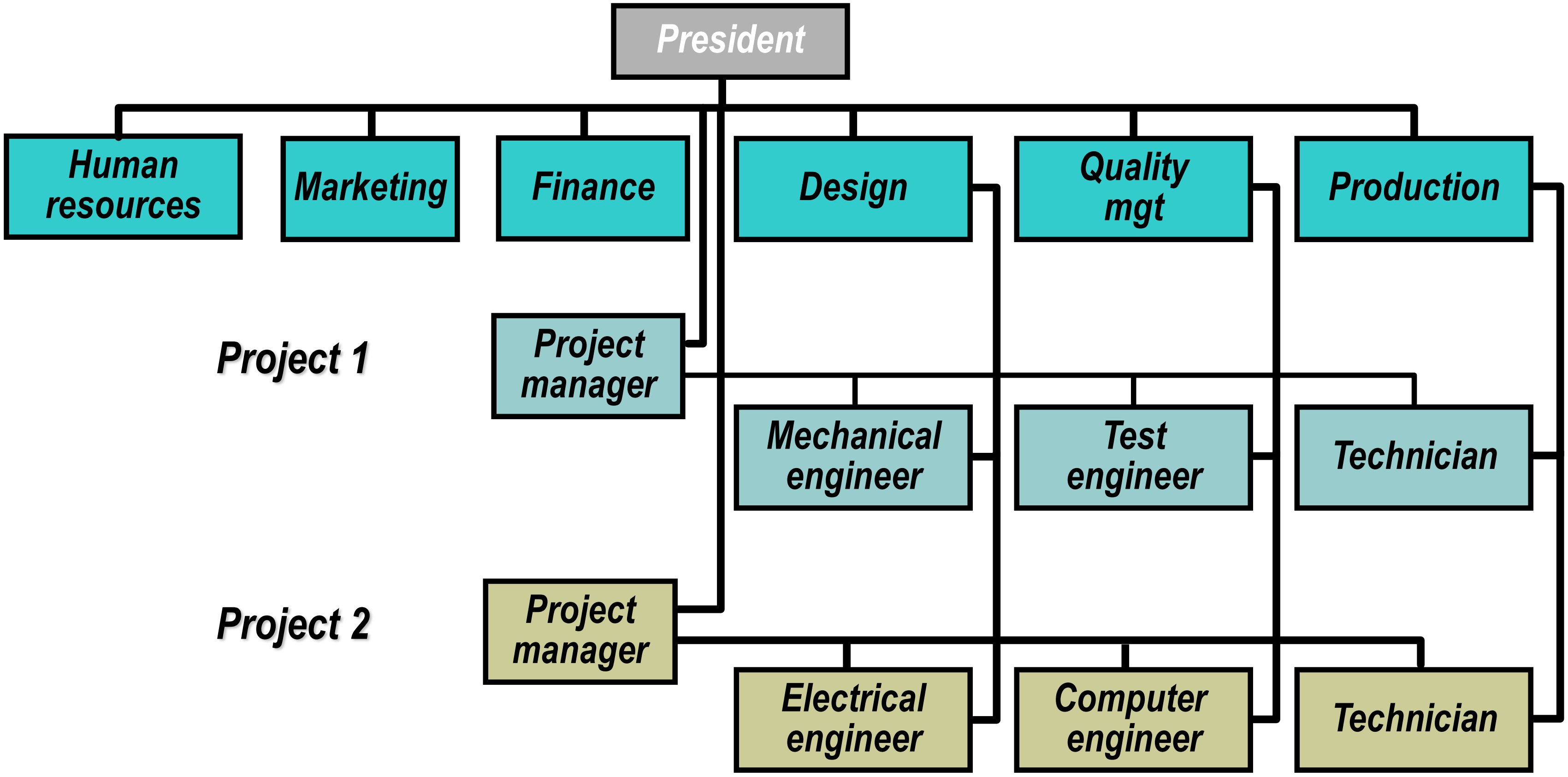


Project organisation

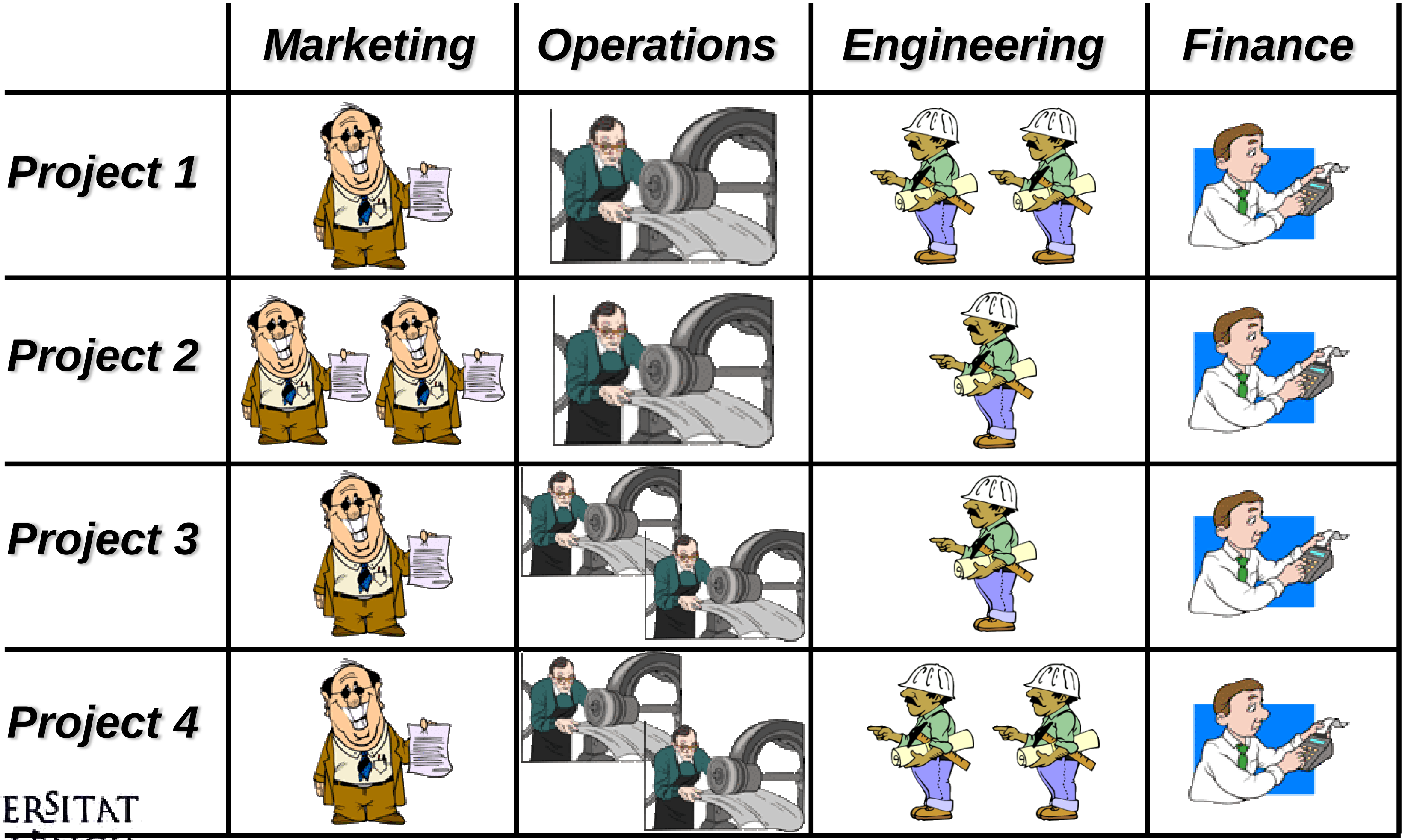
- ☑ Often temporary structure
- ☑ Uses specialists from entire company
- ☑ Headed by project manager
  - ☑ Coordinates activities
  - ☑ Monitors schedule and costs
- ☑ Permanent structure called 'matrix organisation'



