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Project Management

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Project Management

Time and resource management

Planning and controlling project activities

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Topics

Building networks of project activities and Gantt diagrams.

Project Management Methods:

- CPM
- Planning with limited resources
- PERT
- Time / cost commitment

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Term List

- AON – Networks “Activity on Node”
- AOA – Networks “Activity on Arc”
- CPM – Method “Critical Path Method”
- PERT - Method “Program Evaluation and Review Technique”
- BAG - “Brook’s Algorithm”

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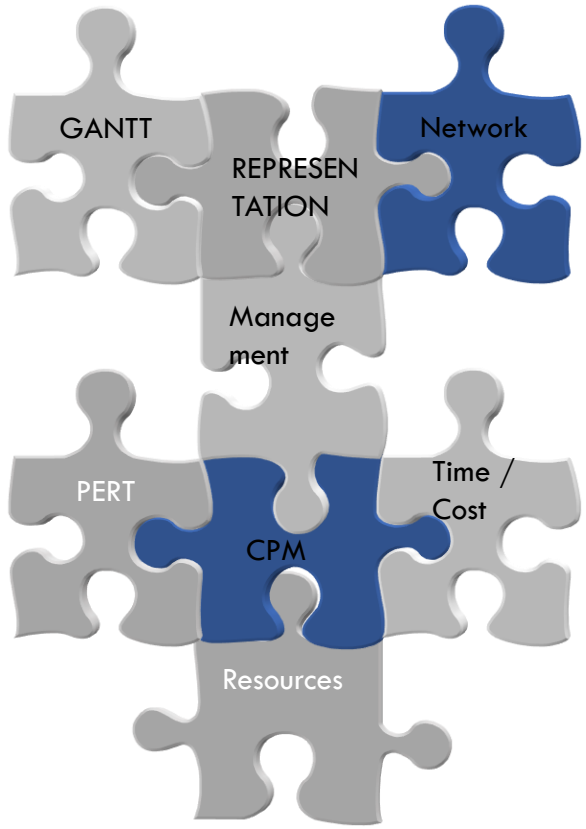
Summary - Project Duration?

Project planning

- Activities
- AON and AOA networks
- Gantt diagrams

Time management

- CPM Method
- Time / cost commitment
- PERT method
- Resource allocation



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Project Representation

Activities - Precedences

AON Network - AOA Network

Gantt diagram

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[Work Breakdown Structure - WBS]

The WBS is a hierarchical structure of all activities and sub-activities necessary for the project to be carried out successfully.

- successively divide complicated activities into several smaller activities
- all levels of the WBS where the total amount of work for a level must match the element of the level immediately above
- find a balance between the definition of elements that can be managed and that have an adequate dimension for realization.

Although there is a wide variety of WBS, one of the most common, according to Kerzner (2009, p. 435), is that of six levels:

- Management Levels: **(1) Complete** program; (**2) Project**; **(3) Task**
- Technical Levels: **(4) Subtask**; **(5) Work package**; **(6) Effort level**

WBS serves as the basis for a set of project management processes:

- Responsibility matrix; Activity network; Costs; Risk analysis; Organizational structure; Control

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Work Breakdown Structure - Templates

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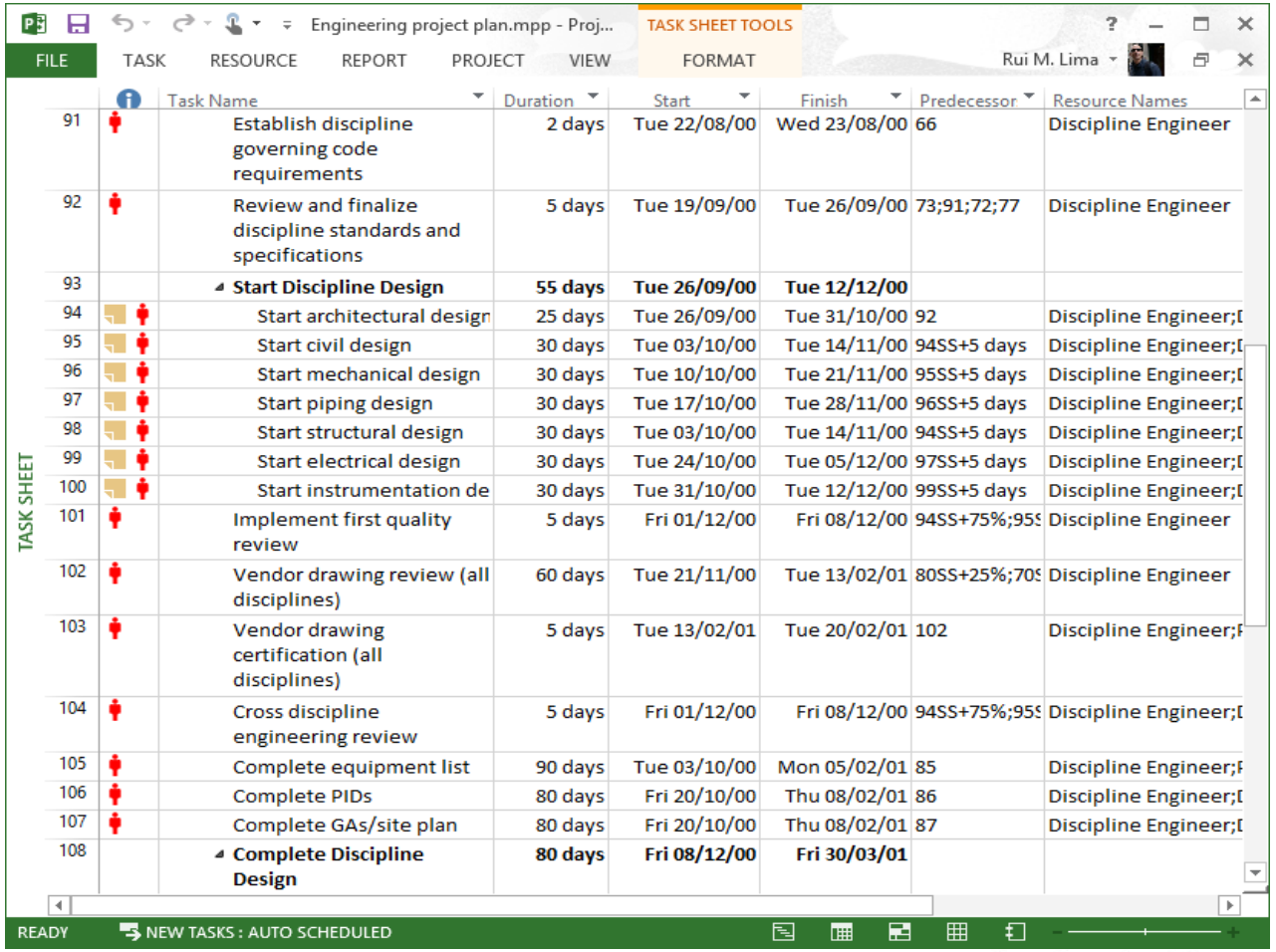
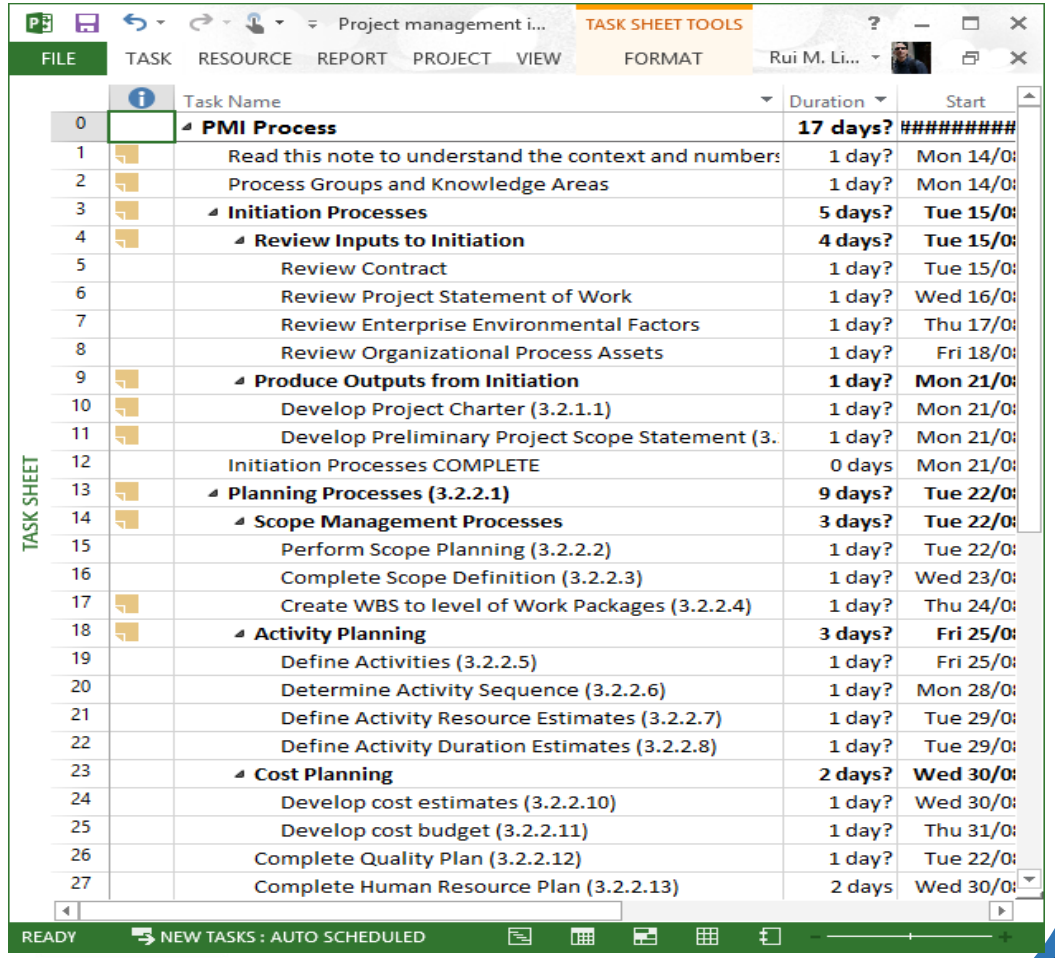


