Industrial Project Management (MDP 232)

Lecture Notes

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Table of Contents

1. Introduction

Projects definition

Projects are unique, one-time operations designed to accomplish a specific set of objectives in a limited time frame. Project operations are unique, and one-time operations.

Examples for Projects

- Organizing Olympic games
- Producing a movie
- Producing a book
- Running a political campaign
- Construction (house, bridge, school…etc.)
- Re-planning a city after an earthquake
- Launching a space shuttle
- Re-engineering a business process
- Merging two companies
- Introducing new products
- Organizing graduation ceremony
- Graduation project

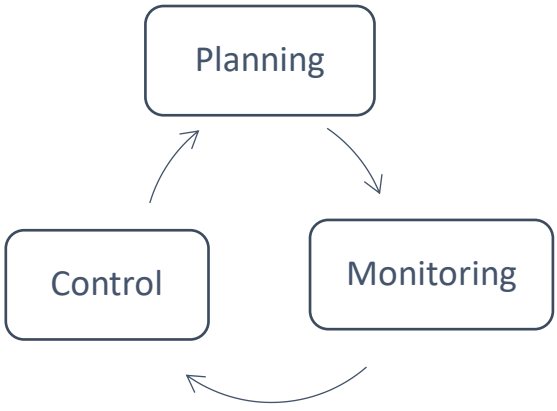
Project management definition

It is the planning, organizing, directing, and controlling of company resources to achieve a relatively short-term objective that has been established to complete a project.

Managing projects involve the following tasks:

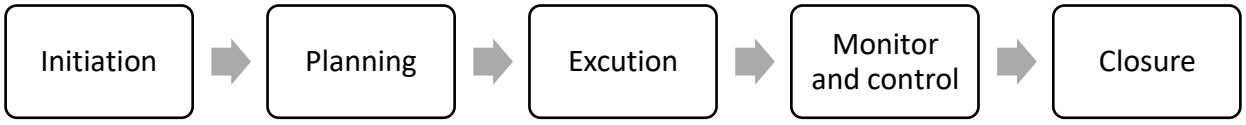
- Identifying tasks
- Making time estimates
- Projecting resource requirements
- Preparing budgets
- Monitoring progress
- Revising plans as needed

Managing projects require:



Project Life cycle

The project life cycle has 5 phases:



The project manager is responsible for effectively managing the following:

- The work
- The human resources
- Communications
- Quality
- Time
- Costs

Key decisions in project management

- Deciding which projects to implement (Feasibility study)
- Selecting the project team
- Planning and designing the project
- Managing and controlling project resources
- Deciding if and when a project should be terminated

Project Objectives Must Be…

- Fit organizational objectives
- Realistic
- Specific (Not vague)
- Time limited
- Written
    - Clarification
    - Accessible to all
    - Resolution of conflict
- Achievable
- Measurable
- Deliverable (A single end result)

2. Work Breakdown Structure (WBS)

Definition of WBS

- It is a hierarchical decomposition of all the tasks to be accomplished for a project to be completed. Each descending level of the WBS represents an increasingly detailed definition of the project work.
- It is the process of subdividing project deliverables into smaller, more manageable components.
- It is a deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables.

Why do we need to make WBS:

- Responsibility and resources are easily assigned
- Time can be calculated / detected
- Work Breakdown Structure (WBS)
- WBS detects exact relations between activities
- Reports and management tasks should be included
- Time required to make WBS may exceed the time for project scheduling
- WBS is the source of all data

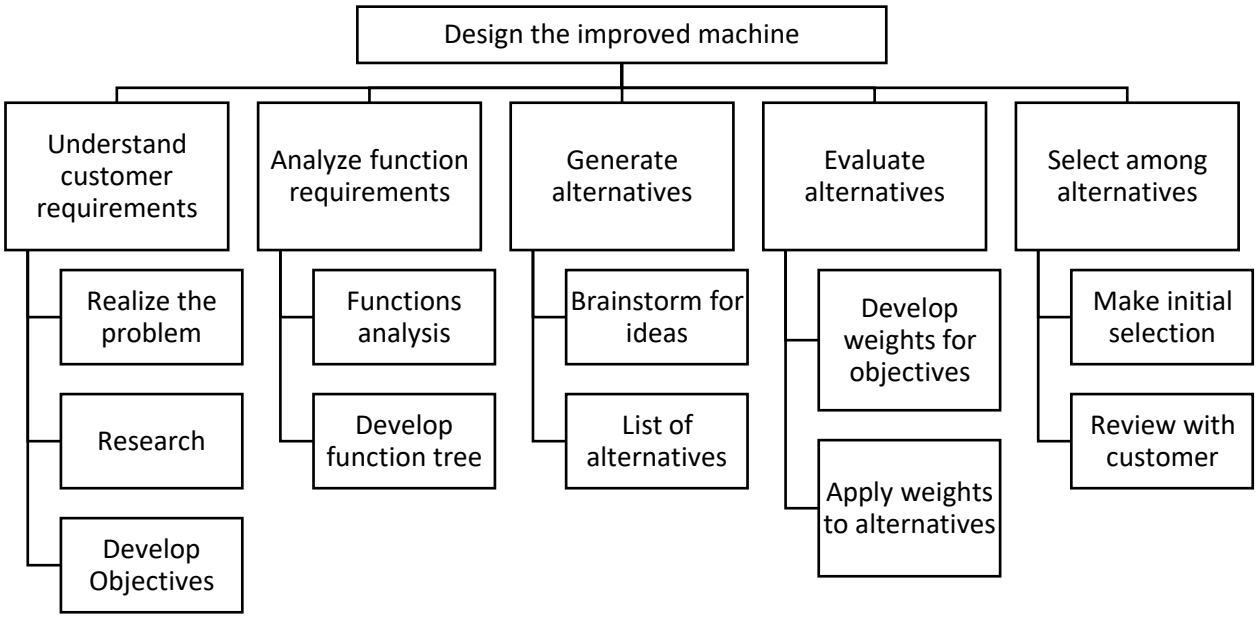
Principle of 100% rule

- WBS includes 100% of the work defined by the project scope.
- It is applied to all levels of the hierarchy.
- The sum of work at a "lower" level must be equal to 100% of work of an "upper" level.

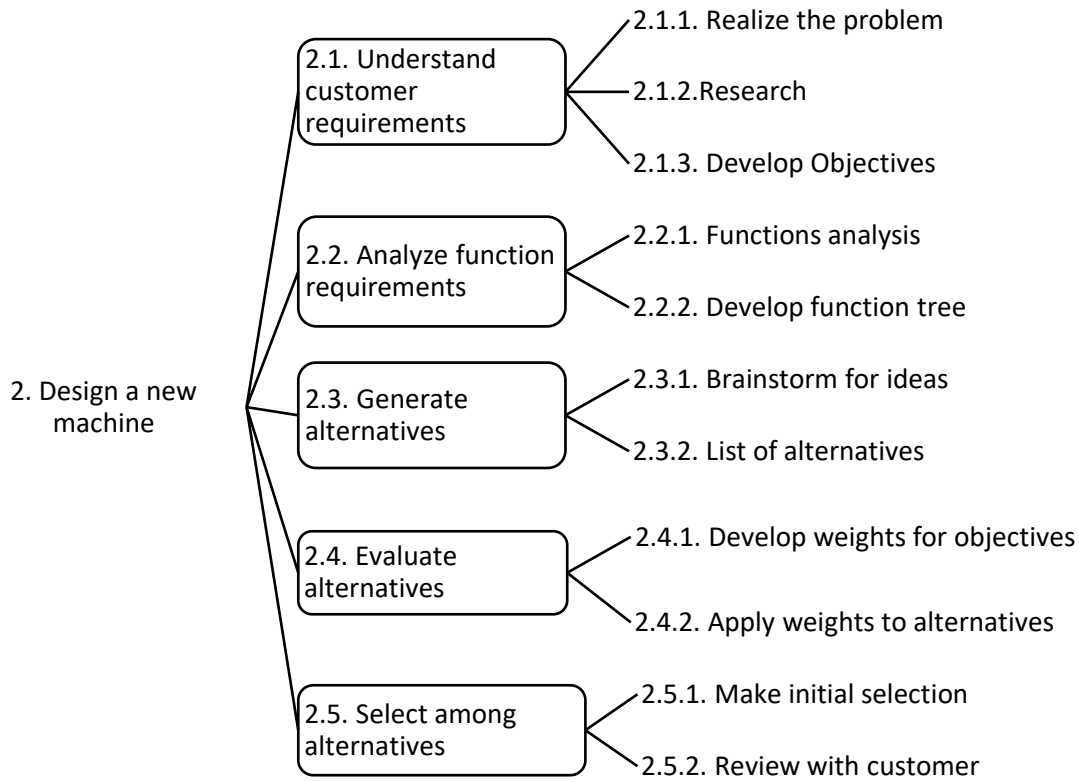
General notes on WBS

- Each activity in the WBS should contain a verb because it describes work to be done.
- The activity should be clear enough without any.
- For activities that need a decision, write the activity, and not the decision (e.g. "list the criteria of the team member", NOT "Choose students of GPA > 2).
- Activities that do not consume time do not belong to the WBS (e.g. "The place should be clean")
- Activities that are not time-limited do not belong to the WBS (e.g. "Managing the maintenance of the devices monthly")

Forms of WBS



2. Design the improved machine.
    2.1. Understand customer requirements
        2.1.1. Realize the problem
        2.1.2. Research
        2.1.3. Develop Objectives
    2.2. Analyze function requirements
        2.2.1. Functions analysis
        2.2.2. Develop function tree
    2.3. Generate alternatives
        2.3.1. Brainstorm for ideas
        2.3.2. List of alternatives
    2.4. Evaluate alternatives
        2.4.1. Develop weights for objectives
        2.4.2. Apply weights to alternatives
    2.5. Select among alternatives
        2.5.1. Make initial selection
        2.5.2. Review with customer



Do it yourself

In a project of lab foundation, make the WBS for the phase of buying the computers.

3. Time Estimation

Time has to be estimated, not guessed.

What is the activity time that we need to estimate?

Effort (E): Labor time required to complete an activity
Duration (D): Clock time taken from starting till ending the activity

- Work is interrupted regularly by emails, phone calls, meetings, coffee breaks, socializing, etc.
- *(i)* is the percent of regular interruptions during the activity work.
- Estimates have been made for regular interruptions. Data indicates its range as (***25*** to 33***)*** %.

$$E = (1 - i) \times D$$
$$D = \frac{E}{(1 - i)}$$

Unplanned interruptions may result due to: a system / power crash, events of random nature, less effort exerted, departmental work, the boss stopping in to visit on an unrelated matter. (*j*) is the percentage for unplanned interruptions. By experience percentage is extra 33%.

$$E = (1 - j) \times (1 - i) \times D$$
$$D = \frac{E}{(1 - i)(1 - j)}$$

Activity time estimation methods

- Similarity to others
- Study historical data
- Expert advice
- Three-point technique
- Delphi technique
- Wide band Delphi technique

Comparison between methods

Method	Description
Similarity to others	Uses and advantages • For activities that are similar to activities completed in other projects. • Where data is available • In most cases, estimates are good enough

Method	Description
Expert advice	Procedure Let an expert estimate the duration of the activity Uses • For tasks of a ***breakthrough technology*** or a technology that is being used for the ***first time*** in the organization For tasks of ***no local experience*** or even skilled professionals in the technology of the task.
Three-point technique	Procedure • The method uses three estimates of activity duration estimated by experts: • Optimistic (O) • Pessimistic (P) • Most likely (M) • The values depend on the collective memory of professionals who have worked on similar activities but for which there is no recorded history. $T_E = \frac{O + 4M + P}{6}$
Delphi technique	Procedure • A small number of experts (5 or 6) make their estimates independently of one another. • The results are tabulated and shared with everybody independently and anonymously, who are then asked for a second estimate. • A third (or more) estimate is given in the same manner. • The average of the last estimate is the one chosen Advantages • No discussion or collaboration between the members. Members are not even aware of who the other members are.
Wide band Delphi technique	Procedure • Combines the Delphi and three-point methods. • Involves several experts (as in the Delphi technique). At each iteration, each gives his optimistic, pessimistic, and most likely estimates (as the three-point technique). ***Extreme estimates are excluded***. Averages are computed for each of the three estimates, and the averages are used as the optimistic, pessimistic, and most likely estimates of activity duration.