A sample project organisation



Matrix organisation

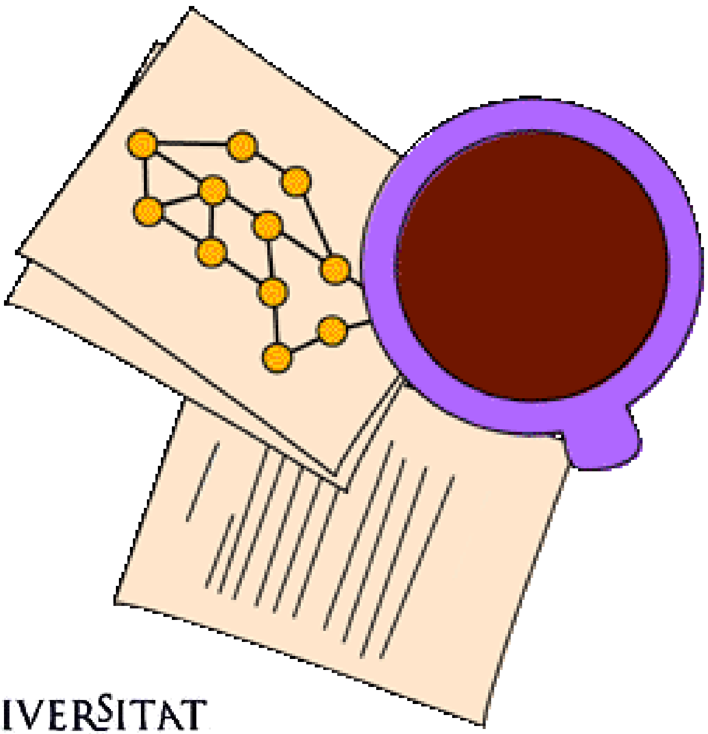


Project scheduling

- ☑ Identifying precedence relationships
- ☑ Sequencing activities
- ☑ Determining activity times & costs
- ☑ Estimating material & worker requirements
- ☑ Determining critical activities

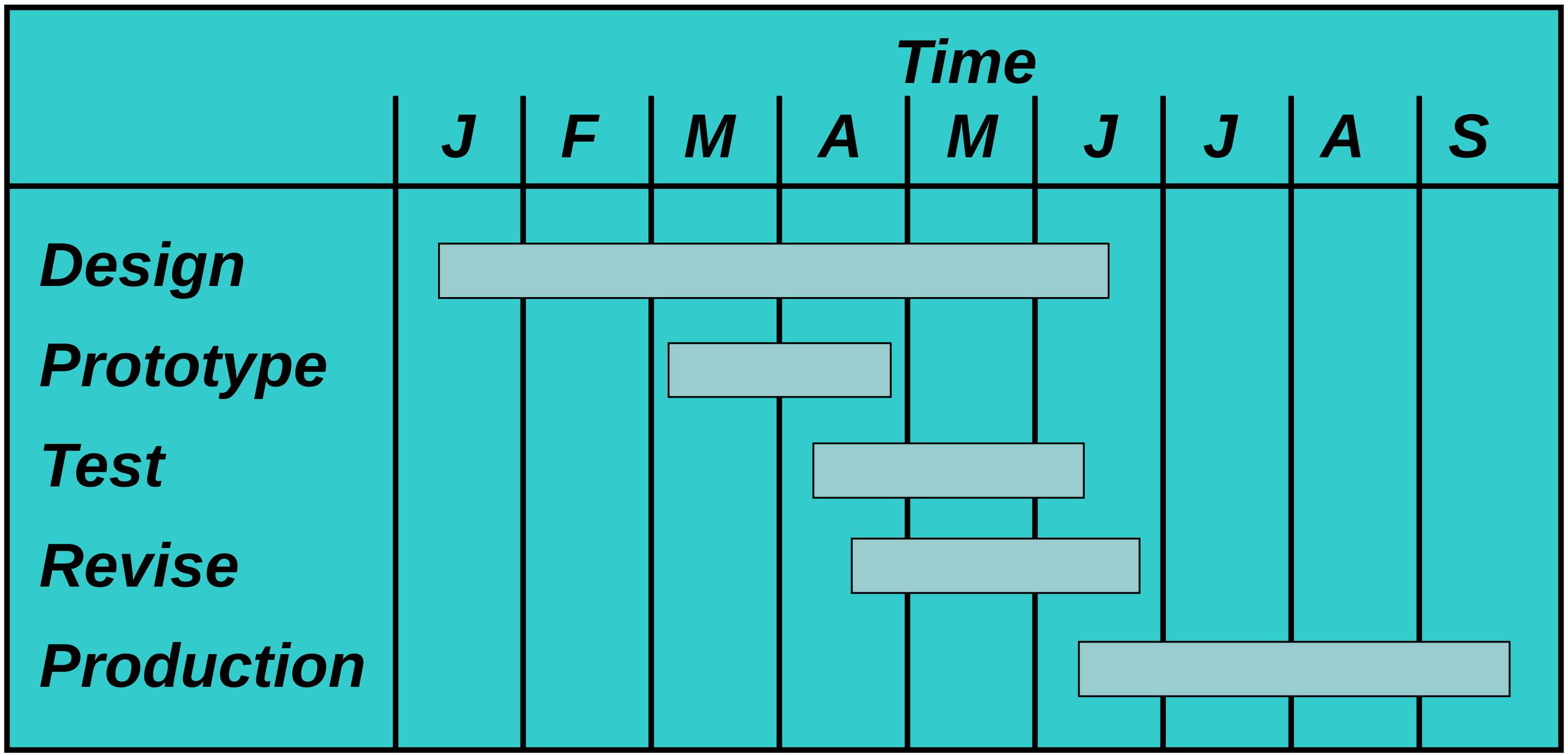
8.2.- Project planning and control techniques