	Task Name	Duration	Start	Finish	Predecessor	Resource Names
91	Establish discipline governing code requirements	2 days	Tue 22/08/00	Wed 23/08/00	66	Discipline Engineer
92	Review and finalize discipline standards and specifications	5 days	Tue 19/09/00	Tue 26/09/00	73;91;72;77	Discipline Engineer
93	**Start Discipline Design**	**55 days**	**Tue 26/09/00**	**Tue 12/12/00**		
94	Start architectural design	25 days	Tue 26/09/00	Tue 31/10/00	92	Discipline Engineer;D
95	Start civil design	30 days	Tue 03/10/00	Tue 14/11/00	94SS+5 days	Discipline Engineer;D
96	Start mechanical design	30 days	Tue 10/10/00	Tue 21/11/00	95SS+5 days	Discipline Engineer;D
97	Start piping design	30 days	Tue 17/10/00	Tue 28/11/00	96SS+5 days	Discipline Engineer;D
98	Start structural design	30 days	Tue 03/10/00	Tue 14/11/00	94SS+5 days	Discipline Engineer;D
99	Start electrical design	30 days	Tue 24/10/00	Tue 05/12/00	97SS+5 days	Discipline Engineer;D
100	Start instrumentation de	30 days	Tue 31/10/00	Tue 12/12/00	99SS+5 days	Discipline Engineer;D
101	Implement first quality review	5 days	Fri 01/12/00	Fri 08/12/00	94SS+75%;95	Discipline Engineer
102	Vendor drawing review (all disciplines)	60 days	Tue 21/11/00	Tue 13/02/01	80SS+25%;70	Discipline Engineer
103	Vendor drawing certification (all disciplines)	5 days	Tue 13/02/01	Tue 20/02/01	102	Discipline Engineer;F
104	Cross discipline engineering review	5 days	Fri 01/12/00	Fri 08/12/00	94SS+75%;95	Discipline Engineer;D
105	Complete equipment list	90 days	Tue 03/10/00	Mon 05/02/01	85	Discipline Engineer;F
106	Complete PIDs	80 days	Fri 20/10/00	Thu 08/02/01	86	Discipline Engineer;D
107	Complete GAs/site plan	80 days	Fri 20/10/00	Thu 08/02/01	87	Discipline Engineer;D
108	**Complete Discipline Design**	**80 days**	**Fri 08/12/00**	**Fri 30/03/01**		



	Task Name	Duration	Start
0	**PMI Process**	**17 days?**	##########
1	Read this note to understand the context and numbers	1 day?	Mon 14/0
2	Process Groups and Knowledge Areas	1 day?	Mon 14/0
3	**Initiation Processes**	**5 days?**	**Tue 15/0**
4	**Review Inputs to Initiation**	**4 days?**	**Tue 15/0**
5	Review Contract	1 day?	Tue 15/0
6	Review Project Statement of Work	1 day?	Wed 16/0
7	Review Enterprise Environmental Factors	1 day?	Thu 17/0
8	Review Organizational Process Assets	1 day?	Fri 18/0
9	**Produce Outputs from Initiation**	**1 day?**	**Mon 21/0**
10	Develop Project Charter (3.2.1.1)	1 day?	Mon 21/0
11	Develop Preliminary Project Scope Statement (3.	1 day?	Mon 21/0
12	Initiation Processes COMPLETE	0 days	Mon 21/0
13	**Planning Processes (3.2.2.1)**	**9 days?**	**Tue 22/0**
14	**Scope Management Processes**	**3 days?**	**Tue 22/0**
15	Perform Scope Planning (3.2.2.2)	1 day?	Tue 22/0
16	Complete Scope Definition (3.2.2.3)	1 day?	Wed 23/0
17	Create WBS to level of Work Packages (3.2.2.4)	1 day?	Thu 24/0
18	**Activity Planning**	**3 days?**	**Fri 25/0**
19	Define Activities (3.2.2.5)	1 day?	Fri 25/0
20	Determine Activity Sequence (3.2.2.6)	1 day?	Mon 28/0
21	Define Activity Resource Estimates (3.2.2.7)	1 day?	Tue 29/0
22	Define Activity Duration Estimates (3.2.2.8)	1 day?	Tue 29/0
23	**Cost Planning**	**2 days?**	**Wed 30/0**
24	Develop cost estimates (3.2.2.10)	1 day?	Wed 30/0
25	Develop cost budget (3.2.2.11)	1 day?	Thu 31/0
26	Complete Quality Plan (3.2.2.12)	1 day?	Tue 22/0
27	Complete Human Resource Plan (3.2.2.13)	2 days	Wed 30/0

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Work Breakdown Structure – Example

Kerzner (p.439)

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TABLE 11–2. WORK BREAKDOWN STRUCTURE FOR NEW PLANT CONSTRUCTION AND START-UP

Program: New Plant Construction and Start-up	01-00-00
Project 1: Analytical Study	01-01-00
Task 1: Marketing/Production Study	01-01-01
Task 2: Cost Effectiveness Analysis	01-01-02
Project 2: Design and Layout	01-02-00
Task 1: Product Processing Sketches	01-02-01
Task 2: Product Processing Blueprints	01-02-02
Project 3: Installation	01-03-00
Task 1: Fabrication	01-03-01
Task 2: Setup	01-03-02
Task 3: Testing and Run	01-03-03
Project 4: Program Support	01-04-00
Task 1: Management	01-04-01
Task 2: Purchasing Raw Materials	01-04-02

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Project Representation
Activities and Precedences