Solved example

Using Wide band Delphi technique, find the estimated time for the following readings collected from six experts.

	Optimistic time (days)	Most likely time (days)	Pessimistic time (days)
Expert 1	10	30	65
Expert 2	9	19	42
Expert 3	21	21	39
Expert 4	4	10	22
Expert 5	4	22	44
Expert 6	9	30	49
Averages	**8**	**23**	**43.5**

$$Time\ estimate = \frac{8 + 4 \times 23 + 43.5}{6} = 23.9s\ days$$

Do it yourself

Using Wide band Delphi technique, find the estimated time for the following readings collected from six experts. Do not exclude extreme values.

	Optimistic time (days)	Most likely time (days)	Pessimistic time (days)
Expert 1	10	20	65
Expert 2	8	19	42
Expert 3	21	21	39
Expert 4	7	10	22
Expert 5	4	22	44
Expert 6	9	30	49

Project time estimation techniques

Method	Description
Bottom-up	Estimating the time / cost of individual work items and rolling them up to the project total • An accurate method of estimating • An expensive method of estimating • Accuracy is driven by the size of the work items
Top-down	Use the actual time / cost of a similar project as the basis of estimating the current project. • Useful if there is a limited amount of information about the existing project • A form of expert judgment • Accurate within 25% • Useful when projects are similar in fact, not just appearance Advantages: Quick, inexpensive Risk: Projects may not be comparable, may have unique aspects (i.e., new environmental rules)
Parametric	Uses mathematical modeling to develop an estimate (weeks / stage) • Most useful if the model is scalable (EGP/m^2 for building a single house is not scalable to EGP/m^2 of a 50 story high rise office building) Advantage: – Usually faster, easier, less expensive than bottom-up. – Easy to computerize Risk: The historical model may not be appropriate for the estimate or may be out of date

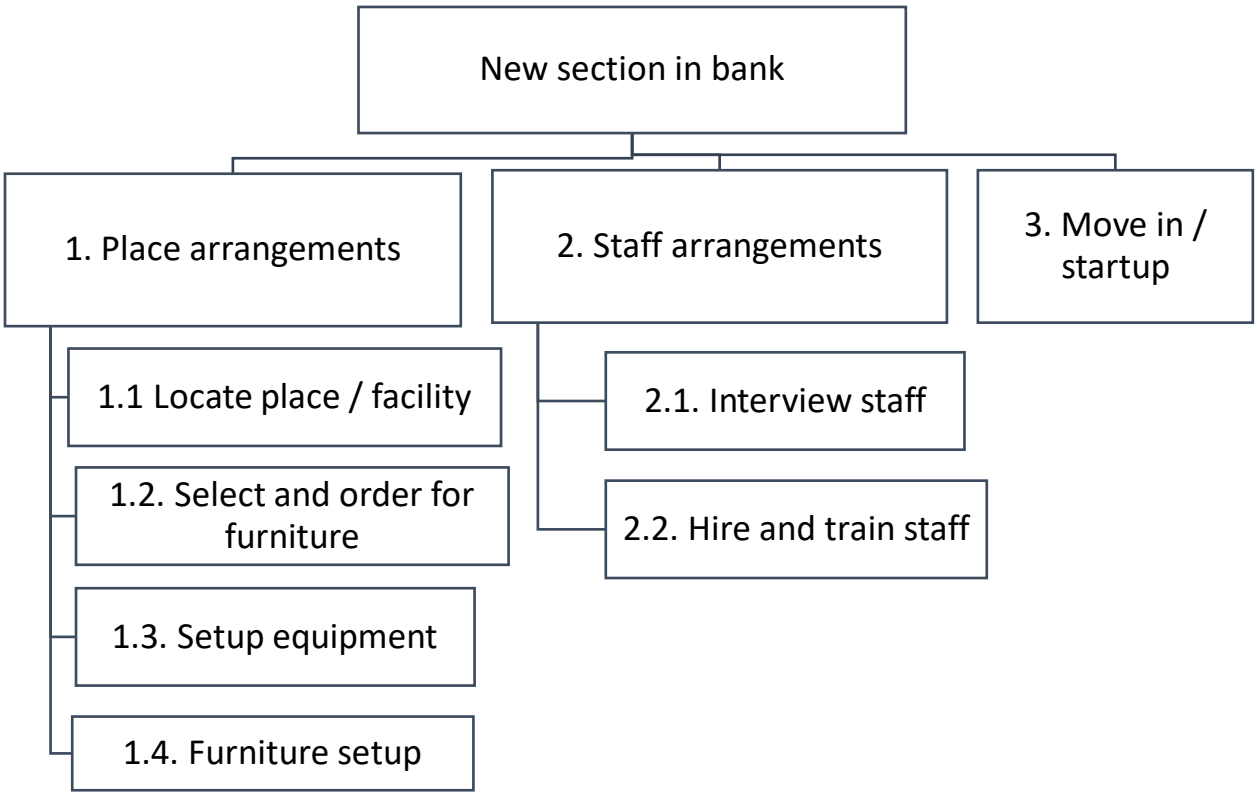
4. Network Construction

Definitions

Network diagram (Precedence diagram)	Diagram of activities that shows sequential relationships by arrows and nodes.
Activities	Steps that consume resources and/or time
Events	Starting & finishing of activities
Path	A sequence of activities that leads from the staring node to the ending node

Solved example 1

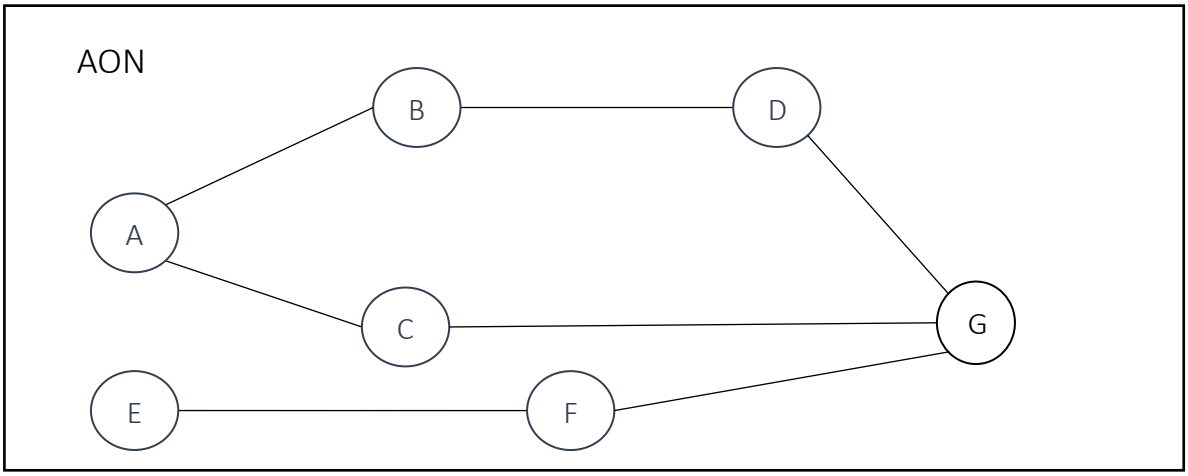
Project phases for a bank project

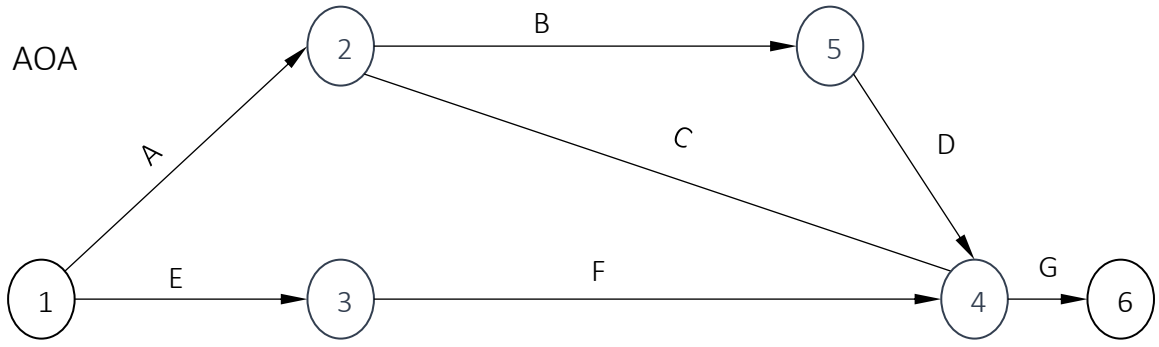


Description	Code
1.1. Locate place / facility	A
1.2. Select and order for furniture	B
1.3. Set up equipment	C
1.4. Furniture set up	D
2.1. Interview staff	E
2.2. Hire and train staff	F
3. Move in / startup	G

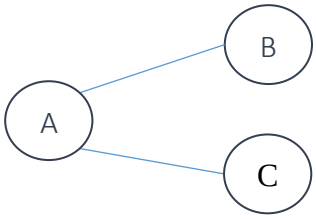
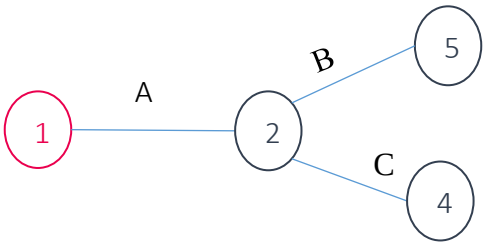
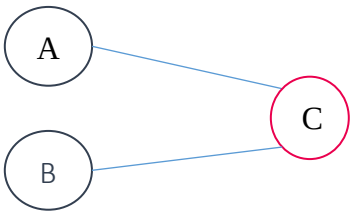
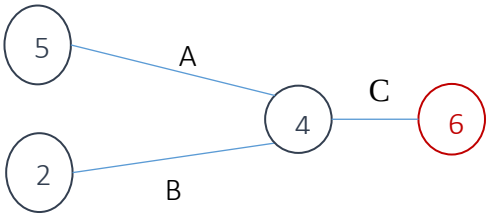
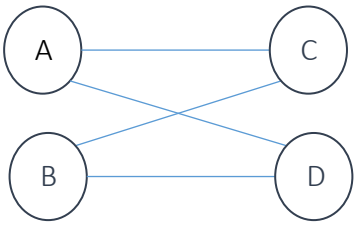
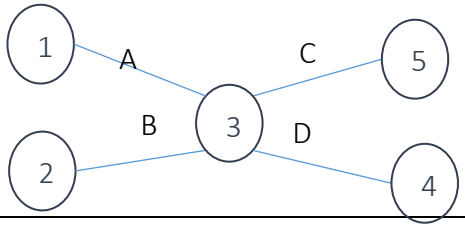
Activity	Predecessor
A	--
B	A
C	A
D	A, B
E	--
F	E
G	C,D,F

A network consists of nodes and arrows. Activities of the project can be represented either on the nodes or on the arrows. Activity-ON-Node is noted as AON. Activity-On-Arrow is noted as AOA





Relations in AON & AOA

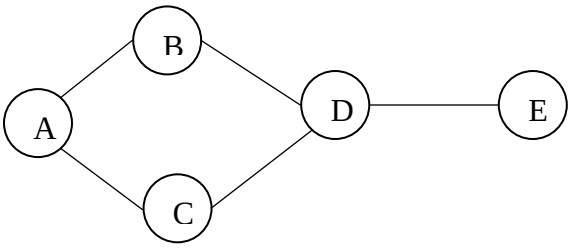
	Relation	AON	AOA
1	In sequence		
2	One activity precedes two activities (Diverge)		
3	Two activities precede one activity (converge)		
4	Two activities precede two activities (Converge/Diverge)		