Project management techniques

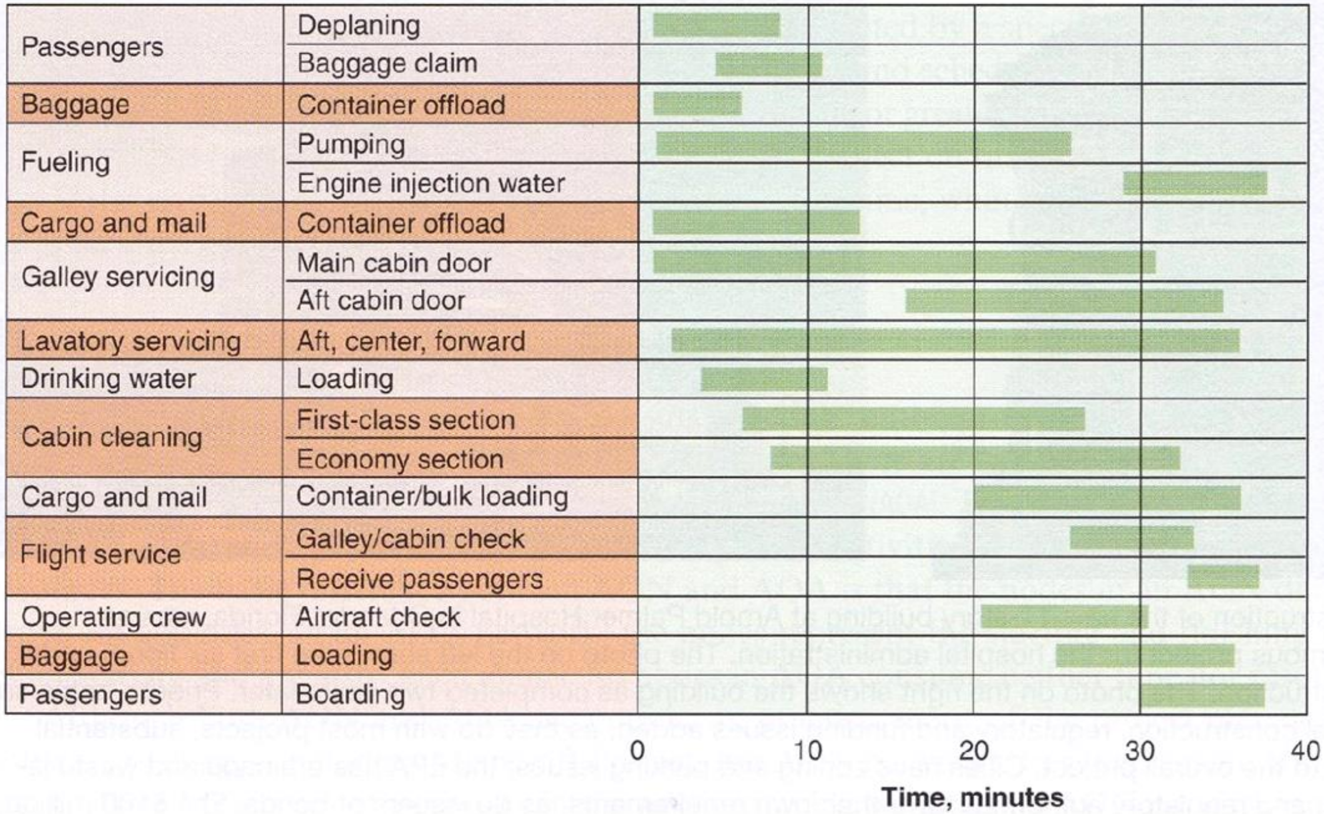


- ☑ Gantt chart
- ☑ Critical path method (CPM)
- ☑ Program evaluation and review technique (PERT)

A simple Gantt chart



A not so simple Gantt chart



Gantt Chart of Service Activities for a Delta Jet during a 40-Minute Layover

Delta saves $50 million a year with this turnaround time, which is a reduction from its traditional 60-minute routine.

PERT and CPM

- Network techniques
- Developed in 1950s
  - CPM by DuPont for chemical plants (1957)
  - PERT by Booz, Allen & Hamilton with the US Navy for Polaris missiles (1958)
- Consider precedence relationships and interdependencies
- Each uses a different estimate of activity times

Six steps PERT & CPM

1. Define the project and prepare the work breakdown structure
2. Develop relationships among the activities - decide which activities must precede and which must follow others
3. Draw the network connecting all of the activities

Six steps PERT & CPM

4. Assign time and/or cost estimates to each activity
5. Compute the longest time path through the network – this is called the critical path
6. Use the network to help plan, schedule, monitor, and control the project

Questions PERT & CPM can answer

1. ***When will the entire project be completed?***
2. ***What are the critical activities or tasks in the project?***
3. ***Which are the noncritical activities?***
4. ***What is the probability the project will be completed by a specific date?***

Questions PERT & CPM can answer

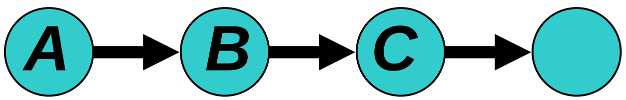
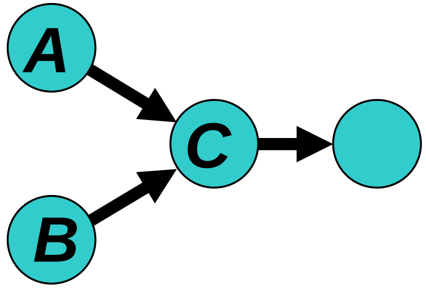
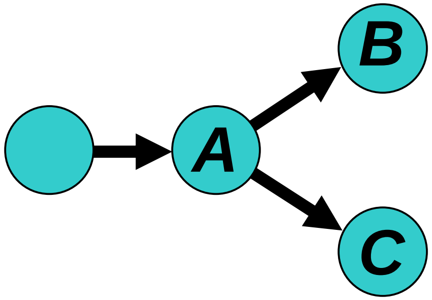
5. ***Is the project on schedule, behind schedule, or ahead of schedule?***
6. ***Is the money spent equal to, less than, or greater than the budget?***
7. ***Are there enough resources available to finish the project on time?***
8. ***If the project must be finished in a shorter time, what is the way to accomplish this at least cost?***