Activity	Precedences	Duration
A	-	5
B	-	4
C	-	3
D	A	1
E	C	2
F	C	9
G	C	5
H	B, D, E	4
I	G	2

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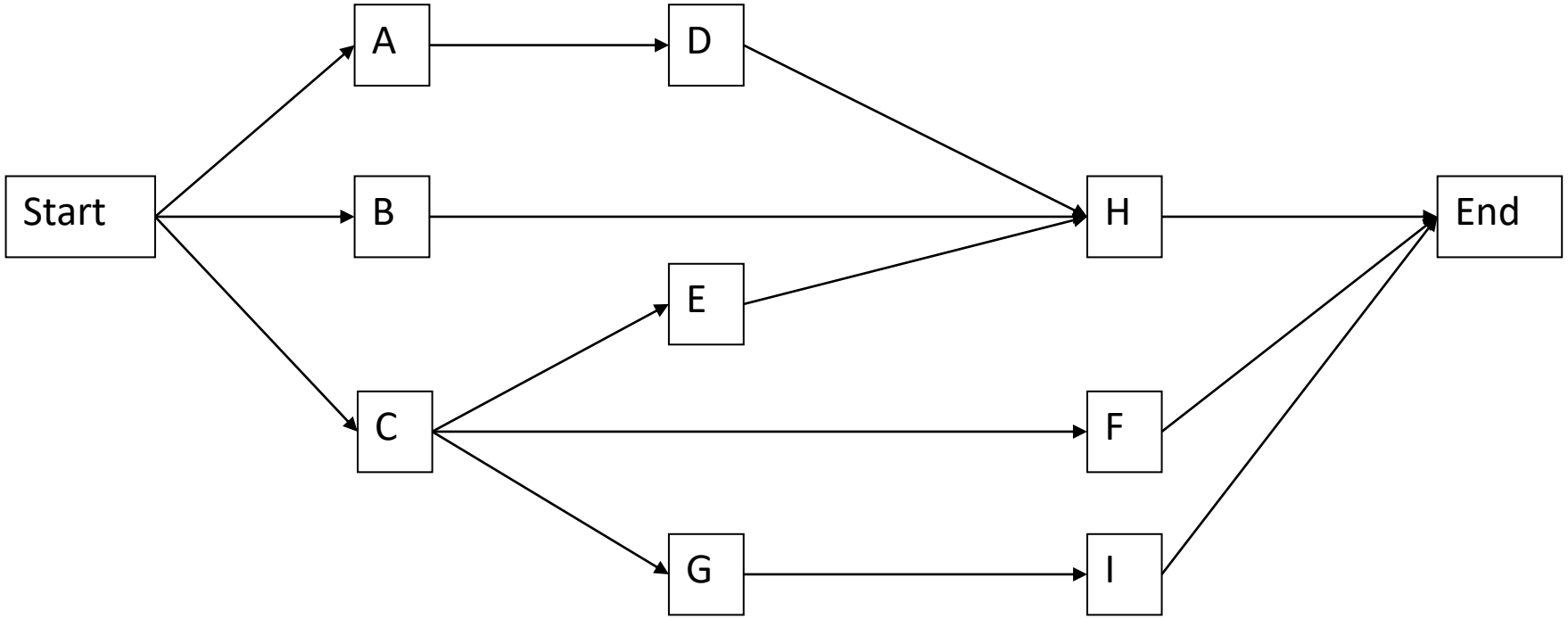
Project Representation
“Activity on Node” Network



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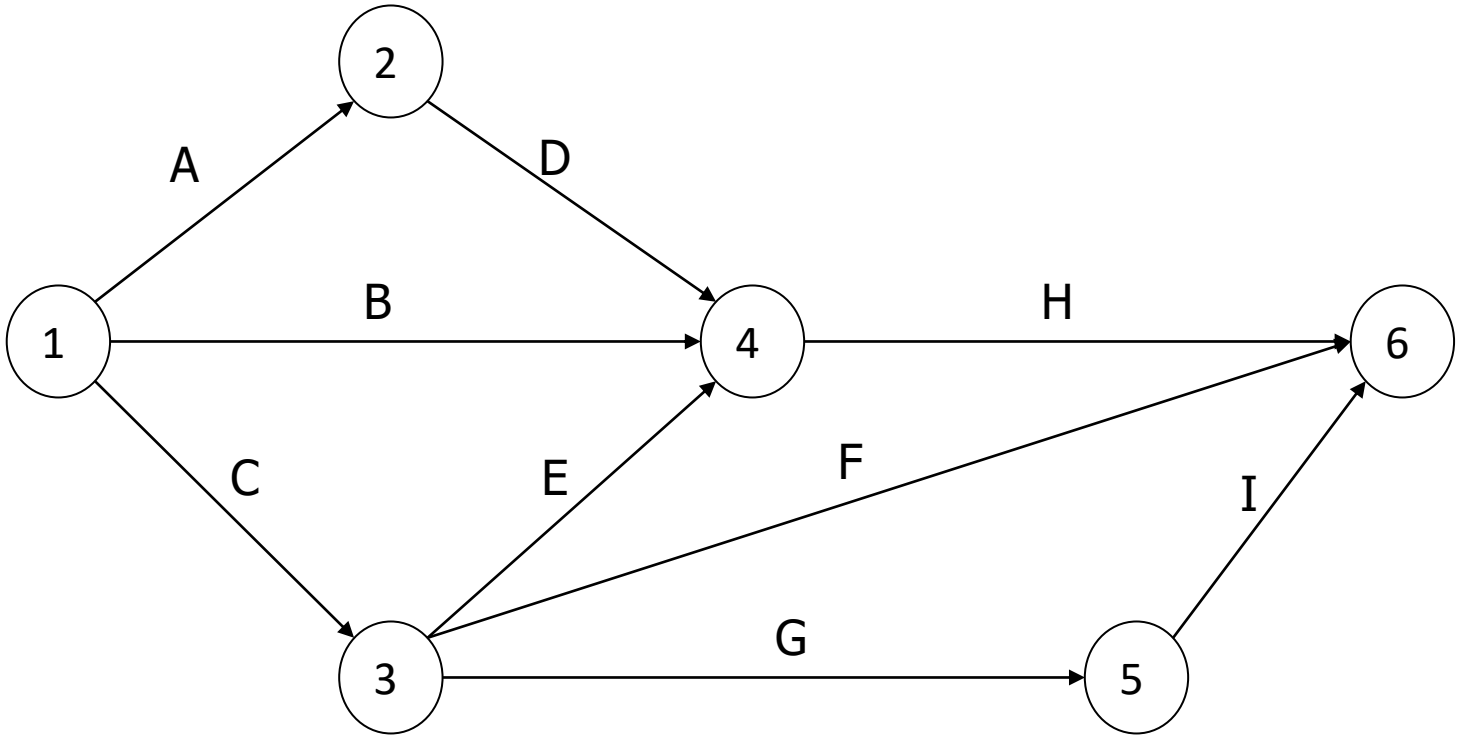
Project Representation
"Activity on Arc" Network



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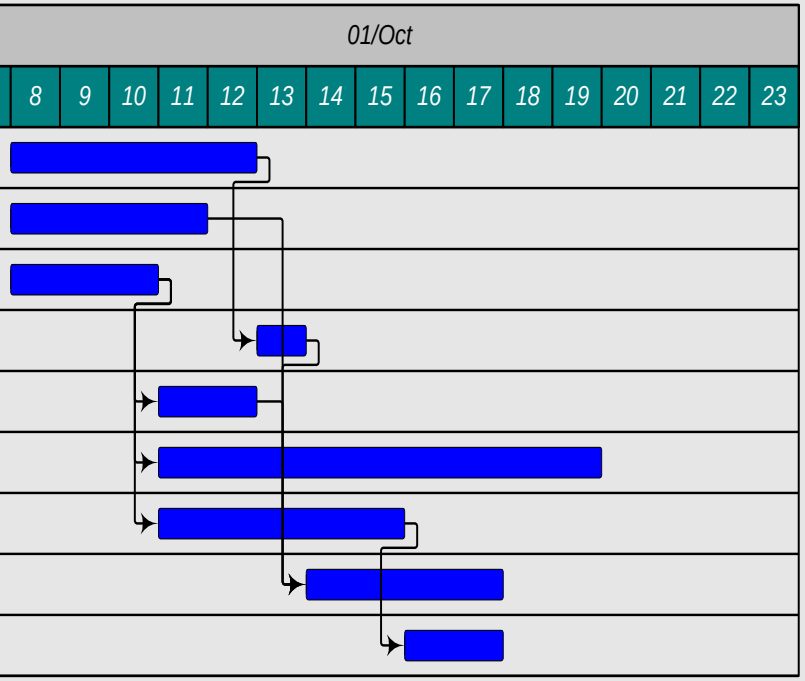
Project Representation
Gantt Diagram