Comparing AON and AOA

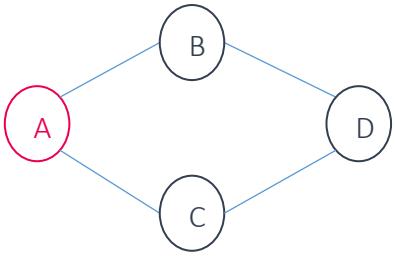
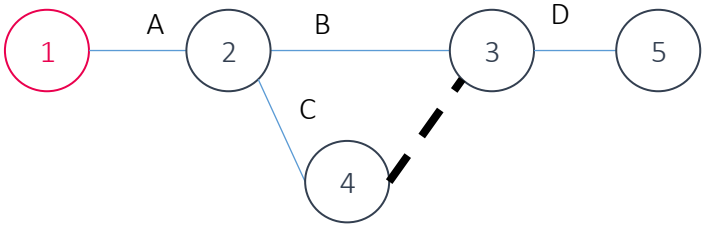
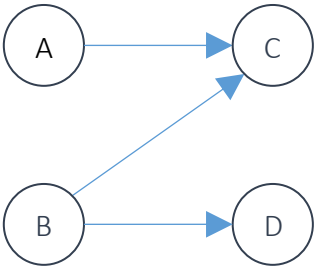
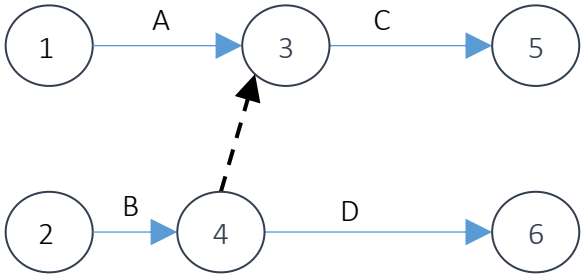
Point of comparison	AON	AOA
Uses	AON networks focus on tasks	AOA networks focus on events.
Advantages	• Easier to understand • Easier to create • For inexperienced users • Easier to modify changes • Its representation is unique.	• Easier tracking of activities on the network • Easier representation in case of multiple precedence relationships (Less interference)

Solved example 2

From the following AON network, construct the AOA network.



Dummy activities

Use	AON	AOA
1. Two activities have the same starting and ending point		
2. When activities share some, but not all, precedence activities		

Precedence relationships

	Name	Description
1		
2		
3		
4		

Do it yourself

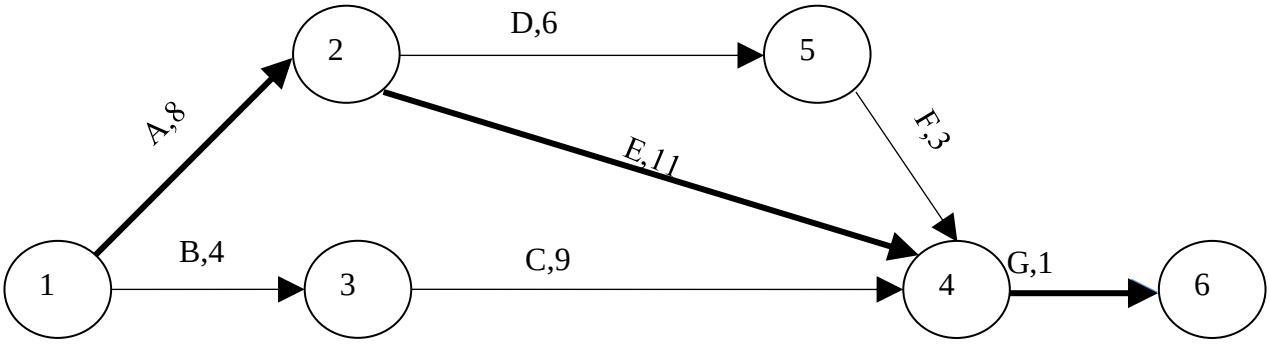
Construct the AOA, and the AON networks for the following activities.

Activity	A	B	C	D	E	F	G	H	I	J	K
Precedes / Successors	B	C, D	E	End	End	G, H	I	J	End	K	End

5. Critical Path Method (CPM)

Definitions

Critical Path	The longest path in the precedence diagram
Slack	Allowable delay for a path

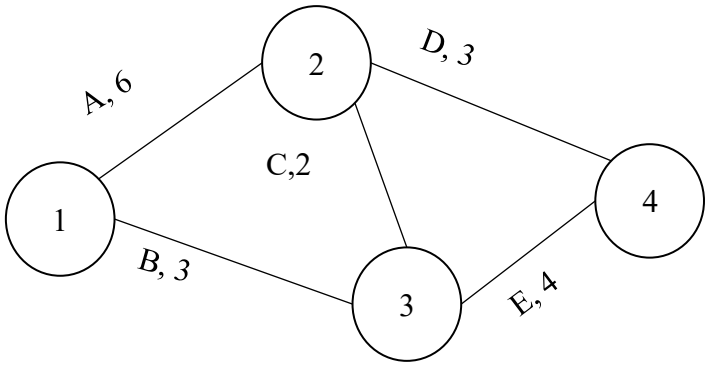


Path	Duration (time units)	Slack (time units)
A-D-F-G	18	2
A-E-G	20	0
B-C-G	14	6

Solved example

Construct a network for the activities of the following project for scheduling classes in classrooms. Find the critical path (CP) using the CPM.

Activity	Begin Event	End Event	Description	Time (days)
A	1	2	Encounter available classrooms	6
B	1	3	Encounter lectures & tutorials	3
C	2	3	Detect capacities of classes	2
D	2	4	Make interior work	3
E	3	4	Make schedule	4



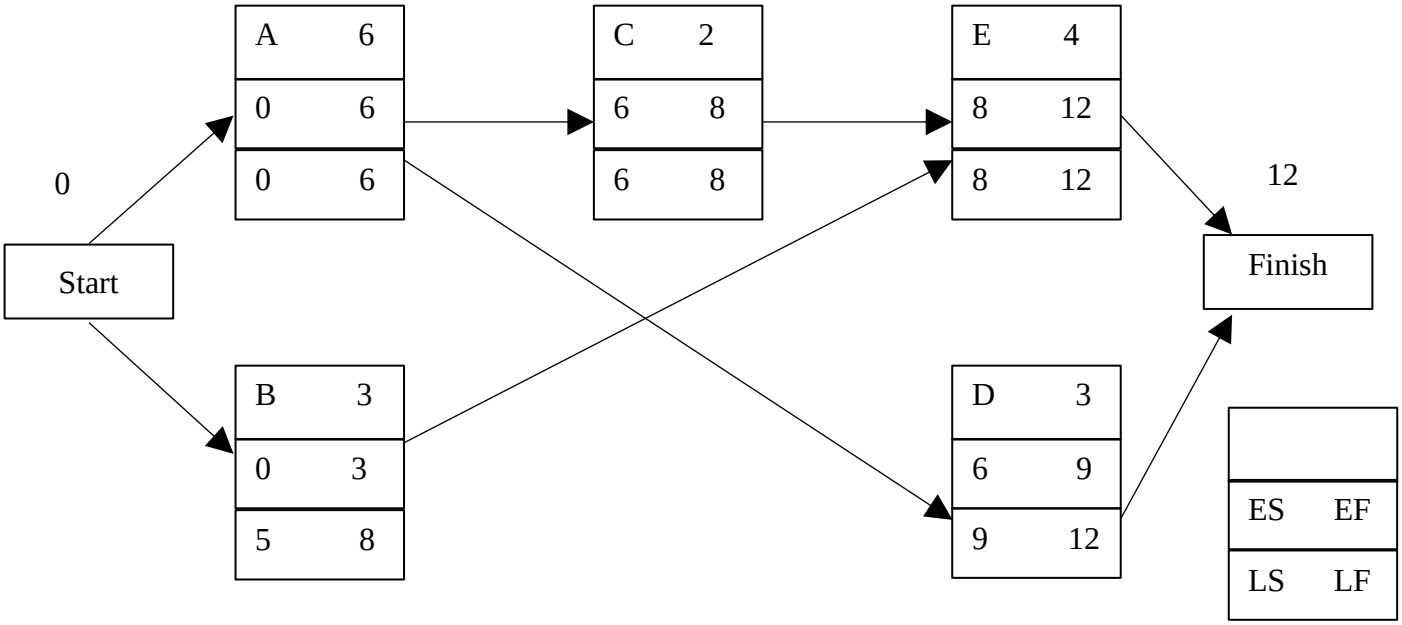
Calculations of Earliest Start (ES), Earliest Finish (EF), Latest Start (LS) & Latest Finish (LF) for activities

They are calculated using the following relations
For starting activities: ES = 0
For non-starting activities: ES = Max. EF (for all predecessors السابقين)
For ending activities: LF = Max. EF
For non-ending activities: LF = Min. LS (for all successors اللاحقين)

Activity	ES	EF	LS	LF	Slack
A	0	6	0	6	0
B	0	3	5	8	5
C	6	8	6	8	0
D	6	9	9	12	3
E	8	12	8	12	0

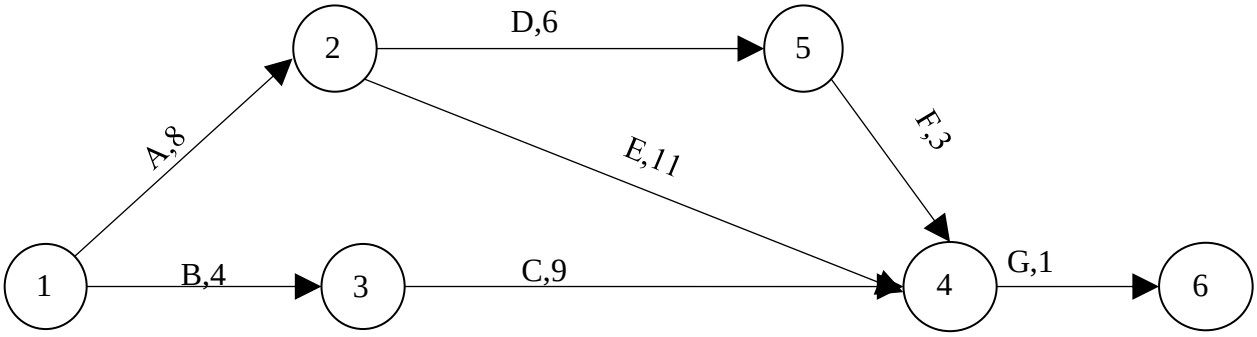
The Critical Path is: ACE

CPM on network



Do it yourself

Find the critical path and the project duration using the critical path method (CPM)



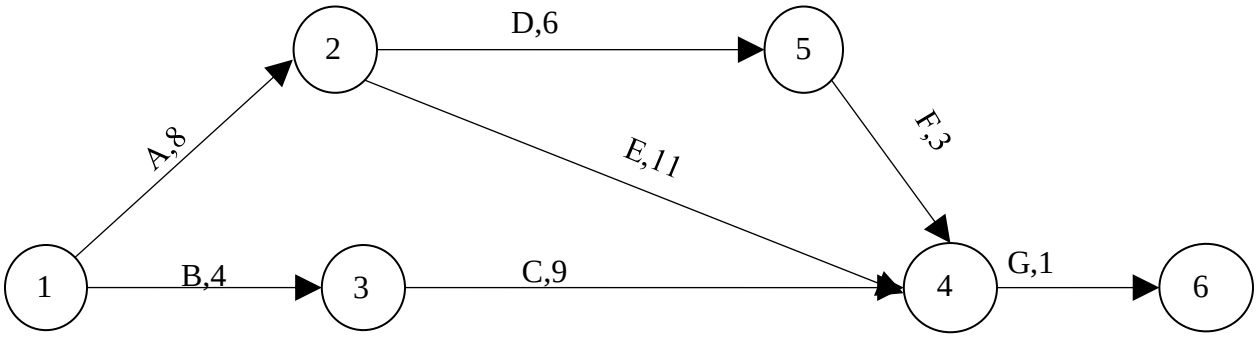
Total and free slacks:

The *total slack* is the allowable delay in an activity that does not affect the TOTAL project duration.
The *free slack* is the allowable delay in an activity that does not affect the EARLY start of the next activity.

$$Total\ slack_i = LS_i - ES_i$$
$$Free\ slack_i = \min(ES_{successors}) - EF_i$$

Solved example

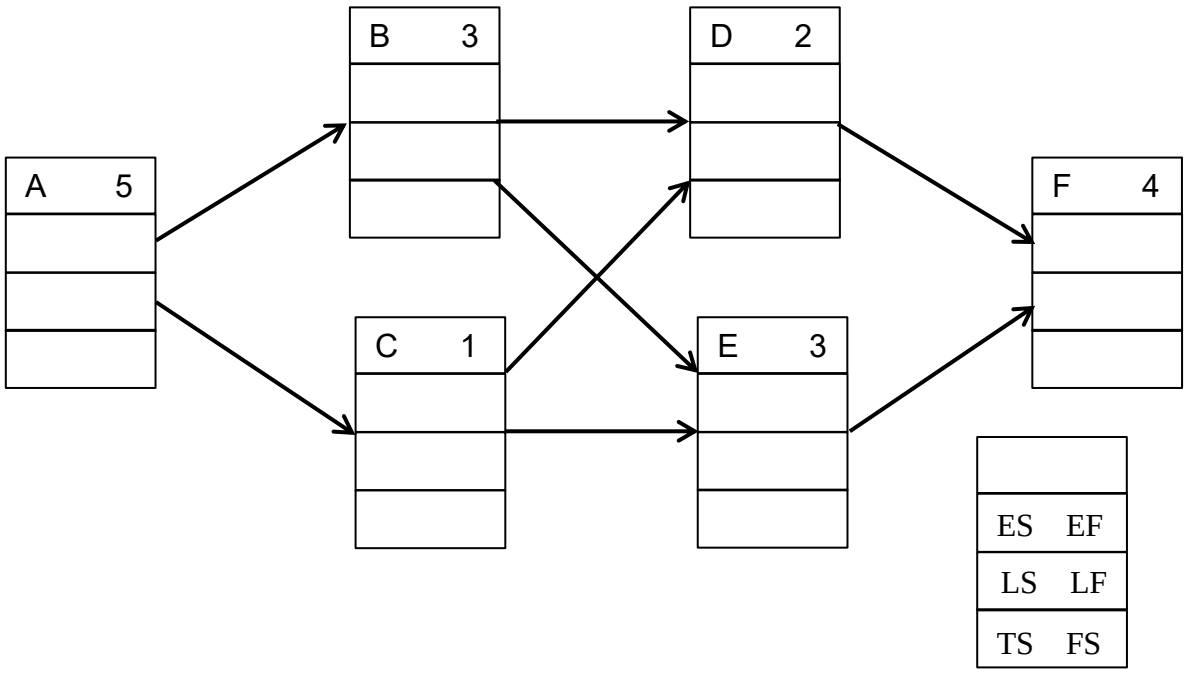
Find the total and free slack for all the activities in the project.



Activity	ES	EF	LS	LF	Total slack	Successor	Free Slack
A	0	8	0	8	0	No need	0
B	0	4	6	10	6	C	0
C	4	13	10	19	6	G	6
D	8	14	10	16	2	F	0
E	8	19	8	19	0	No need	0
F	14	17	16	19	2	G	2
G	19	20	19	20	0	--	0

Do it yourself

Find the total and free slacks of the following project using the CPM.



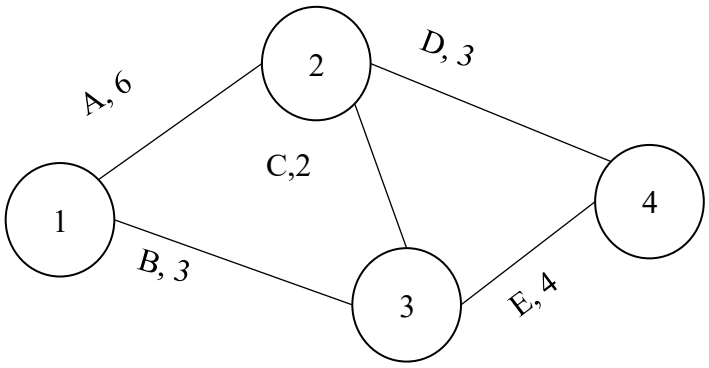
6. Gantt Chart

Definition:

A **Gantt chart** is a graphical depiction of a project schedule. It is a type of bar chart that shows the start and finish dates of several elements of a project that include resources, milestones, tasks and dependencies. Henry **Gantt**, an American mechanical engineer, designed the **Gantt chart.**

Solved example 1:

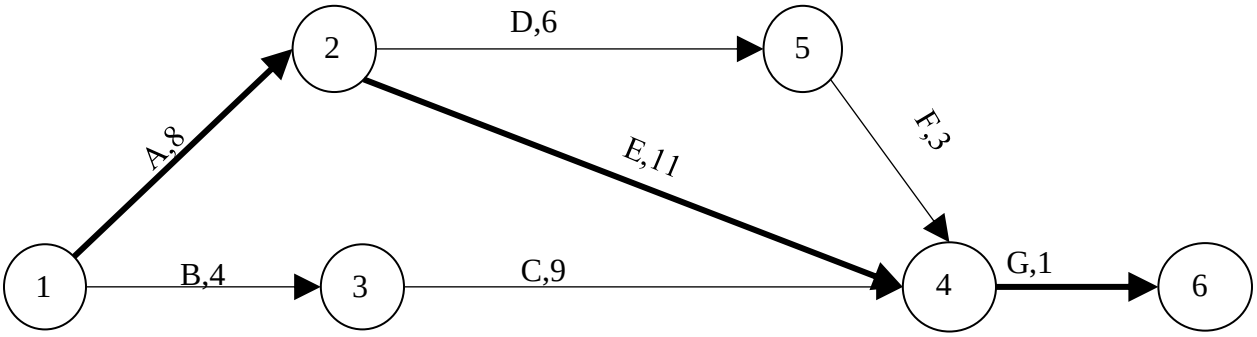
Classes schedule



	Class Schedule project											
Activity	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												

Do it yourself

For the project of making a new bank activity, represent the activities on a Gantt chart showing the slacks, and the relations between the activities.



	New bank activity project (weeks)																				

7. Program Evaluation and Review Technique (PERT)

Types of activity times

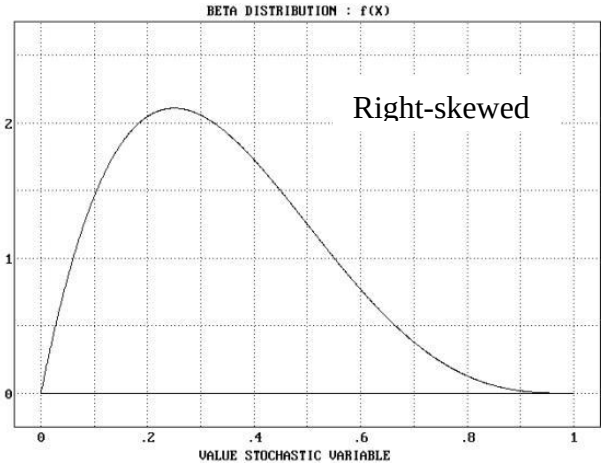
Activity times are either:

Deterministic: Time estimates that are fairly certain

Probabilistic: Time estimates that allow for variation

Probabilistic time estimates involve three time estimates for each activity instead of one.

1- *Optimistic time (O):* the time required under optimum conditions.
2- *Pessimistic time (P)*: the time required under the worst conditions.
3- *Most likely time (M)*: the most probable time required.



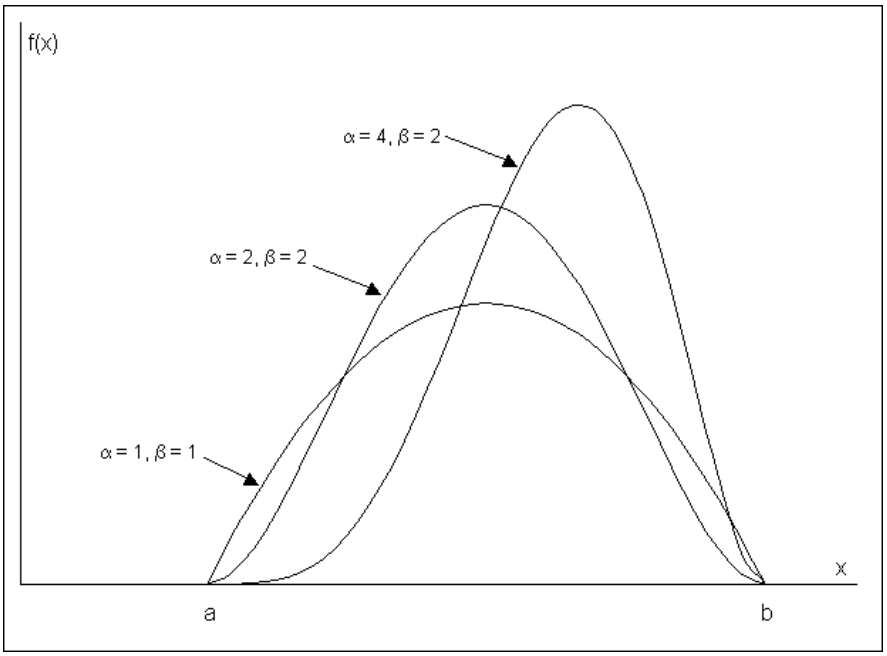
$Te =$ Expected time of an activity

$$Te = \frac{a + 4m + b}{6}$$

$$v = \left(\frac{b - a}{6}\right)^2$$

Optimistic (a)	Most likely (m)	Pessimistic (b)	Expected time (Te)	Variance ($v = \sigma^2$)
5	6	7	6	1/9
3	6	9	6	1
1	6	11	6	25/9
1	6	7	5.33	1
5	6	16	7.5	3.36

The Beta distribution

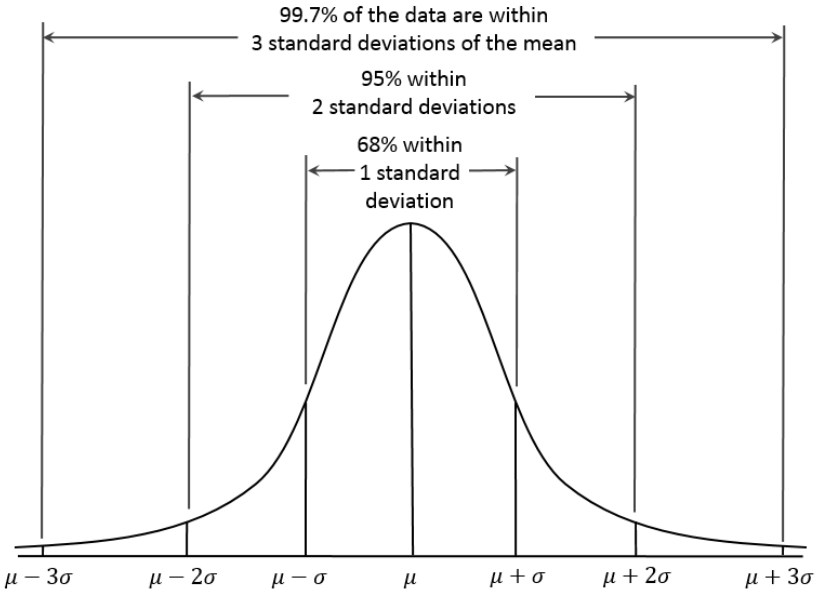


There is no real theoretical justification for using the beta distribution.
The size of the variance reflects the degree of uncertainty. The larger the variance, the greater the uncertainty.