Example

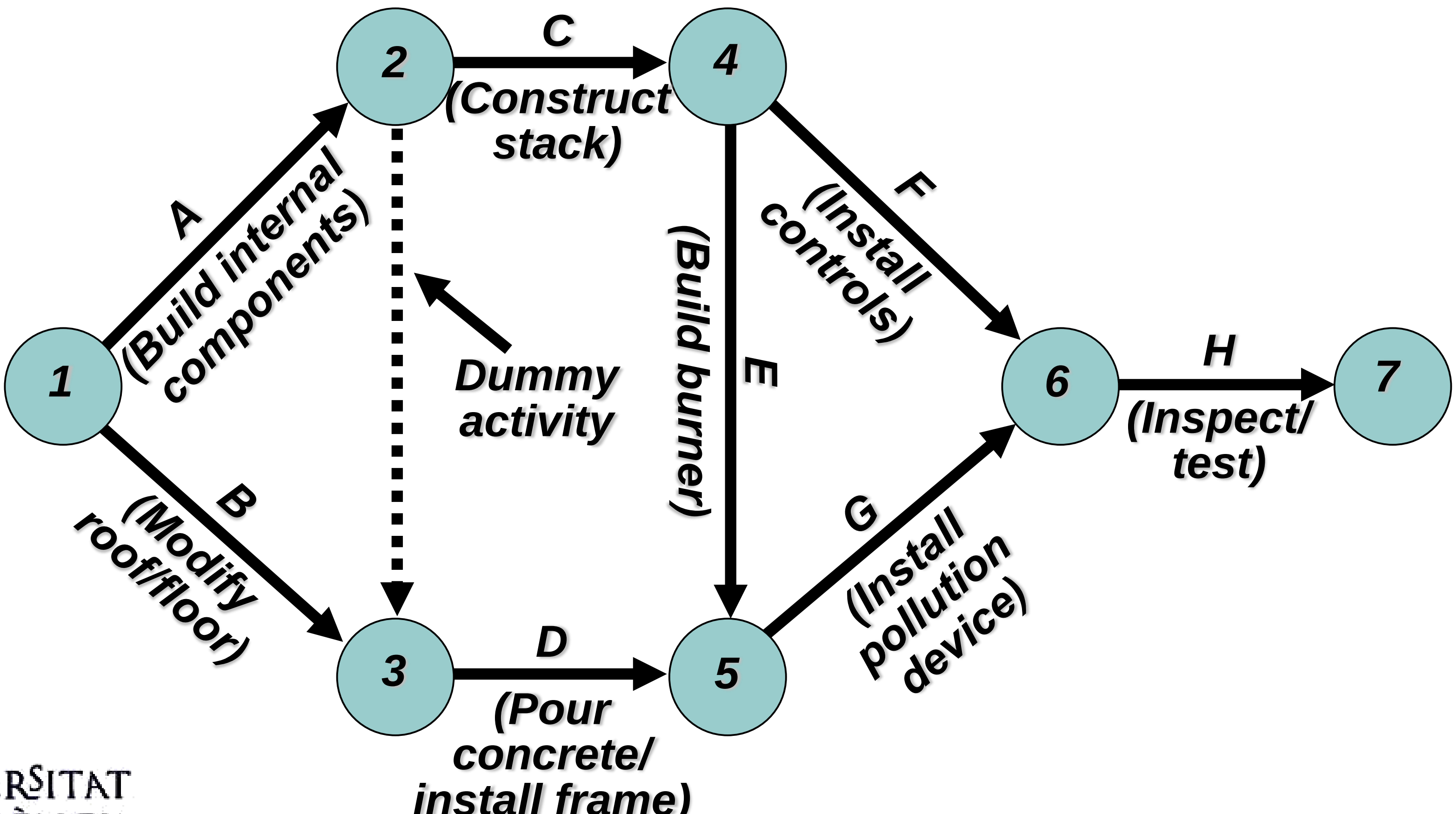
Milwaukee Paper Manufacturing Activities and predecessors

Activity	Description	Immediate predecessors
A	Build internal components	—
B	Modify roof and floor	—
C	Construct collection stack	A
D	Pour concrete and install frame	A, B
E	Build high-temperature burner	C
F	Install pollution control system	C
G	Install air pollution device	D, E
H	Inspect and test	F, G

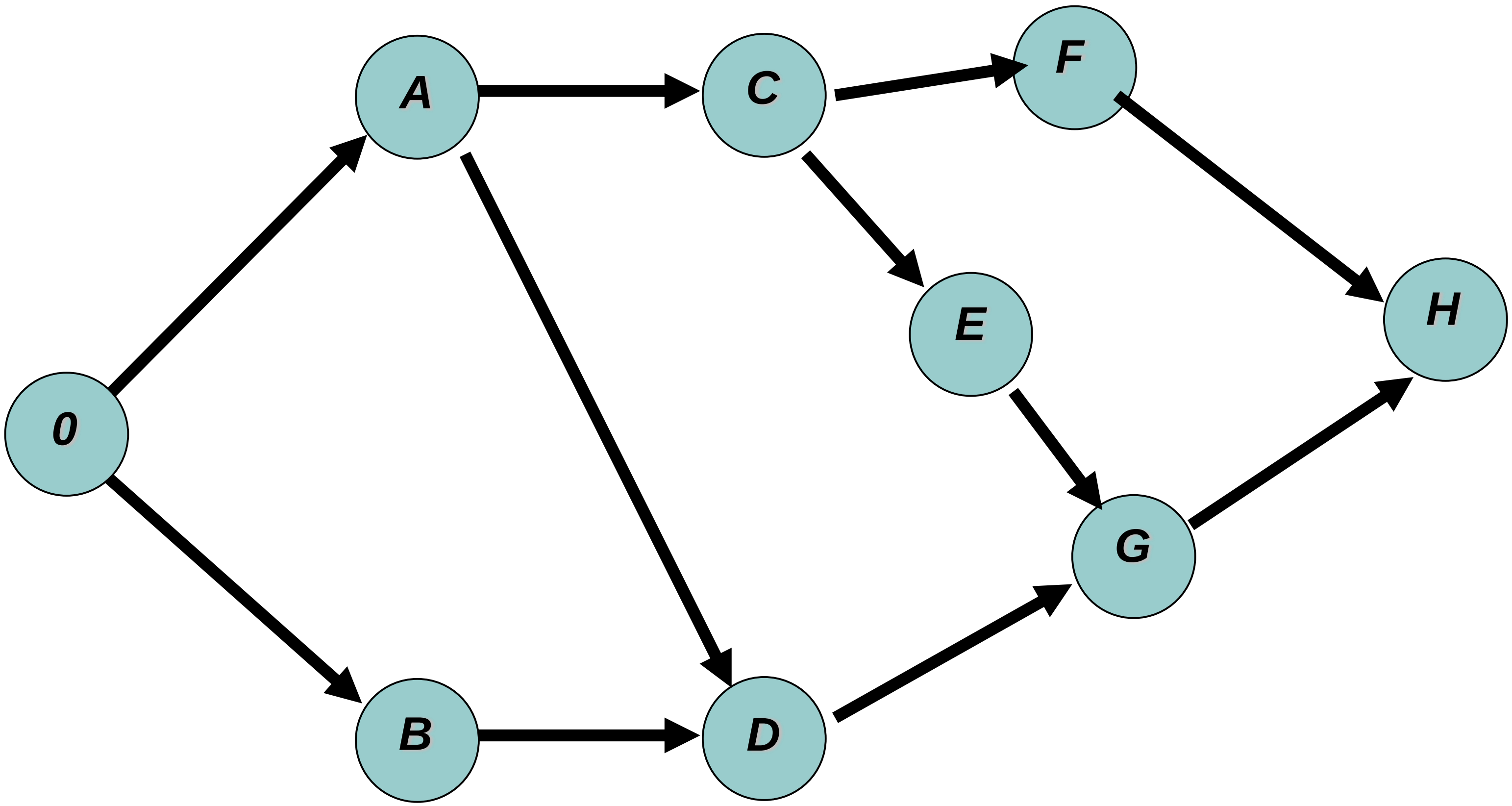
AON network conventions

	Activity meaning	Activity on arrow (AOA)
(a)	***A comes before B, which comes before C***	
(b)	***A and B must both be completed before C can start***	
(c)	***B and C cannot begin until A is completed***	