ID	Task Name	Start Date	End Date	Duration
1	A	2001/10/08	2001/10/13	5d
2	B	2001/10/08	2001/10/11	4d
3	C	2001/10/08	2001/10/10	3d
4	D	2001/10/13	2001/10/13	1d
5	E	2001/10/11	2001/10/12	2d
6	F	2001/10/11	2001/10/19	9d
7	G	2001/10/11	2001/10/15	5d
8	H	2001/10/14	2001/10/17	4d
9	I	2001/10/16	2001/10/17	2d



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Activities: duration, precedence, restrictions

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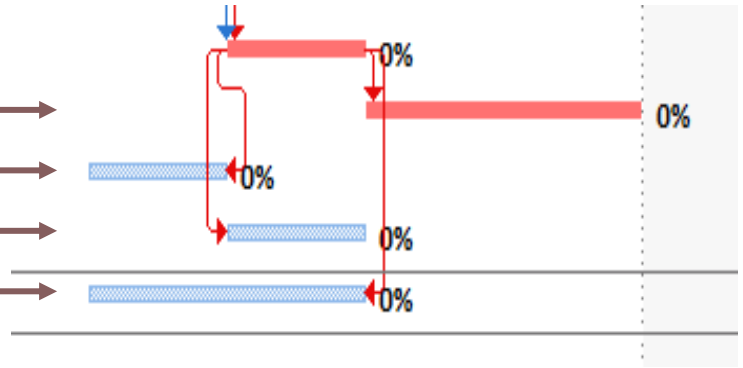
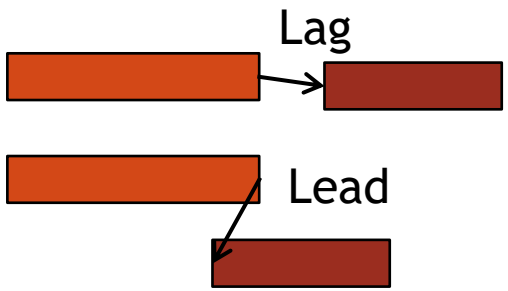
Duration + Precedence

- FS: Finish to Start
- SF: Start to Finish
- SS: Start to Start
- FF: Finish to Finish



- Lead + Lag Time



Restrictions

- ASAP – As Soon As Possible
- ALAP – As Late As Possible

- SNET – Start No Earlier Than
- SNLT – Start No Later Than
- FNET – Finish No Earlier Than
- FNLT – Finish No Later Than

- MSO – Must Start On
- MFO – Must Finish On

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CPM Method

Representation Of Activities – Network Construction
Times And Slack Calculation
Critical Path

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CPM Method
Representation of Events - Nodes

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Node / Events

- ET – “Early Event Time”
- LT – “Late Event Time”

Beginning and / or conclusion of activities.

There is a single start and end event for the project.

They must be numbered from left to right and from top to bottom.

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CPM Method
Representation of Activities - Arcs

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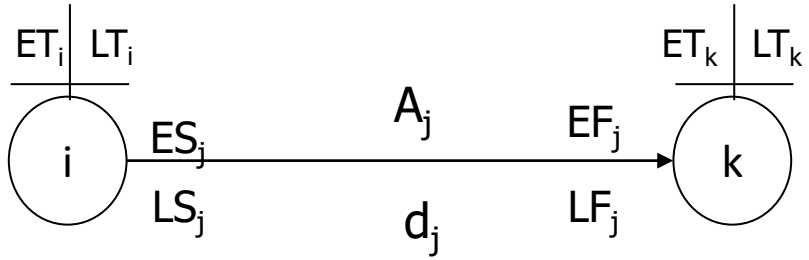
Arcs / activities

- “Activity” – j: Aj
- “Duration” – : dj



- “Earliest Start” – ESj = ETi
- “Latest Finish” – LFj = LTk
- “Latest Start” – LSj = LTk - dj
- “Earliest Finish” – EFj = ETi + dj

No activity can be represented by more than one arc.

Two activities cannot have the same beginning and end events.

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CPM Method - Slacks off

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Total Slack

Maximum delay that an activity can have in relation to its earlier start date, without compromising the project's completion time

- FTotal = LTk - ETi - dj

Safety slack

- Similar to the previous one, but in this case, it assumes that the direct precedents of an activity have already been delayed as much as they could
- FSafety = LTk - LTi - dj

Free slack

Maximum delay that an activity can have in relation to its earlier start date, without preventing the following activities from starting on their earlier dates

FFree= ETk - ETi - dj

Independent slack

It is the time margin available when the previous activity is completed at a later date and the next activity is considered to have started at the earliest date.

- FIndependent = max{ ETk – LTi - dj, 0 }

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CPM Method - Critical Path

Critical Path (CP): consists of the longest sequence of activities that connect the network's initial node to its final node, thus determining the project's execution period.

Critical activities are how they integrate the critical path and directly contribute to the duration of the project. They are activities without slacks off.

Exercise: Solve the exercise presented in the “Activity representation” by the CPM method, determining:

- All times and breaks.
- Critical Path.

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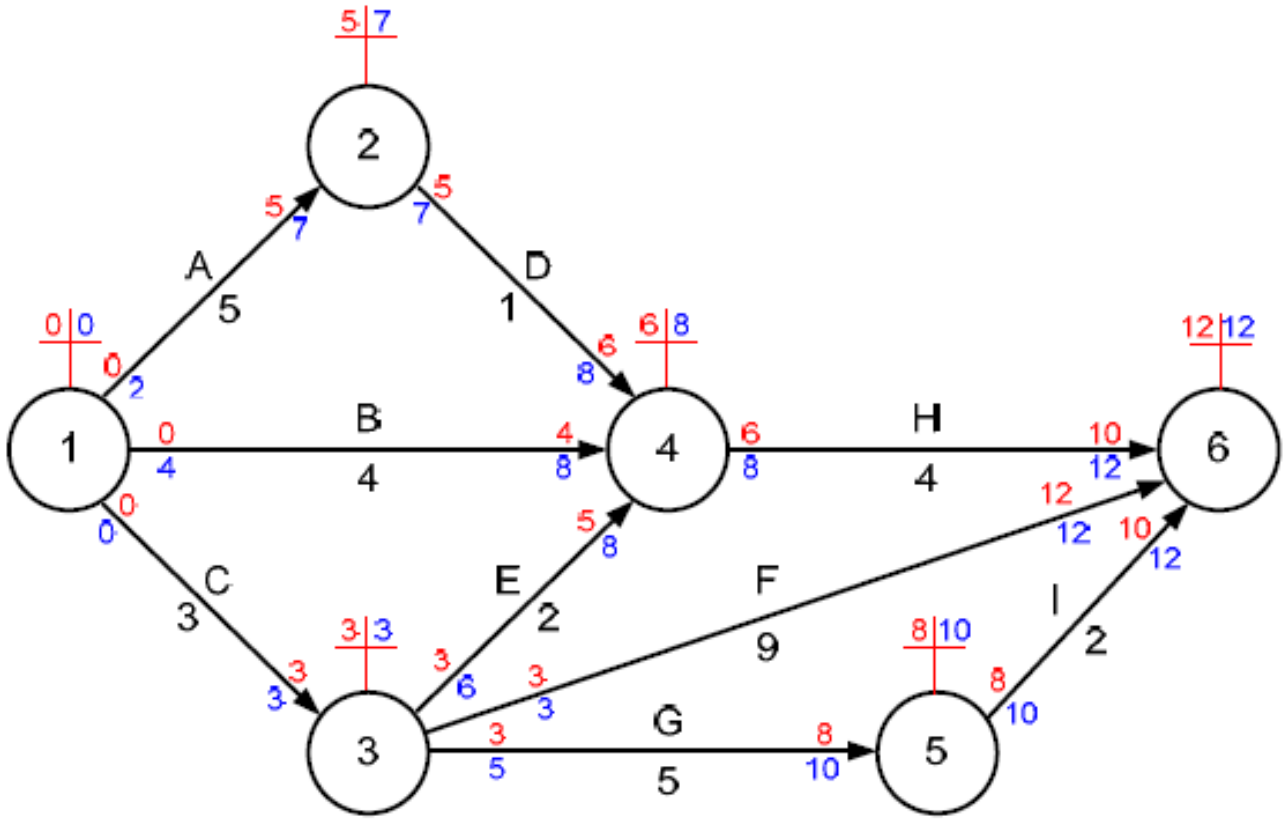
CPM Method
Critical Path - Exercise