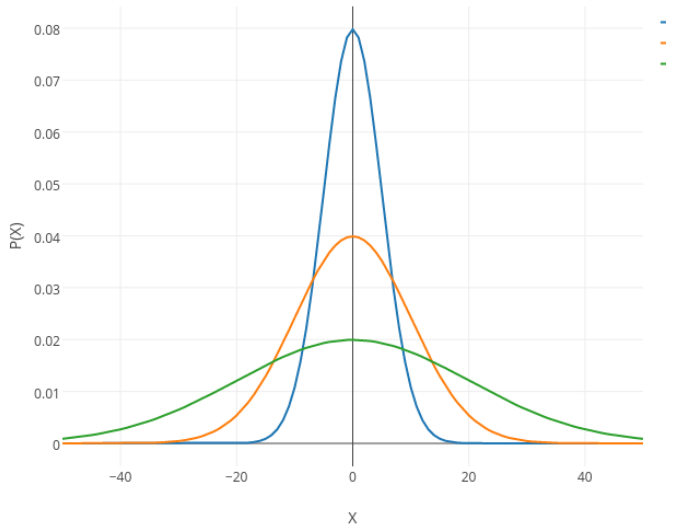
It is used to describe probabilistic time estimates because:

1- It can be symmetrical, or skewed to either the right or the left according to the nature of the activity.
2- The mean and variance can be obtained from the three estimates.
3- The distribution is unimodal with a high concentration off probability surrounding the most likely time estimate.

Normal distribution



Normal distribution curve



Different normal distribution curves

Project time and variance of time

Expected Project time $= \sum_1^I Te_i$ (for activities on the critical path)

Variance of project time $= \sum_1^I v_i$ for activities on the critical path)

Solved example 1

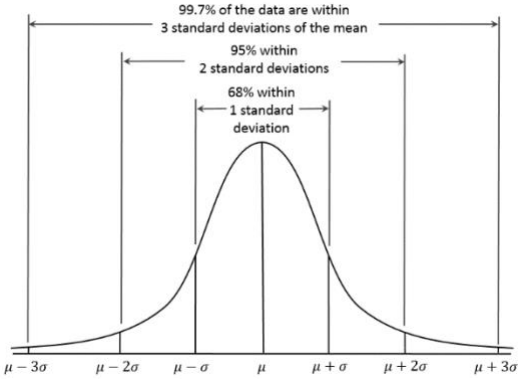
You're a project planner for General Dynamics. A submarine project has an expected completion time of 40 weeks, with a standard deviation of 5 weeks.
What is the probability of finishing the submarine in 50 weeks or less?
Assume that project completion time follows a normal distribution.

μ = 40 weeks , σ = 5 weeks

$$Z = \frac{50 - 40}{5} = +2$$

From tables:

Probability (Z = +2) = 97.72%

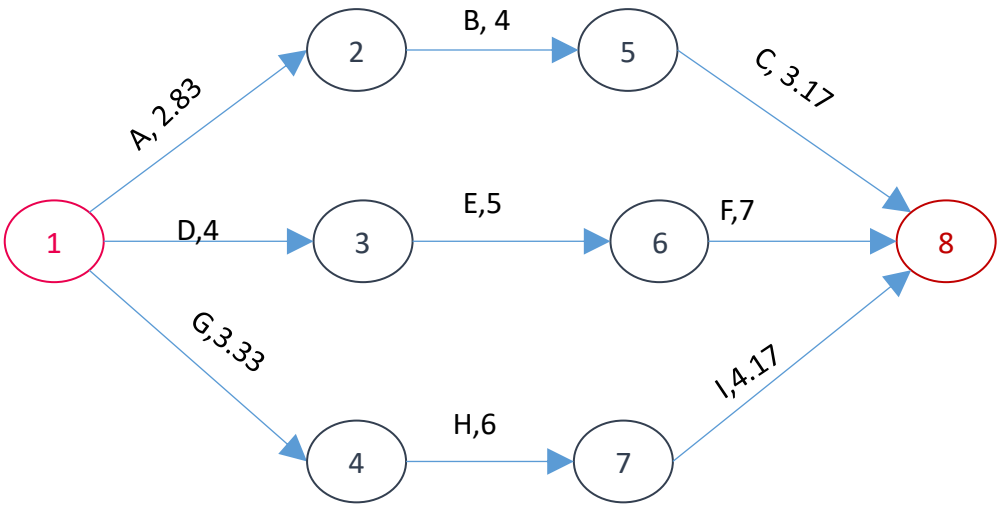


The probability of completing the project in 50 weeks or less is 97.72%

Solved example 2

For the following project, what is the expected duration of the project? What is its standard deviation?

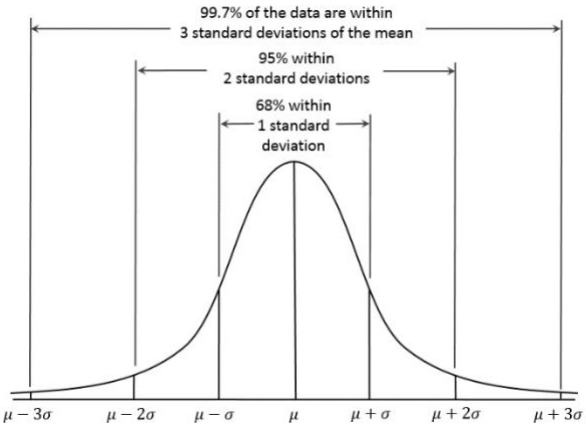
Activity	Precedence	Optimistic time (a)	Most likely time (m)	Pessimistic time (b)	Te	$v = \sigma^2$
A	--	1	3	4	2.83	9/36
B	A	2	4	6	4	16/36
C	B	2	3	5	3.17	9/36
D	--	3	4	5	4	4/36
E	D	3	5	7	5	16/36
F	E	5	7	9	7	16/36
G	--	2	3	6	3.33	16/36
H	G	4	6	8	6	16/36
I	H	3	4	6	4.17	9/36



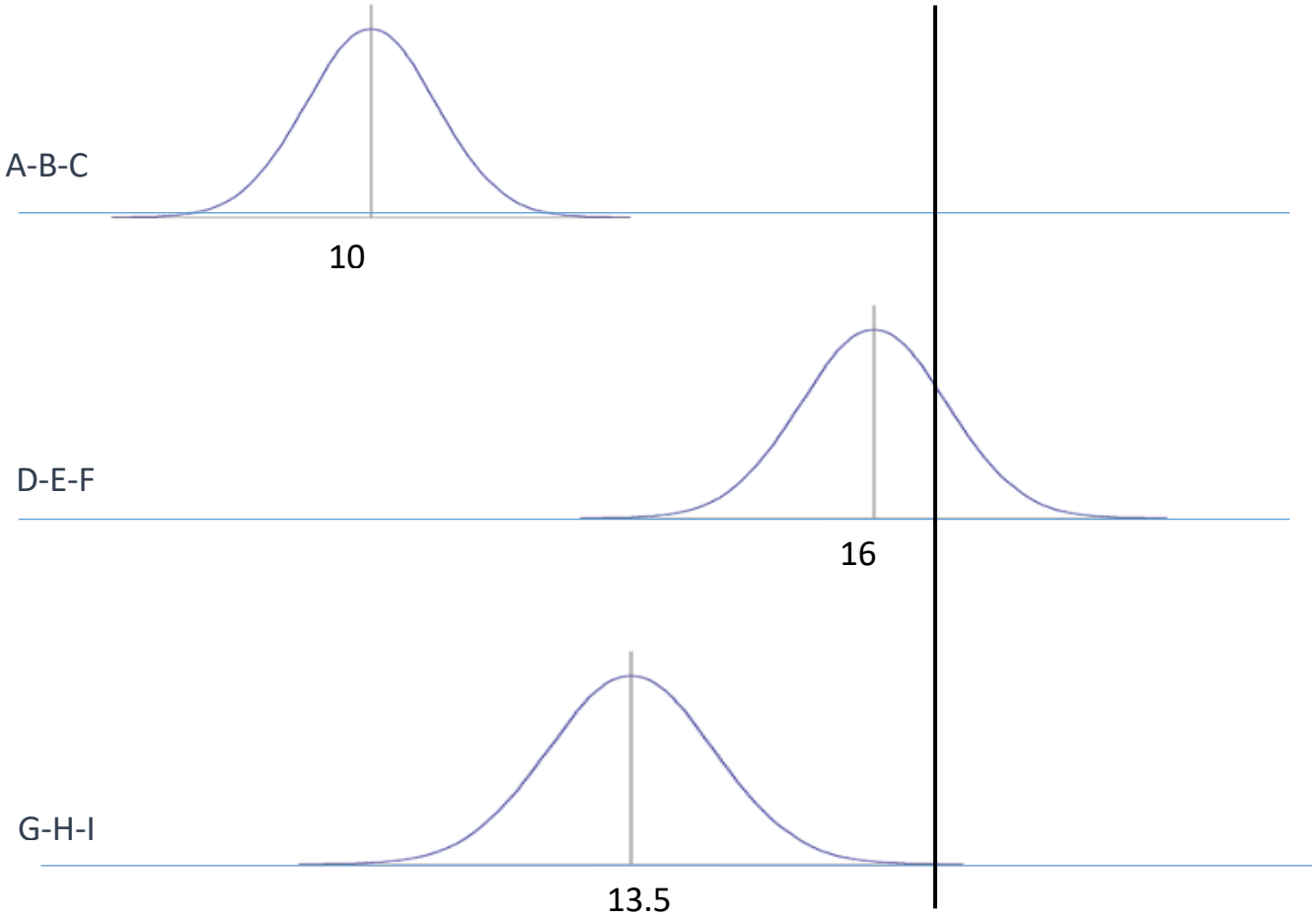
Path	Te	v	σ
A-B-C	10	0.941	0.97
D-E-F	16	1	1.00
G-H-I	13.5	1.145	1.07

Critical path is: D-E-F
Project duration = 16 weeks
The variance of the project time = 1 week
The standard deviation of the critical path = 1 week

- What is the probability of finishing the project in less than 17weeks?
- What is the probability of finishing the project in less than 15 weeks?
- What is the probability of finishing the project in more than 19 weeks?