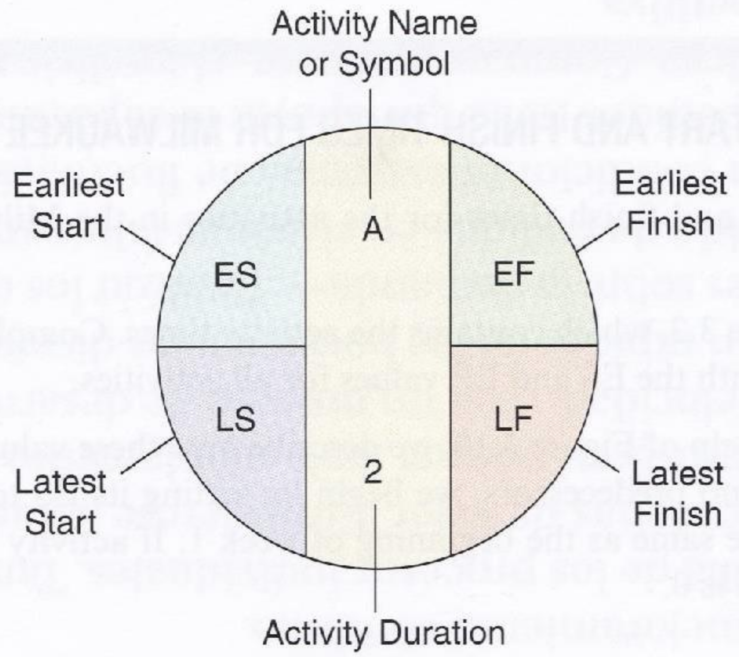
Network for Milwaukee Paper AOA



Network for Milwaukee Paper AON



Network for Milwaukee Paper AON



Notation Used in Nodes for Forward and Backward Pass

Determining the project schedule

Perform a critical path analysis

- ☑ ***The critical path is the longest path through the network***
- ☑ ***The critical path is the shortest time in which the project can be completed***
- ☑ ***Any delay in critical path activities delays the project***
- ☑ ***Critical path activities have no slack time***

Determining the project schedule

Perform a critical path analysis

Activity	Description	Time (weeks)
A	Build internal components	2
B	Modify roof and floor	3
C	Construct collection stack	2
D	Pour concrete and install frame	4
E	Build high-temperature burner	4
F	Install pollution control system	3
G	Install air pollution device	5
H	Inspect and test	2
	Total time (weeks)	25

Perform a critical path analysis

This analysis is made in two passes:

1) Forward pass: consists of calculation of early start and early finish dates, from start up to the end of the project.

Earliest start of an activity(ES): the earliest time at which an activity can be started.

Earliest start rule: ES of an activity will be the maximum EF time of its predecessors.

Earliest finish (EF): ES + activity time

When reaching the end of the project, we will know what is the minimum time in which it can be attained.

Perform a critical path analysis

2) Backward pass: consists of calculation of late start and late finish dates, from the end back up to the start of the project.

We start by writing in the last node (end node): LF=EF

In each node, we calculate :

Latest finish (LF) = latest time by which a node must be finished so as to not delay completion time for the entire project = Min (LS of all immediate following activities) .

Latest start (LS)= LF- activity time

Perform a critical path analysis

3) Calculating slack time + critical path determination

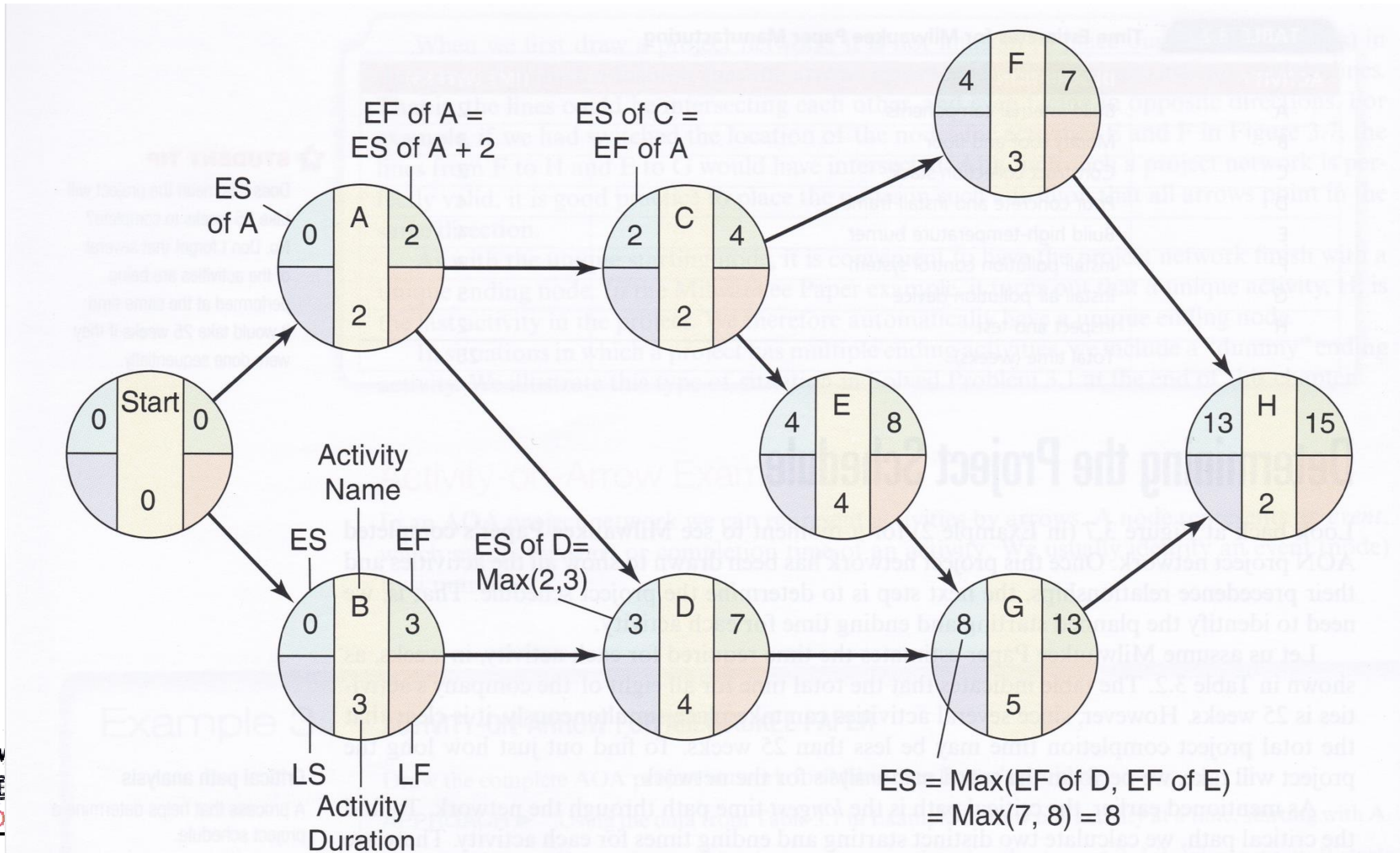
Slack time = LS-ES, or LF-EF (equal by definition)

It is the time an activity can be delayed without compromising the duration of the project.