CP – CF – 12 days

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Build the AOA network and determine all activity times and all clearances for an activity.

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Activity	Precedence	Duration
A	-	4
B	-	10
C	B	6
D	B	8
E	A, B	7
F	A	4
G	C, D, E	8
H	C, D, E	7
I	F, H	5

Make the representation of the project with the AOA type precedence diagram.

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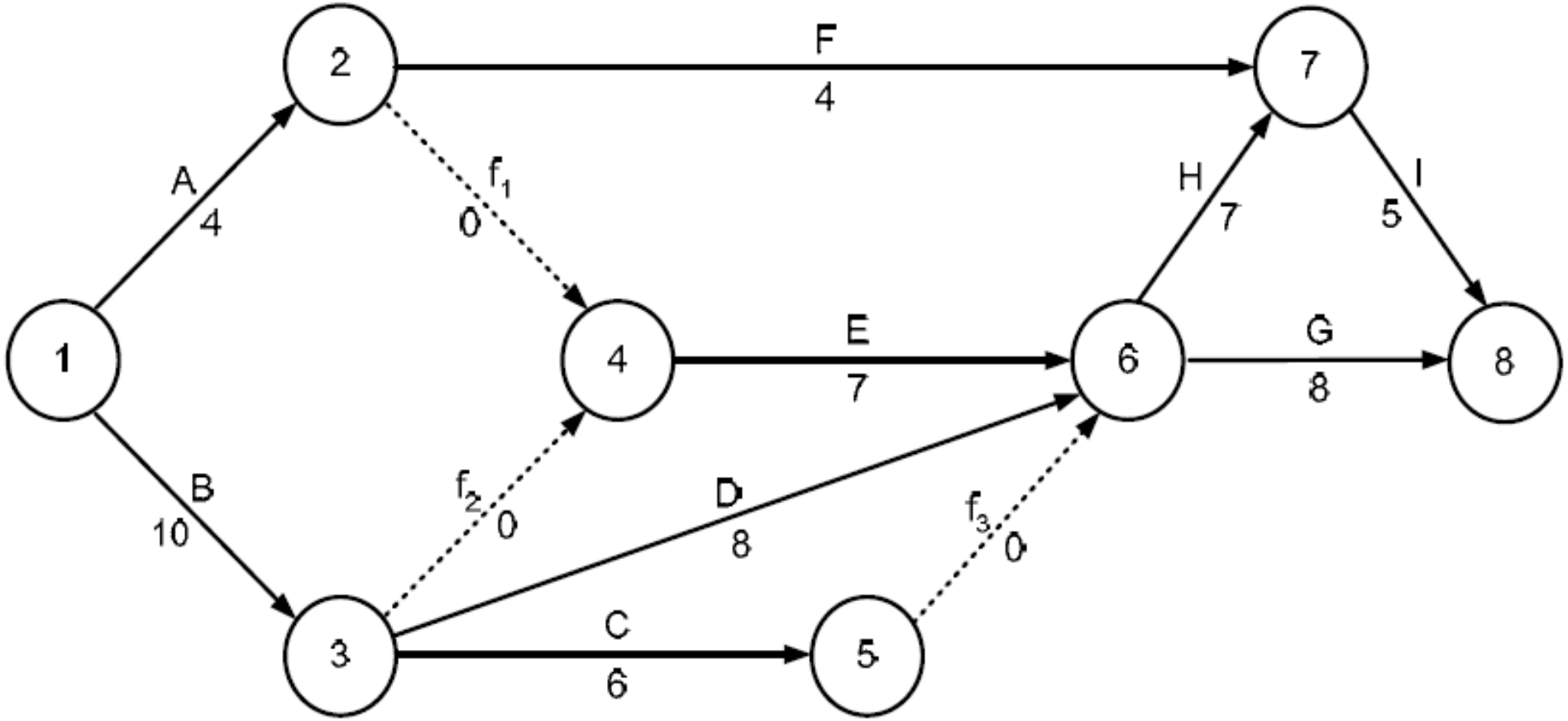
AOA network



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Planning with Resource Restriction

Planning with scarce resources

Lang's heuristic

Brooks algorithm

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Resource-Constrained Planning
LANG Heuristic

- Sort activities in ascending order from their later start time.
- When there is equality, priority is given to:
  - activity with less total slack;
  - activity with a longer duration;
  - activity with the greatest need for resources.

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Resource-Constraints Planning
Brooks algorithm (BAG)

Descending ordering of activities according to their ACTIM value.

ACTIM is the maximum time that each activity controls over the network and corresponds to the maximum time of the project, considering this activity as initial.

In case of equality, Lang's heuristic can be used.

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Brooks Algorithm (BAG) Exercise

Considering the activities, precedence, duration and resources required for each activity, indicated in the table, resolve the following questions.

- Build the network, of activities in the branches, of the project, indicating the early and late times of each event, and the early and late start and end of each activity.
- Indicate the critical path and its duration, considering that there are no resource restrictions, and construct the respective Gantt chart.
- Considering that only 24 collaborators are available to carry out the project, build the sequence of activities, allocating resources by the Brooks algorithm. Indicate the duration of the project, and the delay verified by the fact that the resources are not unlimited.
- What is the minimum number of workers to subcontract, and in what period(s) so that the project is not delayed?

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Brooks Algorithm (BAG) Exercise

Activities	Precedences	Duration	Collaborators
A	-	6	6
B	-	6	18
C	-	2	7
D	A	3	10
E	B	7	15
F	B	3	3
G	C	5	8
H	D, E	7	16
I	F	4	9