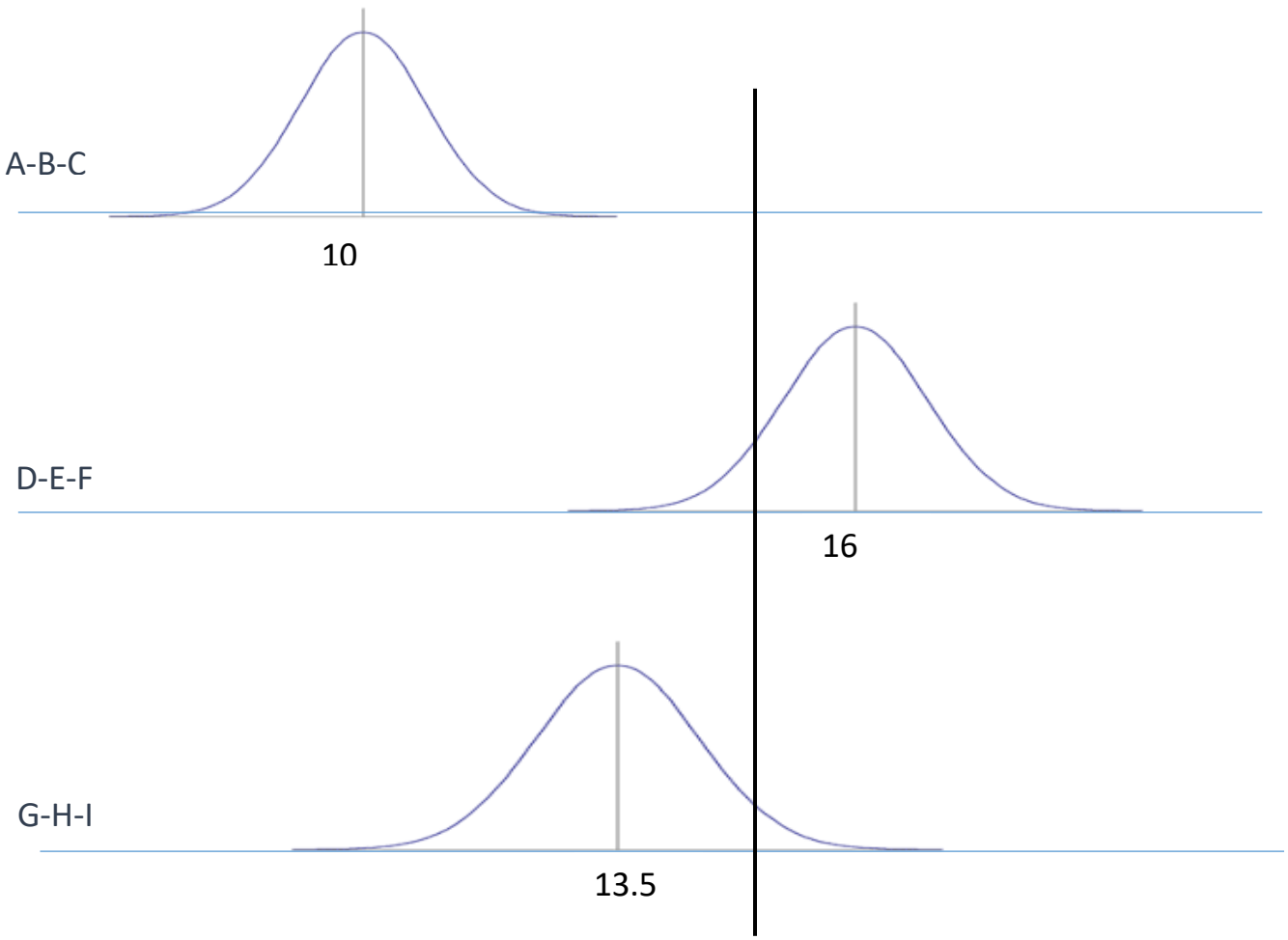


- The probability of finishing the project in less than 17weeks = 84.058%



Path	Te	σ	μ-3σ	μ+3σ	z (x = 17)	Prob. (%)
A-B-C	10	0.97	7.09	12.91	+7.20	1.00
D-E-F	16	1.00	13	19	+1.00	0.841
G-H-I	13.5	1.07	10.29	16.71	+3.27	1.00
Probability of finishing in less than 17 weeks =						84.1%

- The probability of finishing the project in less than 15weeks = 14.62%



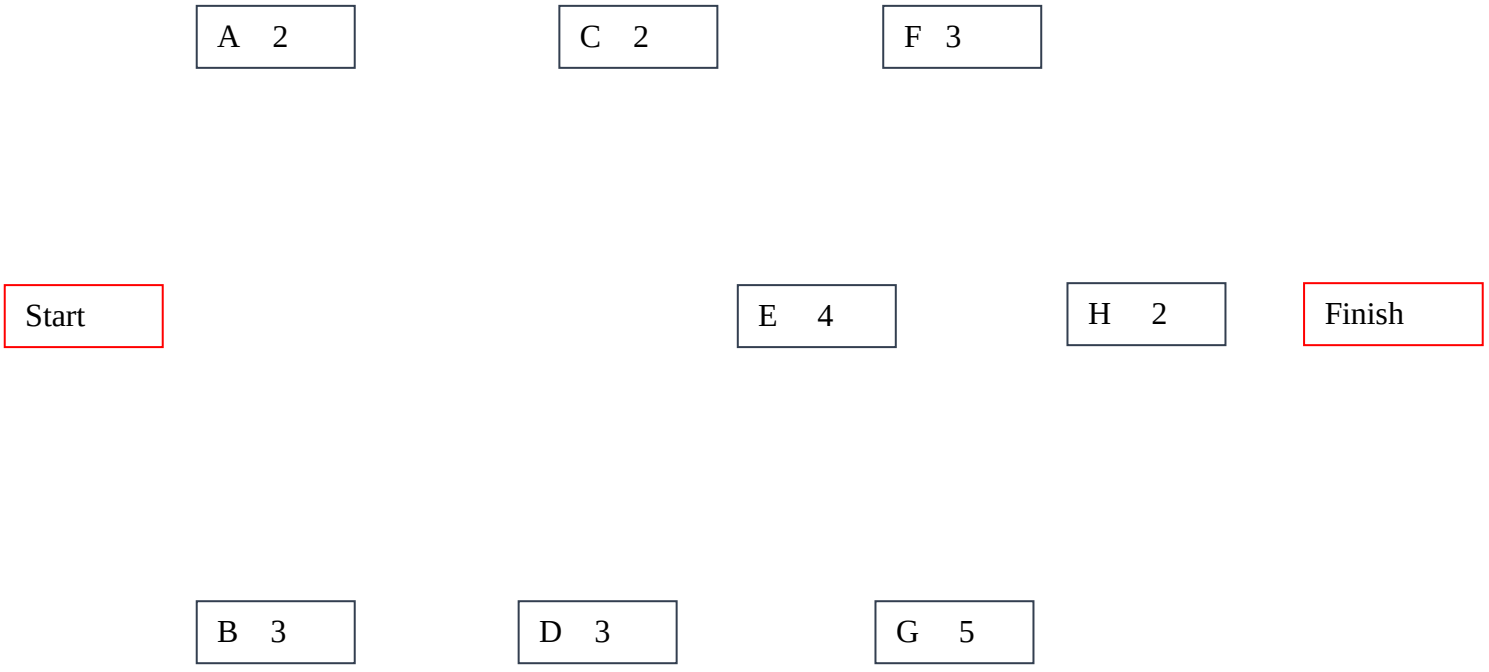
Path	Te	σ	μ-3σ	μ+3σ	z (x = 15)	Prob. (%)
A-B-C	10	0.97	7.09	12.91	+5.20	1.00
D-E-F	16	1.00	13	19	-1.00	0.159
G-H-I	13.5	1.07	10.29	16.71	+1.40	0.9192
Probability of finishing in less than 15 weeks =						14.62 %

Do it yourself

For the following project, find the estimated finishing time, and its standard deviation.

Activity	Description	Pred.	Time			T_E	v
			a	b	m		
A	Build internal components	--	1	3	2		
B	Modify roof and floor	--	2	4	3		
C	Construct collection stack	A	1	3	2		
D	Pour concrete and install frame	B	2	6	4		
E	Build high-temperature burner	C	1	7	4		
F	Install control system	C	1	9	2		
G	Install air pollution device	D, E	3	11	4		
H	Inspect and test	F, G	1	3	2		

Represent the project activities on Gantt chart.



Gantt Chart:

Act.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A															
B															
C															
D															
E															
F															
G															
H															

Path probabilities

Independence assumption

In order to calculate the paths probabilities using normal distribution, paths times should be independent

If an activity occurred on multiple paths, and it far exceeded its completion time, then all paths including this activity will be affected.

Independency is satisfied by:

- Each activity is on one path only
- No activity time depends on another activity time.

Very minor exceptions are accepted; three activities are on multiple paths for a project of 120 activities.

Simulation

For dependent paths

Simulation is used to calculate the paths probabilities for dependent paths.

- This is the practical approach used by project planners.
- Its calculations depend on repeated sampling.
- Each time a scenario is made assuming a time value for each activity.
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- Its calculations depend on repeated sampling.
- Each time a scenario is made assuming a time value for each activity.

Procedure:

1. Create scenarios

For each scenario, assume a duration for each activity, and its probability. Find the critical path for this scenario, its duration and its probability.

2. Calculate project duration by simulation

For each scenario, multiply the project duration by its probability. The summation for all scenarios is the project duration.

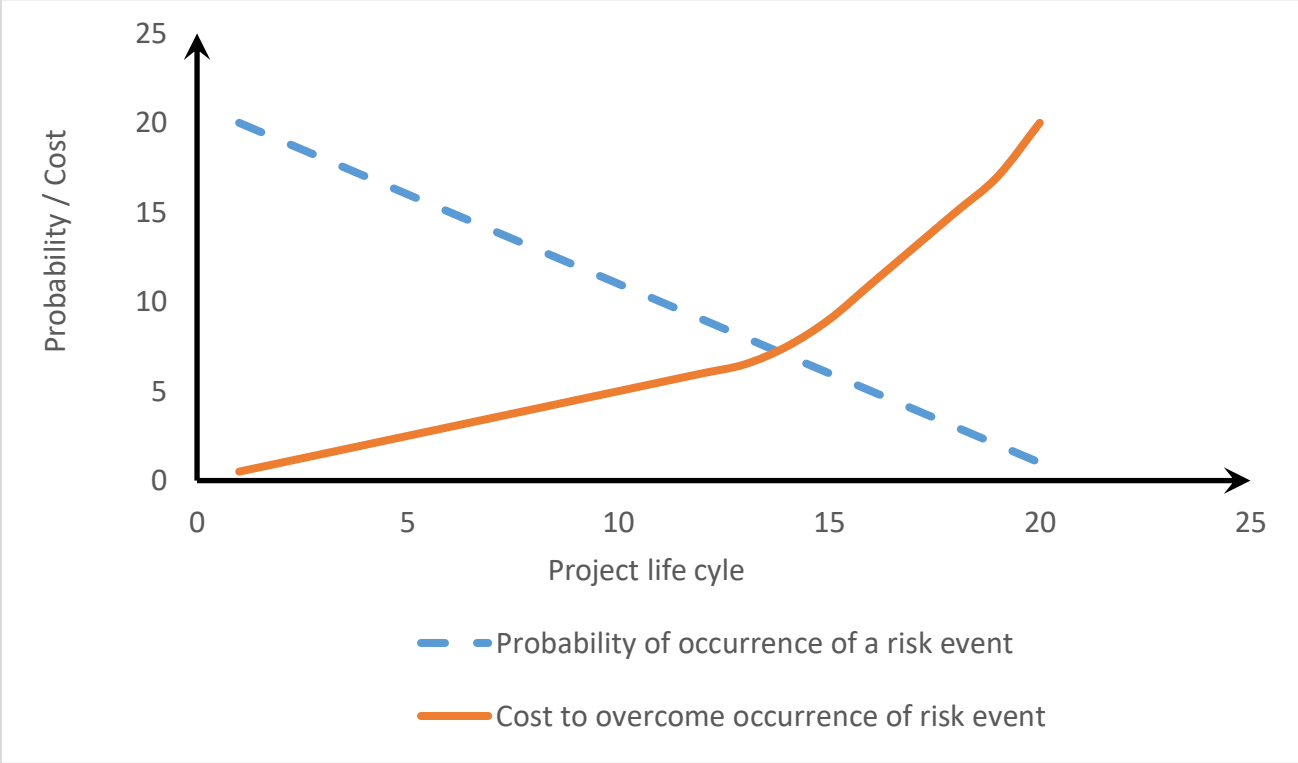
Scenario No.	Time	Probability	Product
1	T_1	P_1	T_1P_1
2	T_2	P_2	T_2P_2
3	T_3	P_3	T_3P_3
4	T_4	P_4	T_4P_4
S	T_S	P_S	T_sP_s
Project duration = $\sum_{i=1}^{S} T_i \times P_i$			

Risk management

Examples of risks:

- Delays
- Increased cost
- Inability to meet technical specs.
- Inability to complete the project

Careful planning reduces risks, but does not eliminate risks



8. Crashing

Definitions

- Crashing is shortening the activity duration by adding resources.
- It is also known as "Cost-Time trade-offs"
- We may need to shorten time for different reasons:
  - To finish earlier than the regular time (example: incentives for early completion).
  - To overcome delays and get back to schedule due to uncontrollable situations (example: weather)
  - To reduce the indirect costs (facility / equipment cost, supervision cost)
- It is required to detect activities that will reduce the sum of direct and indirect costs
- The most potential activities to be crashed are the activities on the critical path