Critical path is formed by the activities without slack time

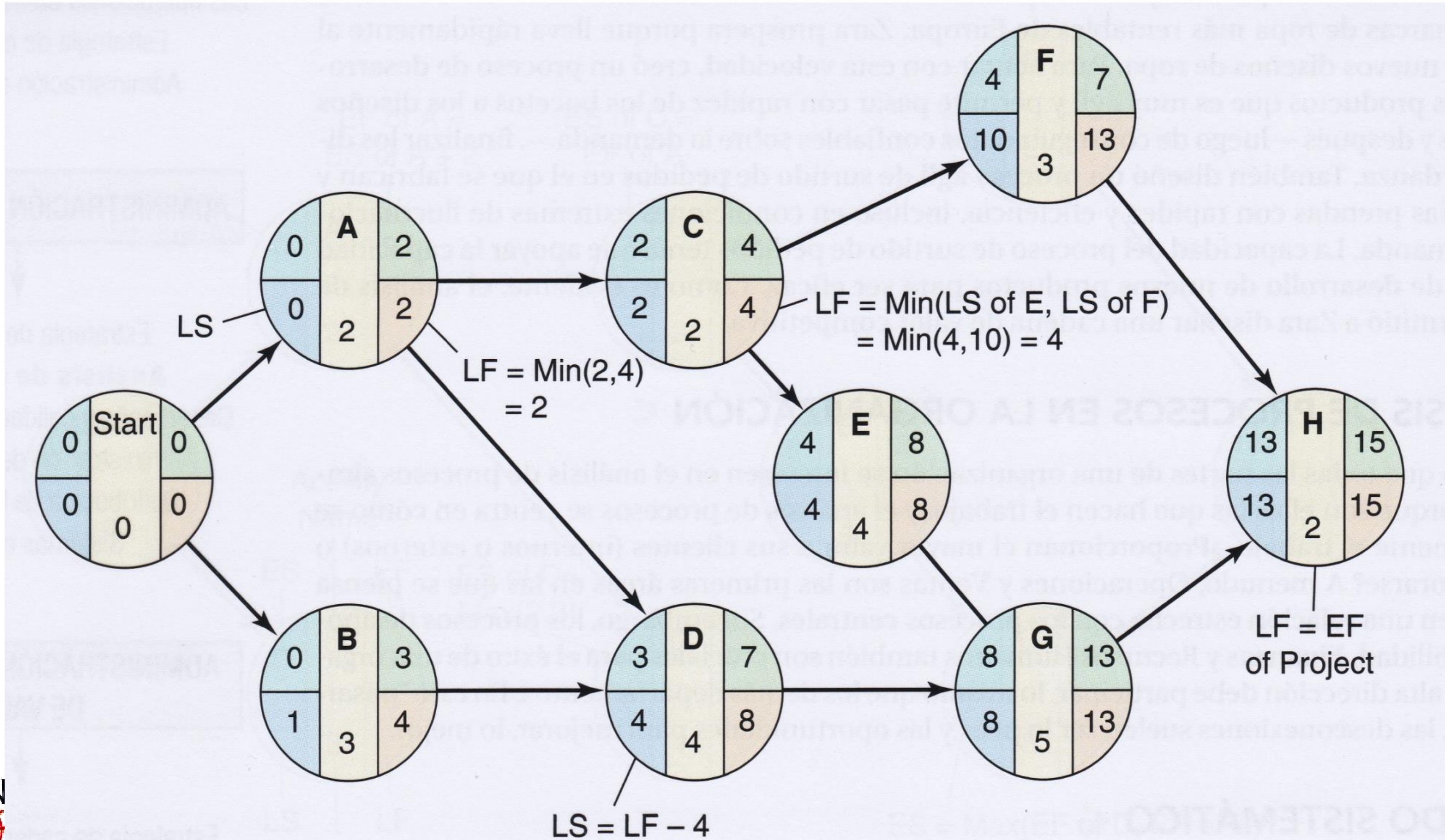
Seeing it with an example

1)Forward pass:



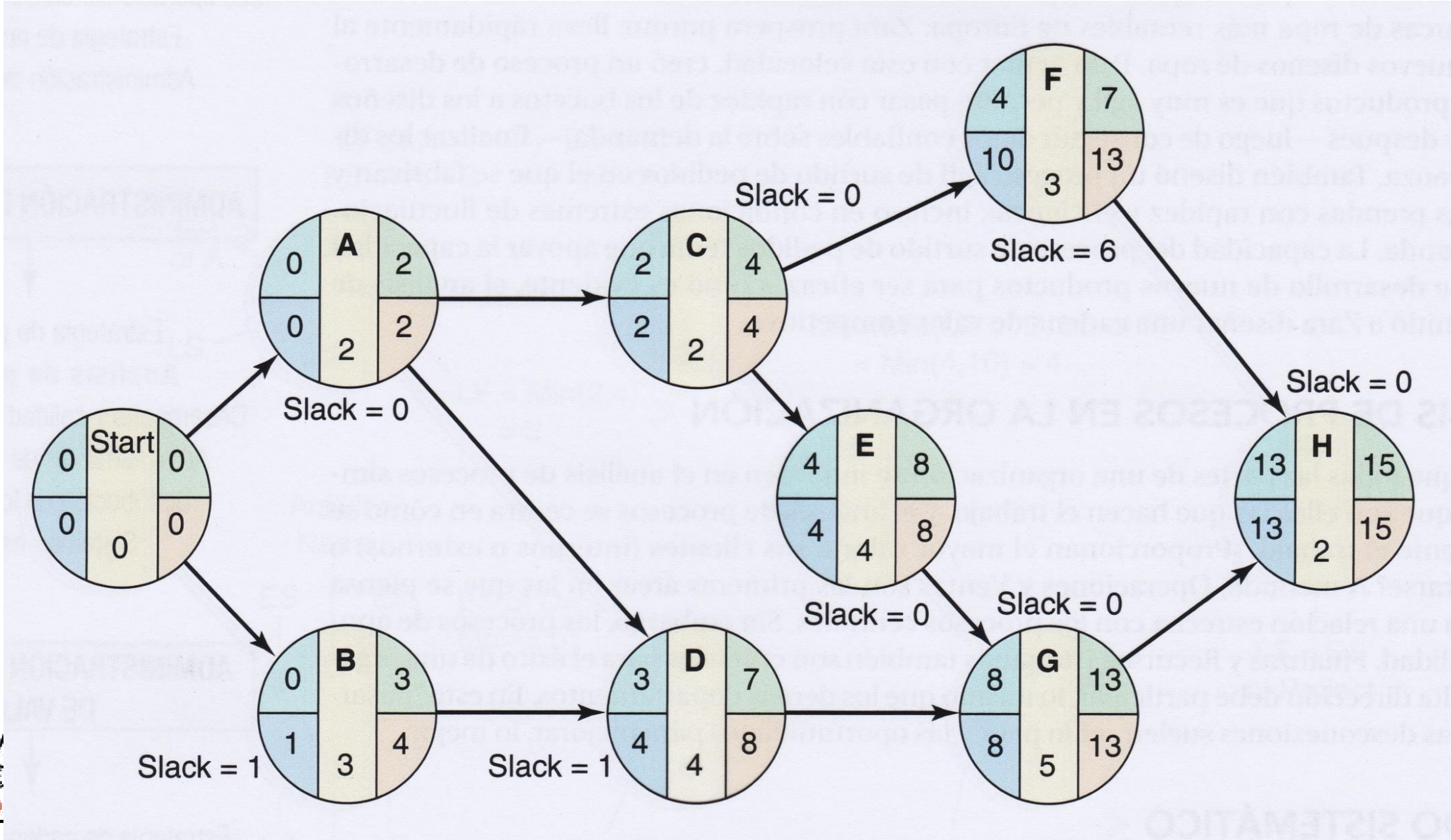
Seeing it with an example

2)Backward pass:



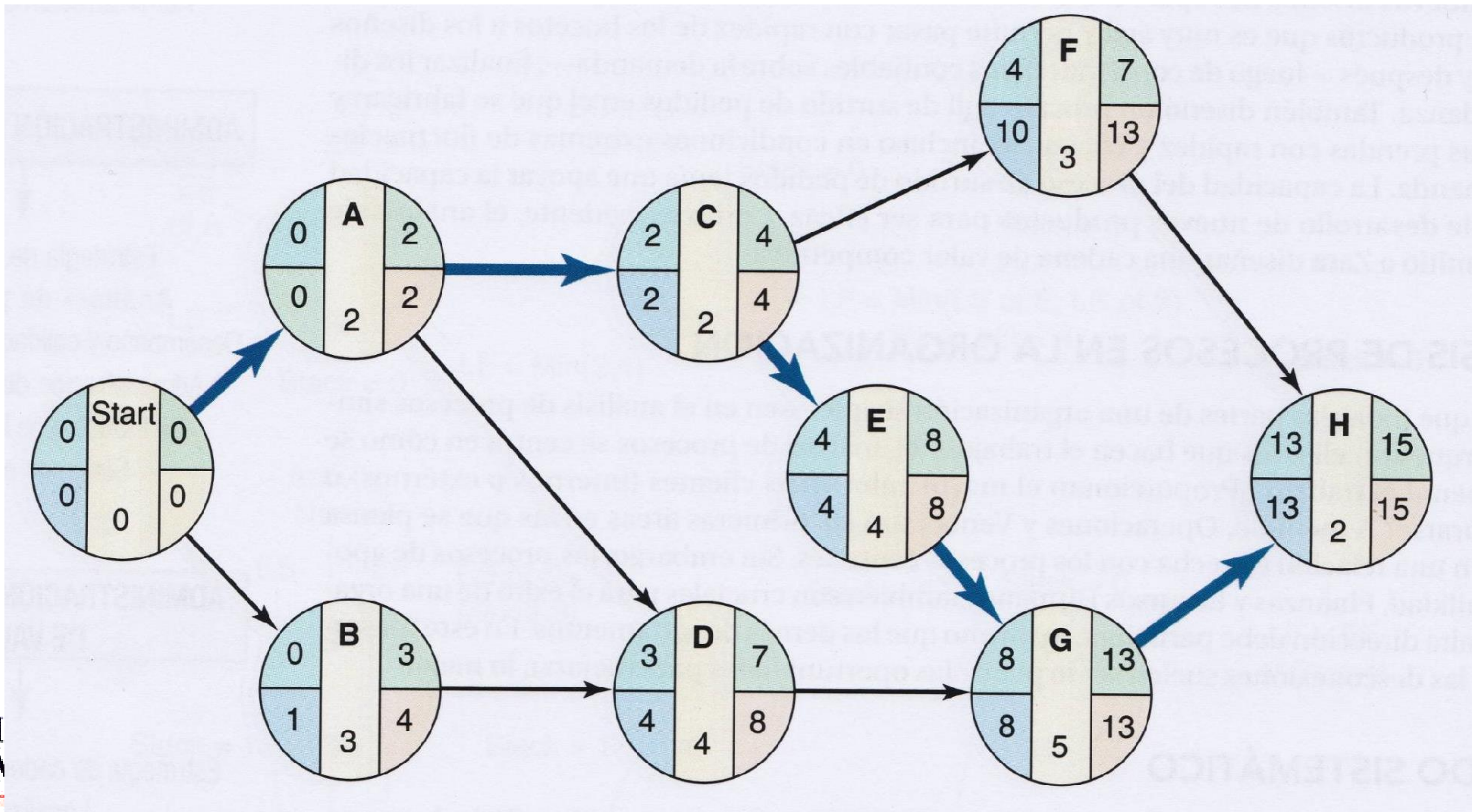
Seeing it with an example

3)Slack time:



Seeing it with an example

3)Slack time + critical path:



Seeing it with an example

3)Slack time + critical path:

TABLE 3.3 **Milwaukee Paper's Schedule and Slack Times**

ACTIVITY	EARLIEST START ES	EARLIEST FINISH EF	LATEST START LS	LATEST FINISH LF	SLACK LS – ES	ON CRITICAL PATH
A	0	2	0	2	0	Yes
B	0	3	1	4	1	No
C	2	4	2	4	0	Yes
D	3	7	4	8	1	No
E	4	8	4	8	0	Yes
F	4	7	10	13	6	No
G	8	13	8	13	0	Yes
H	13	15	13	15	0	Yes

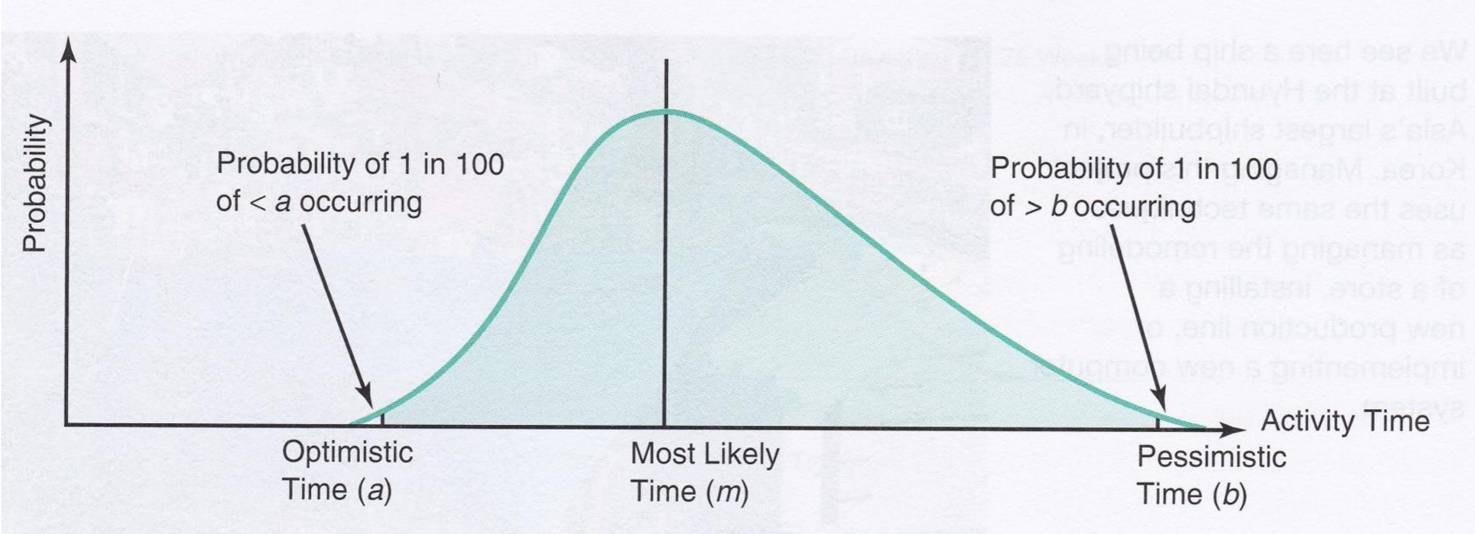
Variability in activity times

- ☑ CPM assumes we know a fixed time estimate for each activity and there is no variability in activity times
- ☑ PERT uses a probability distribution for activity times to allow for variability