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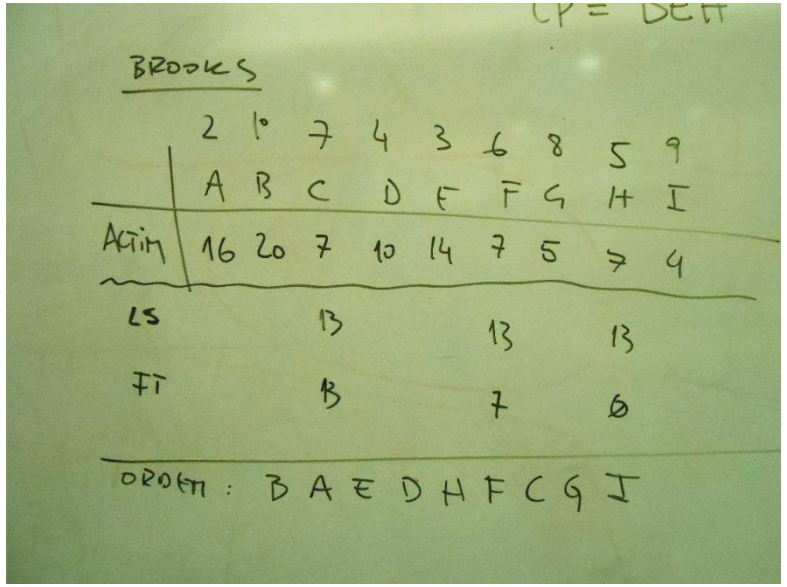
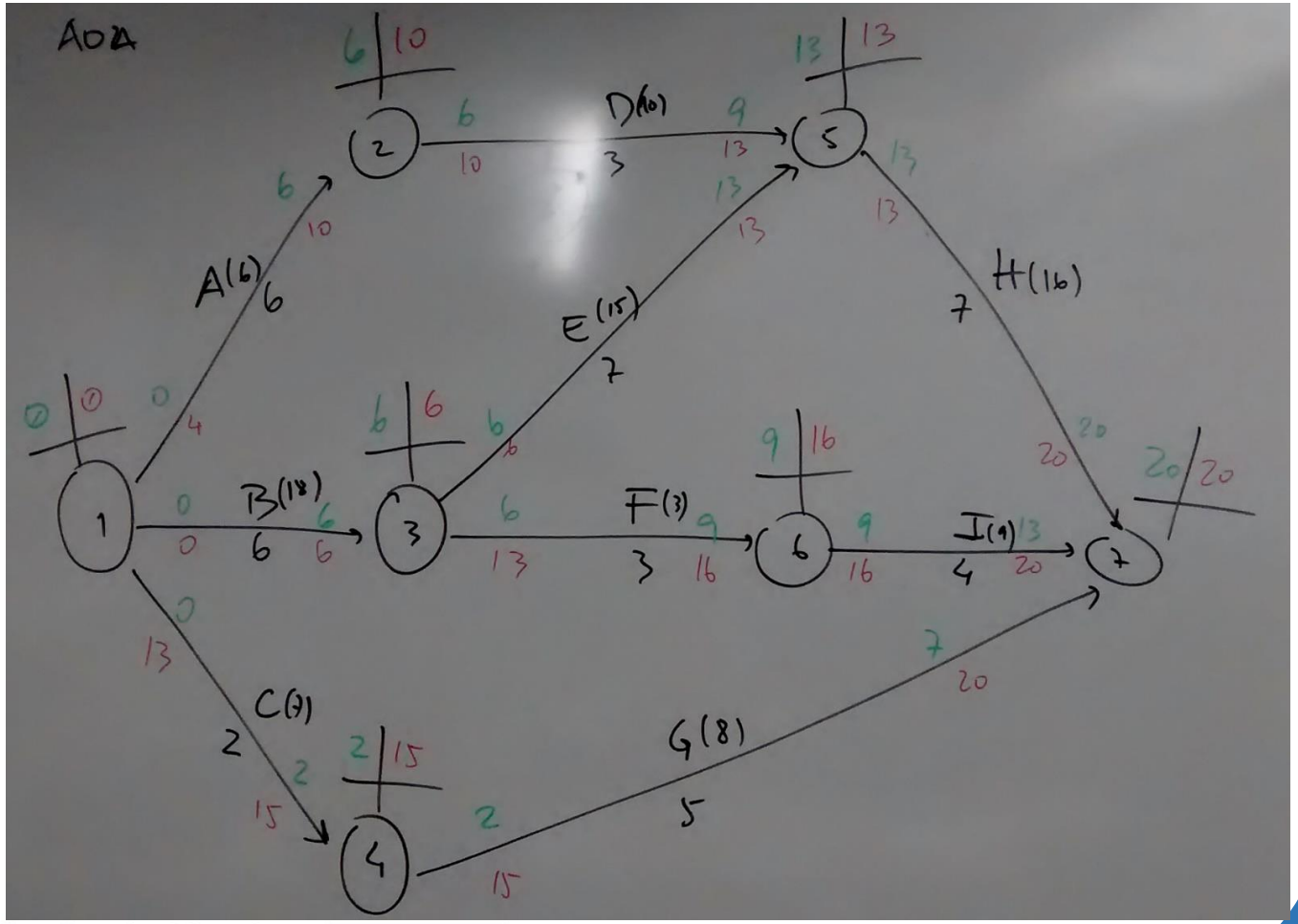
Brooks - Exercise

Network AOA

CP – BEH – 20 days





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Brooks - Exercise

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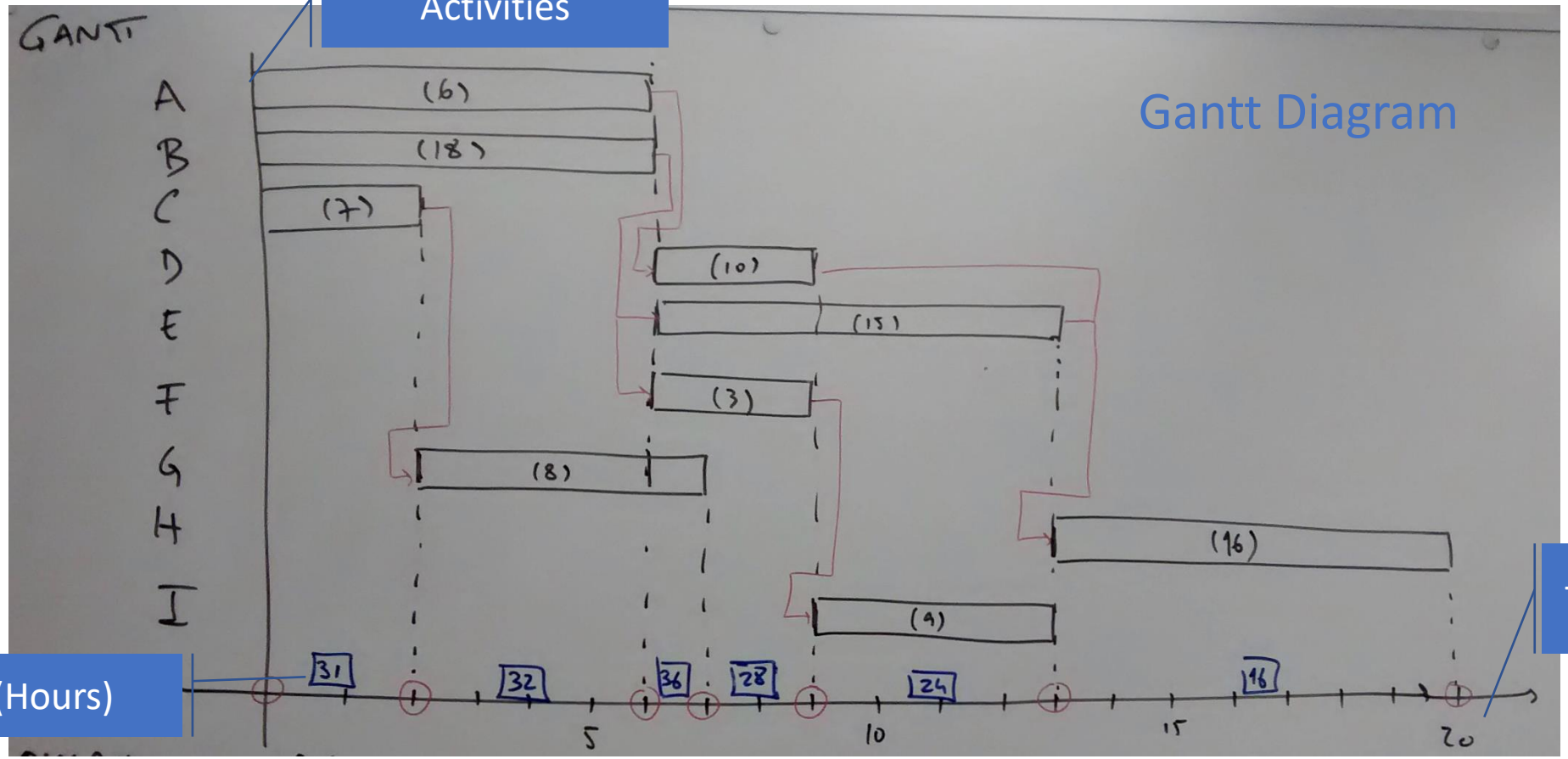