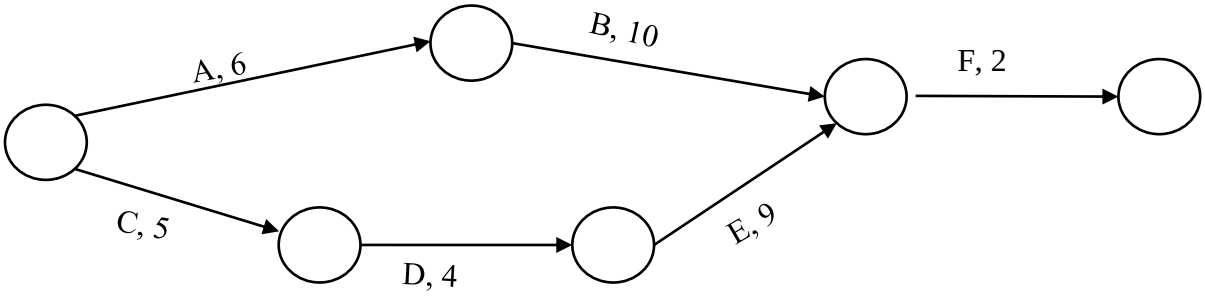
Information needed for crashing

- Precedence of activities
- Regular and crash time of each activity
- Regular and crash cost of each activity

Steps of crashing

- Start crashing of activities with lowest crash cost
- Continue crashing as long as the cost to crash is less than the benefits derived from crashing.
- Update the critical path at every step

Solved example 1



Activity	Time (days)		Cost ($100)		Cost to crash per day ($ / day)
	Normal	Crash	Normal	Crash	
A	6	6	80	80	--
B	10	8	80	90	500
C	5	4	40	43	300
D	4	1	10	31	700
E	9	7	50	62	600
F	2	1	80	88	800

Ascendingly:

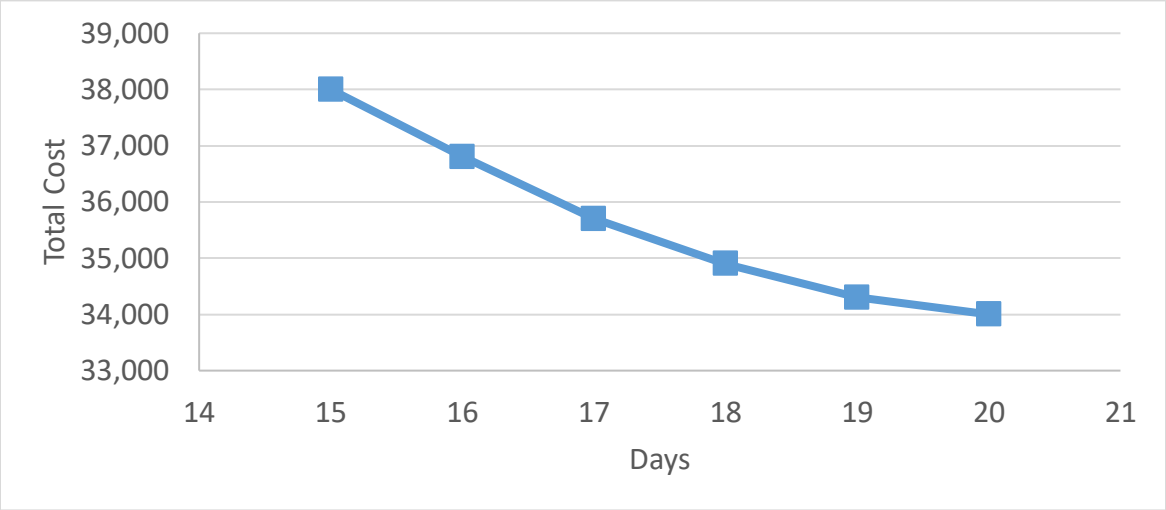
Activity	Cost to crash per day ($)	Available days
C	300	1
B	500	2
D	600	2
E	700	3
F	800	1

Crashing Plan:

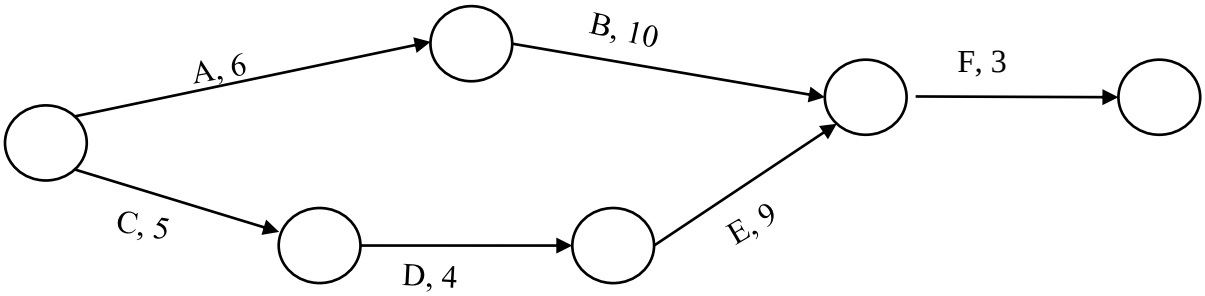
Path	Normal (days)	Crash 1	Crash 2	Crash 3	Crash 4	Crash5
A-B-F	18	18	18	17	16	15
C-D-E-F	20	19	18	17	16	15
Activity crashed	--	C	E	F	E, B	B, D
Days	--	1	1	1	1	1
Cost $	--	300	600	800	1100	1200
Total days	--	1	2	3	4	5
Total cost $	--	300	900	1700	2800	4000
Indirect cost $	--	1000	1000	1000	1000	1000
Savings $	--	700	400	200	xx	xx
Total indirect cost $	--	1000	2000	3000	4000	5000
Total saving $	--	700	1100	1300	1200	1000

- For the objective of least cost for crashing 3 days, crashing cost = $1,700
- For the objective of Crash for max. $1,000 is till crash 2
- For the objective of saving indirect costs:
- For the objective of saving in total costs;
- What is the most economic crashing plan in order to crash the project by 4 days?

  Crash activity C for 1 day, E for 2 days, F for 1 day, B for 1 day. (C:1 , E:2, F:1, B:1)



Solved example 2.



Activity	Time (days)		Cost ($100)		Cost to crash per day ($ / day)
	Normal	Crash	Normal	Crash	
A	6	6	80	80	--
B	10	8	80	90	500
C	5	3	40	46	300
D	4	1	10	31	700
E	9	7	50	62	600
F	3	1	80	96	800

Ascendingly:

Activity	Cost to crash per day ($)	Available days
C	300	2
B	500	2
E	600	2
D	700	3
F	800	2

Crashing Plan:

Path	Normal (days)	Crash 1	Crash 2	Crash 3
A-B-F	19	19	17	15
C-D-E-F	21	19	17	15
Activity crashed	--	C	F	E, B
Days	--	2	2	2
Cost $	--	600	1600	2200
Total days	--	2	4	6
Total cost $	--	600	2200	4400
Indirect cost $	--	2000	2000	2000
Savings $	--	1400	400	xx
Total indirect cost $		2000	4000	6000
Total saving $		1400	1800	1600

- For the objective of least cost for crashing 4 days, crashing cost = $2,200
- For the objective of least cost for crashing 3 days, crashing cost = $1,400
- For the objective of Crash for max. $1,000 is till crash 1; for 2 days
- For the objective of saving indirect costs of $2000/day:
- For the objective of saving in total costs;
- What is the most economic crashing plan in order to crash the project by 4 days?

Crash activity C for 1 day, E for 2 days, F for 1 day, B for 1 day. (C:1 , E:2, F:1, B:1)

Do it yourself

Activity	Precedes	Time (Weeks)		Cost ($100)		
		Normal	Crash	Normal	Crash	
K	L,N	9	8	10	14.10	
L	M	7	6	10	11.25	
N	J	5	4	10	10.45	
M	Q	4	2	10	13.50	
J	Q	6	5	10	10.50	
Q	P,Y	5	3	10	12.25	
P	Z	8	8	10	10.00	
Y	END	7	5	10	10.90	
Z	END	6	5	10	10.90	

What is the shortest possible duration of the project after crashing all possible activities? What is the associated crashing cost?

Path	**Normal**	**Crash1**	**Crash2**	**Crash3**	**Crash4**	**Crash5**

[33 weeks, $1,120]

9. Tools for Managing Project Activities

There are some tools that can help planning project activities, monitoring them, and ensuring a certain quality level. Some of them will be studied in the following:

1- Network diagrams
2- Process decision program charts (PDPC)
3- Affinity diagrams
4- Interrelationship diagrams
5- Prioritization matrices
6- Matrix diagrams

Network diagrams

This is a visual representation of a project's schedule. It helps plan the project from start to finish. It illustrates the scope of the project and the critical path of the project. There are two types of network diagrams; AON, and AOA.

Process decision program charts (PDPC)

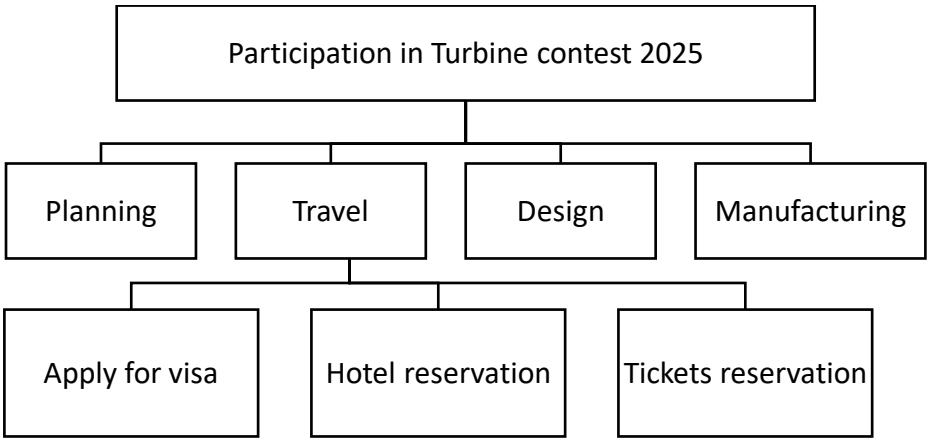
A Process decision program chart systematically identifies what might go wrong in a plan under development. Countermeasures are developed to prevent those problems. By using PDPC, you can either revise the plan to avoid the problems or be ready with the best response when a problem occurs.
The PDPC is implemented during the planning phase.

Procedure of PDPC

1. Develop a tree diagram of the proposed plan.
2. For the third level, brainstorm what could go wrong.
3. Eliminate insignificant problems. Show the rest as a fourth level linked to the tasks.
4. For each potential problem, brainstorm possible countermeasures on the fourth level.
5. Decide how practical each countermeasure is. Use criteria such as cost, time, ease of implementation, and effectiveness.

Example on PDPC

What are the potential problems for "tickets reservation"? How can you overcome them?



Affinity diagrams

Affinity diagrams generate and organize information about a performance indicator without quantifying them in brainstorming sessions. It is concerned with the quality of the tasks carried.