Variability in activity times

- Three time estimates are required
  - Optimistic time (a) – if everything goes according to plan
  - Pessimistic time (b) – assuming very unfavorable conditions
  - Most likely time (m) – most realistic estimate

Variability in activity times



Beta Probability Distribution with Three Time Estimates

Variability in activity times

Estimate follows beta distribution

Expected time:

$$t = (a + 4m + b)/6$$

Variance of times:

$$v = [(b - a)/6]^2$$

Computing variance

Activity	*Optimistic* *a*	*Most Likely* *m*	*Pessimistic* *b*	*Expected Time* $t = (a + 4m + b)/6$	*Variance* $[(b - a)/6]^2$
A	1	2	3	2	.11
B	2	3	4	3	.11
C	1	2	3	2	.11
D	2	4	6	4	.44
E	1	4	7	4	1.00
F	1	2	9	3	1.78
G	3	4	11	5	1.78
H	1	2	3	2	.11

Probability of project completion

Project variance is computed by summing the variances of critical activities

$$\sigma_p^2 = \textit{Project variance}$$

$$= \sum(\textit{variances of activities on critical path})$$

Probability of project completion

Project variance is computed by summing the variances of critical activities

Project variance

$$\sigma_p^2 = .11 + .11 + 1.00 + 1.78 + .11 = 3.11$$

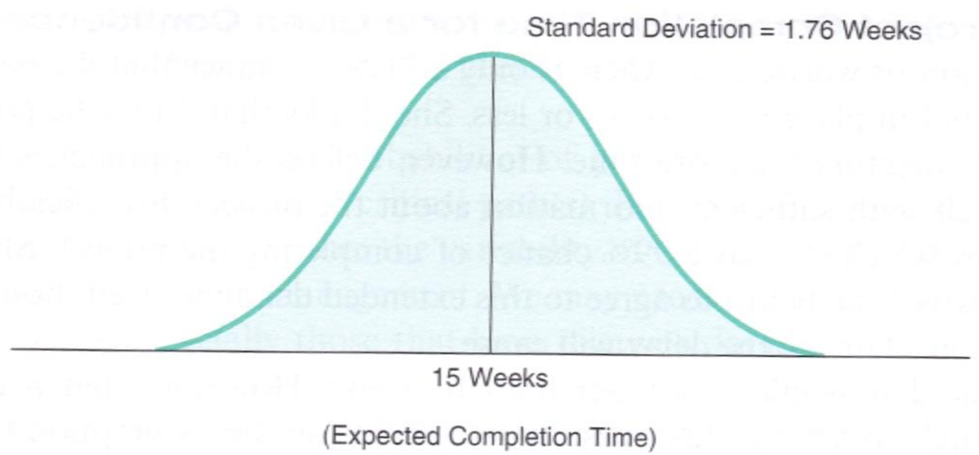
Project standard deviation

$$\sigma_p = \sqrt{\text{Project variance}}$$

$$= \sqrt{3.11} = 1.76 \text{ weeks}$$

Probability of project completion

Having worked with average times, we have now a 50% probability of finishing the project in 15 weeks.

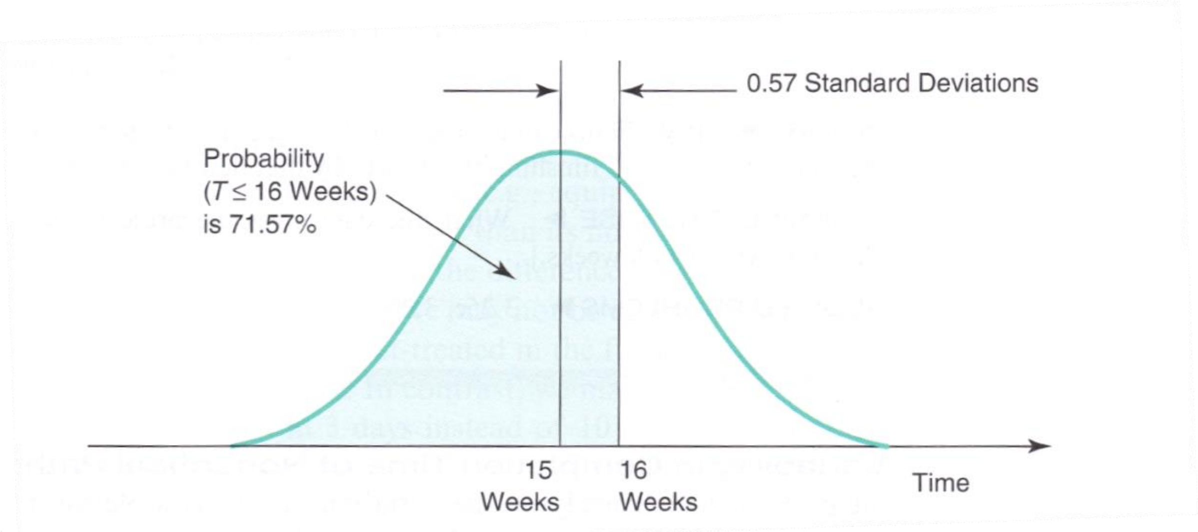


Probability Distribution for Project Completion Times at Milwaukee Paper

Probability of project completion

If we want the probability to be greater than a mere 50%, we must work on some statistics.
Assuming a deadline of 16 weeks, what will be the probability of the project being finished in that time?

The area of the normal distribution at the left of the 16-week deadline is 71.6%→ this is the probability of finishing the project within 16 weeks.



Trade-offs and project crashing

It is not uncommon to face the following situations:

- ☑ The project is behind schedule
- ☑ The completion time has been moved forward

Shortening the duration of the project is called project crashing

Factors to consider when crashing a project

- ☑ The amount by which it is permissible to crash an activity.
- ☑ Taken together, the shortened activity durations will enable us to finish the project by the due date.
- ☑ The total cost of crashing must be as small as possible.

Steps in project crashing

1. Compute the crash cost per time period. If crash costs are linear over time:

$$\text{Crash cost per period} = \frac{\text{(crash cost – normal cost)}}{\text{(normal time – crash time)}}$$

2. Using current activity times, find the critical path and identify the critical activities

Steps in project crashing

3. If there is only one critical path, then select the activity on this critical path that (a) can still be crashed, and (b) has the smallest crash cost per period. If there is more than one critical path, then select one activity from each critical path such that: (a) each selected activity can still be crashed, and (b) the total crash cost of all selected activities is the smallest. Note that the same activity may be common to more than one critical path.

Steps in project crashing

4. Update all activity times. If the desired due date has been reached, stop. If not, return to Step 2.

Crashing the project

Activity	Time (Wks) Normal	Crash	Cost ($) Normal	Crash	Crash Cost Per Wk ($)	Critical path?
A	2	1	22,000	22,750	750	Yes
B	3	1	30,000	34,000	2,000	No
C	2	1	26,000	27,000	1,000	Yes
D	4	2	48,000	49,000	1,000	No
E	4	2	56,000	58,000	1,000	Yes
F	3	2	30,000	30,500	500	No
G	5	2	80,000	84,500	1,500	Yes
H	2	1	16,000	19,000	3,000	Yes

8.3.- Limitations of the PERT-CPM technique

- It assumes independent and clearly defined activities (very often, activity durations inter-depend mutually)
- Activity duration is estimated subjectively
- Its use becomes complicated when an activity starts before completion of its predecessors.