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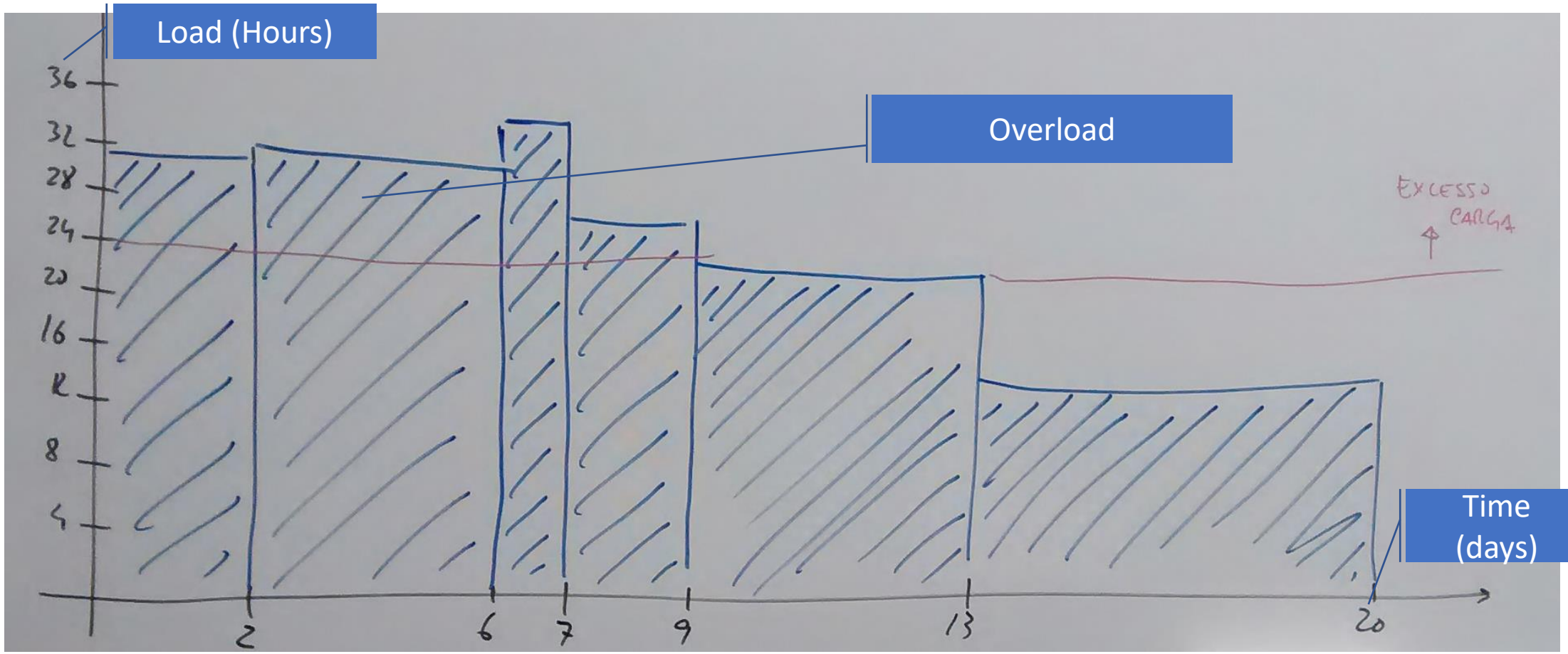
Brooks - Exercise



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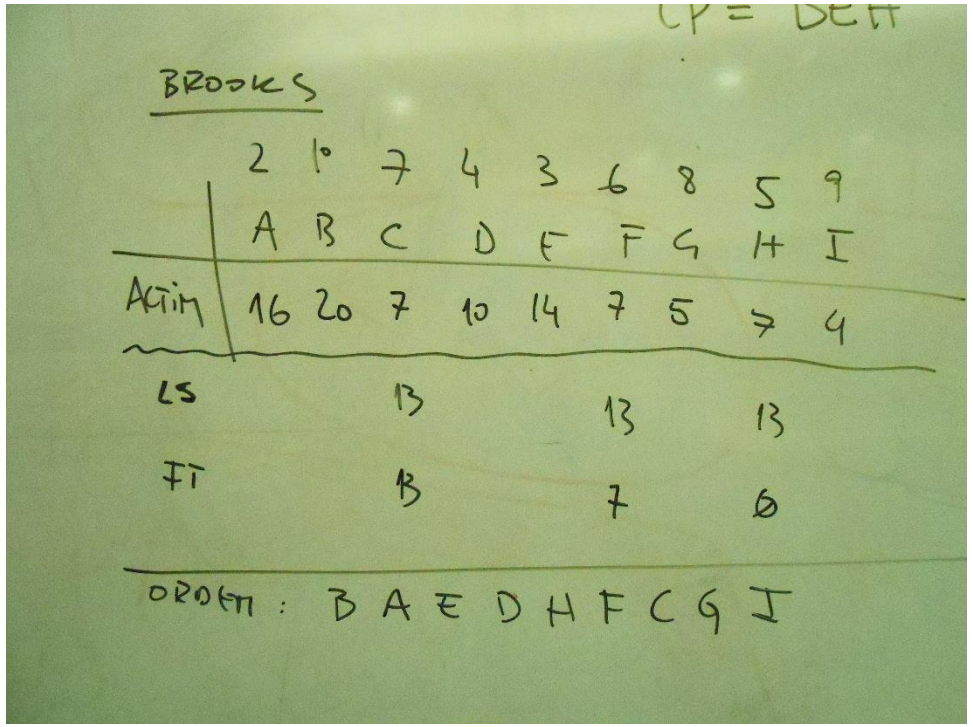
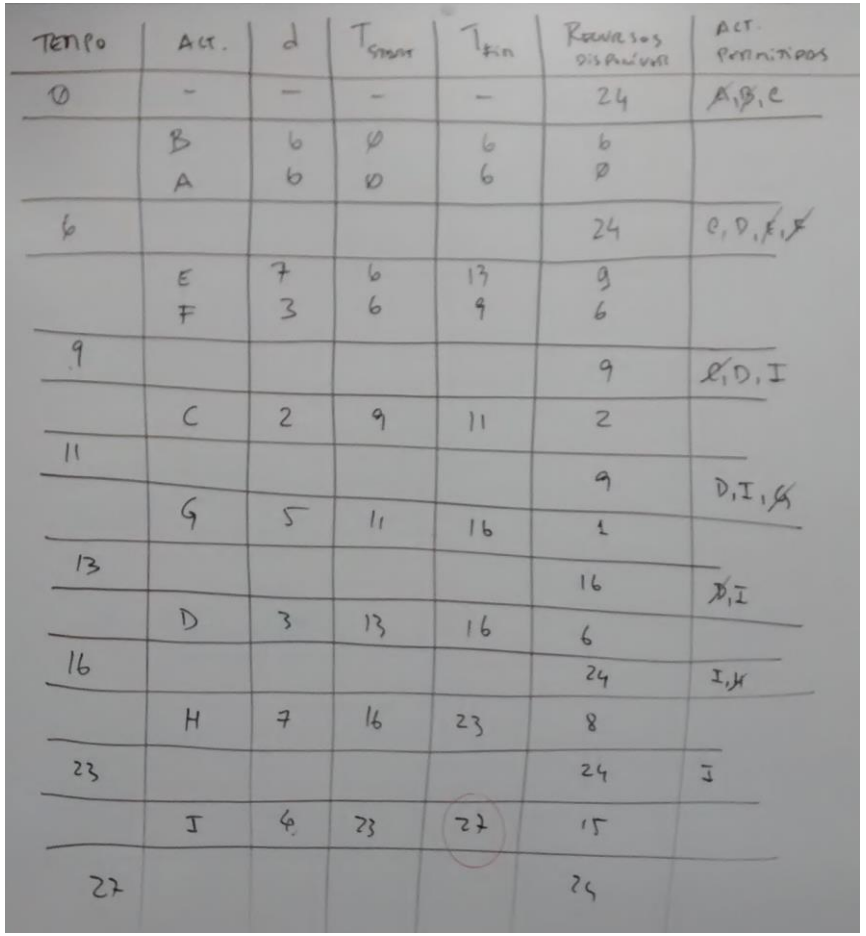
Brooks - Exercise