Procedure of affinity diagram

- Generate ideas
- Display ideas
- Sort ideas
- Create headers
- Draw final diagram

Example on affinity diagram

It is required to monitor the quality of the accommodation and transportation of a European team in Egypt. What are the performance indicators?
All performance indicators for accommodation are:

- موقع الفندق قريب من مكان العمل
- اقتراح أماكن ترفيه
- حجرات فندقية مجهزة
- الالتزام بجدول الأعمال ومواعيده
- حجرات فندقية نظيفة
- اقتراح مكان تبديل عملة
- حجرات فندقية مكيفة
- وجبات الغذاء تناسب ذوقهم
- افطار الفندق مناسب لذوقهم

Categorized and sorted performance indicators:

الفندق	خارج الفندق	المقترحات
موقع الفندق قريب من مكان العمل حجرات فندقية مجهزة حجرات فندقية نظيفة حجرات فندقية مكيفة افطار الفندق مناسب لذوقهم	الالتزام بجدول الأعمال ومواعيده وجبات الغذاء تناسب ذوقهم	اقتراح أماكن ترفيه اقتراح مكان تبديل عملة

All performance indicators for transportation are:

- مواعيد السائق منضبطة
- سيارة مريحة
- سائق حسن المظهر
- السير في الطرق السريعة
- السائق مريح
- سيارة مكيفة

Categorized and sorted performance indicators:

السائق	السيارة	الطريق
مواعيد السائق منضبطة سائق حسن المظهر السائق مريح	سيارة مريحة سيارة مكيفة	السير في الطرق السريعة

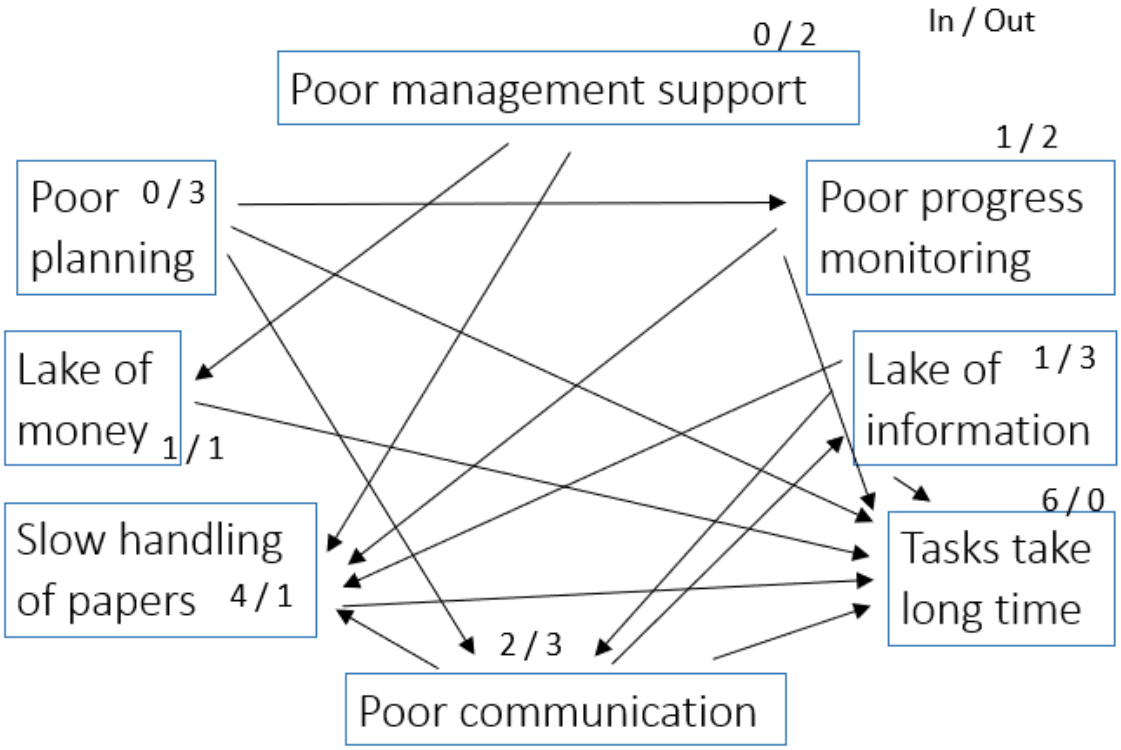
Interrelationship diagrams

Interrelationship diagrams show cause-and-effect relationships. It identifies root causes, but it is mainly used to identify logical relationships in a complex and confusing problem situation. It highlights the area of greatest impact for improvement.
Its main purpose is to help identify relationships that are not easily recognizable.

Example on Interrelationship diagrams

A project of "having a new location for inventory beside the old one" is planned to be finished in one year. After three months of starting, the project manager realized that they have always been on a late schedule. He thought it was a financial problem and paid more money to hurry the activities, but still late. He wanted to realize the real causes of being late.

Brainstorm a mixture of action steps, problems, desired results, and less-desirable effects to be handled.



From the diagram, the most effective causes are the ones with the highest "out". Therefore, the real causes behind the late schedule are:

- Poor planning
- Poor communication
- Lake of information

Prioritization matrices

Prioritization matrices evaluate different problems and choose what to solve first to meet certain objectives.

Types of Prioritization matrices

1. Eisenhower matrix (2 x 2)
2. Six Sigma prioritization matrix

Example on Eisenhower matrix (2x2):

	Urgent	Not urgent
Crucial	Do right now	Do soon
Not crucial	Delegate (تفويض)	Delete

Example on six sigma prioritization matrix

(*PI = Performance Indicator)

Tasks / Problems	Rank of PI 1	Rank of PI 2	Score	Rank
Task 1				
Task 2				
Task 3				
…				
Task N				

Construct a six sigma prioritization matrix for the assignments of five courses given the rank if the grade and the rank of the submission time for each assignment.

Tasks / Problems	Grade	Time	Score	Rank
Assignment 1	1	4	5	2
Assignment 2	3	2	5	2
Assignment 3	2	1	3	1
Assignment 4	5	5	10	5
Assignment 5	4	3	7	4

The table above shows that “Assignment 1” has the highest priority for the grade, and “Assignment 4” has the least priority for the grade. The table also shows that “Assignment 3”

has the highest priority in the time of submission, while “Assignment 4” has the least priority for the time.
From the results of the score, “Assignment 3” has the highest priority as it has the least score, while “Assignment 4” has the least score, and hence has the least priority.

Matrix diagram

The matrix diagram shows the relationships between objectives, factors, and causes. It analyzes data within an organization's structure.

Types of matrix diagrams:

L-shaped : relationship between two groups of items.

T-shaped : relationship between three groups of items.

Y-shaped : relationship between three groups of items.

X-shaped : relationship between four groups of items.

Roof-shaped : relation between one group of items to themselves.

L-shaped matrix diagram

It shows a relationship between two groups of items.

Example: Lighting types that will be used to decorate Eltahrir square.

	Laser spot	Led spot	Led line (m)
Square	2	50	600
The Complex	1	100	2000
Museum	3	200	3000
Streets	0	0	2000
Buildings	0	100	2000
Total	6	450	9600

T-shaped matrix diagram

It shows a relationship between three groups of items, without showing the relation between two groups of them.

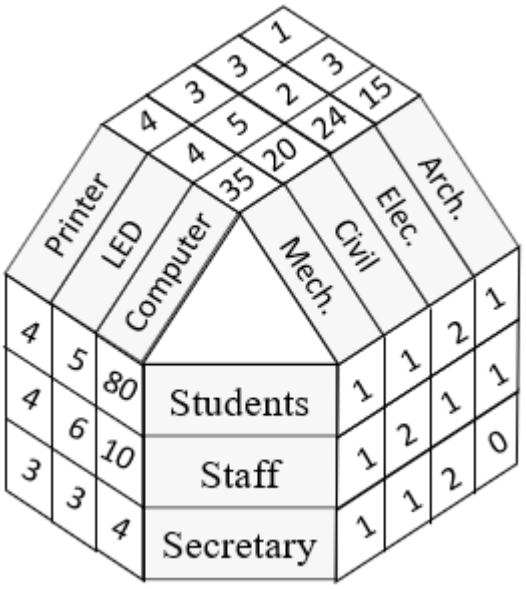
To represent the data for making labs in four departments in the faculty.

Printers	4	4	3
LED's	5	6	3
Computers	80	10	4
	Student	Staff	Secretary
Mechanical	1	1	1
Electrical	1	2	1
Civil	2	1	2
Architecture	1	1	0

The lower part of the T-shaped matrix shows the number of labs in each department. The higher part of the matrix shows the number of devices for each type of lab.
The matrix does not show the relation between the number of devices and the departments. This deficiency is avoided in the Y-shaped matrix.

Y-shaped matrix diagram

It shows a relationship between three groups of items, while showing the relation between each group and the other two.
To represent the data for making labs in four departments in the faculty.



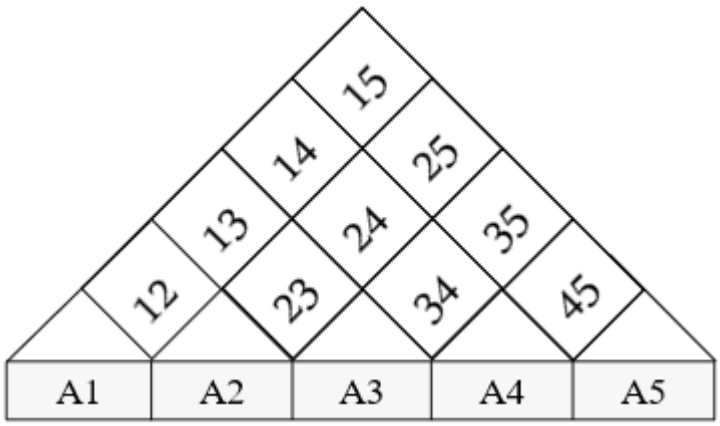
X-shaped matrix diagram

It shows a relationship between four groups of items.
It can be used to relate (product & transportation method) to (plant & market)

6	7	6	Plant C	5	4	10
20	15	6	Plant B	5	6	30
50	10	50	Plant A	60	10	40
Trans C	Trans B	Trans A		Product A	Product B	Product C
20	30	38	Market A	30	8	50
28	1	4	Market B	20	3	10
28	1	20	Market C	20	9	20

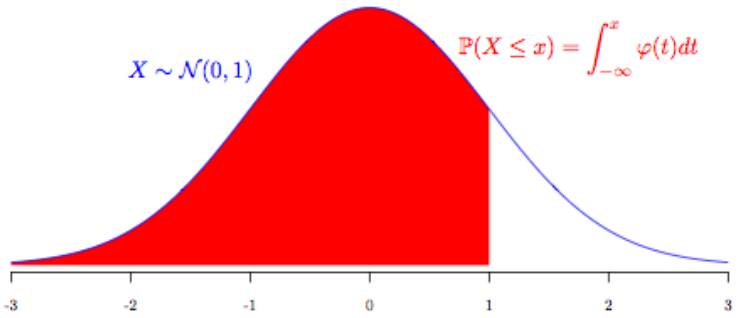
Roof-shaped matrix diagram

It shows a relationship between one group of items and themselves.
It can be used to represent the cooperation between team members.

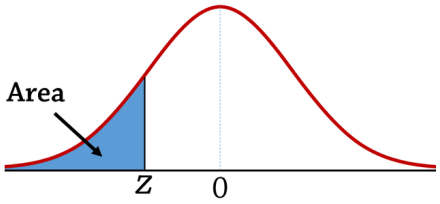


10. Appendix

Different forms of normal distribution tables (Z tables)

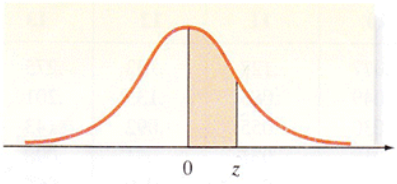


	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
-0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641

TABLE IV Normal Curve Areas



z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.49903	.49906	.49910	.49913	.49916	.49918	.49921	.49924	.49926	.48829
3.2	.49931	.49934	.49936	.49938	.49940	.49942	.49944	.49946	.49948	.49950
3.3	.49952	.49953	.49955	.49957	.49958	.49960	.49961	.49962	.49964	.49965
3.4	.49966	.49968	.49969	.49970	.49971	.49972	.49973	.49974	.49975	.49976
3.5	.49977	.49978	.49978	.49979	.49980	.49981	.49981	.49982	.49983	.49983
3.6	.49984	.49985	.49985	.49986	.49986	.49987	.49987	.49988	.49988	.49989
3.7	.49989	.49990	.49990	.49990	.49991	.49991	.49992	.49992	.49992	.49992
3.8	.49993	.49993	.49993	.49994	.49994	.49994	.49994	.49995	.49995	.49995
3.9	.49995	.49995	.49996	.49996	.49996	.49996	.49996	.49996	.49997	.49997

Source: Abridged from Table I of A. Hald, *Statistical Tables and Formulas* (New York: Wiley), 1952. Reproduced by permission of A. Hald.