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PERT Method

PERT Method Model - Critical Path

Activity Representation Model

Calculation of Project Duration Times

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PERT Method
PERT Method Model

- The duration of each activity is no longer considered deterministic to be considered probabilistic:
  - dj - activity duration j (random variable)
  - mj - average of dj or E [dj]
  - σj2 - dj variance

Method assumptions:

- The activities (respective dj random variables) are probabilistically independent.
- The critical path contains a sufficient number of activities in such a way that the central limit theorem applies.

Therefore, the distribution of the project duration is close to the Normal Distribution, and its average and variation will be equal to the sum of the averages and variations of the activities.

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PERT Method
PERT Method - Critical Path

- The critical path is considered the path with the longest expected duration:

$$\mu_\pi = \sum_{j \in \pi} \mu_j$$

- That will have variance:

$$\sigma_\pi^2 = \sum_{j \in \pi} \sigma_j^2$$

- The duration of the project can only be determined probabilistically, using the accumulated normal distribution:

$$\phi\left(\frac{D - \mu_\pi}{\sigma_\pi}\right)$$

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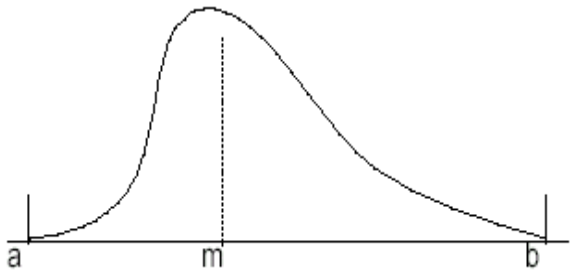
PERT method
Activity duration model

- The duration of each activity is represented by a probability distribution ß.
- This distribution is defined by 3 activity time estimates:

  - a - optimistic estimate of the duration of the activity.
  - m - most likely estimate of the duration of the activity.
  - b - pessimistic estimate of the duration of the activity.

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

$$\sigma^2 = \frac{(b-a)^2}{36}$$



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PERT Method
Calculation of project duration times

- Determine the probability of the project ending in 15 days and 19 days.
- Determine the probability of the project ending in 19 days, considering the 2nd most critical path

Activity	Precedences	a	m	b	μ	σ2
A	-	2	4	12		
B	-	3	6	9		
C	A	1	2	9		
D	A	3	3	9	4	1,00
E	B	1	2	3	2	0,11
F	B	2	8	8	7	1,00
G	C	1	2	9	3	1,78
H	D, E	4	5	12	6	1,78
I	F	1	3	5	3	0,44

$$\mu = \frac{a + 4m + b}{6} \qquad \sigma^2 = \frac{(b-a)^2}{36}$$

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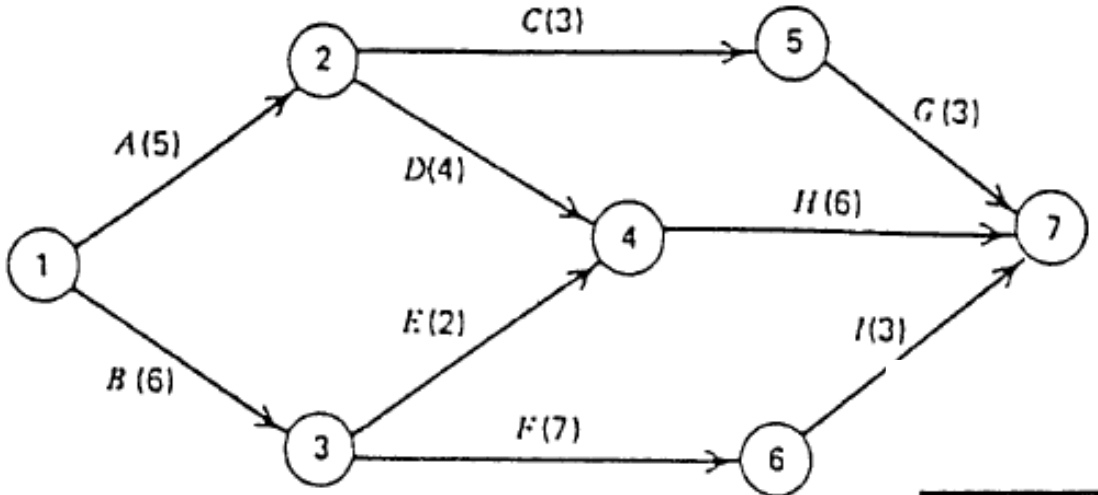
PERT Method
Calculation of project duration times



	P	μ	σ_π^2
1	A-C-G	11	6,33
2	A-D-H	15	5,67
3	B-E-H	14	2,89
4	B-F-I	16	2,44

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PERT Method
Calculation of project duration times

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Calculating the probability of the project ending within 15 UT.

$$Z = \frac{D - \mu_{\pi}}{\sigma_{\pi}} = \frac{15 - 16}{\sqrt{2.44}} = -0.640$$

$$\phi(-0.640) = 1 - \phi(0.640) = 1 - 0.73891 = 0.26109 \approx 26.11\%$$

The reduced normal distribution table was consulted

Calculating the probability of the project ending within 19 UT.

$$Z = \frac{D - \mu_{\pi}}{\sigma_{\pi}} = \frac{19 - 16}{\sqrt{2.44}} = 1.92$$

$$\phi(1.92) = 0.97257 \approx 97.26\%$$

The reduced normal distribution table was consulted

Calculating the probability of the project ending within a period of 19 UT considering the ADH path

$$Z = \frac{D - \mu_{ADH}}{\sigma_{ADH}} = \frac{19 - 15}{\sqrt{5.56}} = 1.70$$

$$\phi(1.70) = 0.95543 \approx 95.54\%$$

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Standard Normal Distribution Table

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Tabela da Distribuição Normal

Area under the Normal Curve from $-\infty$ to Z

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.50000	0.50399	0.50798	0.51197	0.51595	0.51994	0.52392	0.52790	0.53188	0.53586
0.1	0.53983	0.54380	0.54776	0.55172	0.55567	0.55962	0.56356	0.56749	0.57142	0.57535
0.2	0.57926	0.58317	0.58706	0.59095	0.59483	0.59871	0.60257	0.60642	0.61026	0.61409
0.3	0.61791	0.62172	0.62552	0.62930	0.63307	0.63683	0.64058	0.64431	0.64803	0.65173
0.4	0.65542	0.65910	0.66276	0.66640	0.67003	0.67364	0.67724	0.68082	0.68439	0.68793
0.5	0.69146	0.69497	0.69847	0.70194	0.70540	0.70884	0.71226	0.71566	0.71904	0.72240
0.6	0.72575	0.72907	0.73237	0.73565	0.73891	0.74215	0.74537	0.74857	0.75175	0.75490
0.7	0.75804	0.76115	0.76424	0.76730	0.77035	0.77337	0.77637	0.77935	0.78230	0.78524
0.8	0.78814	0.79103	0.79389	0.79673	0.79955	0.80234	0.80511	0.80785	0.81057	0.81327
0.9	0.81594	0.81859	0.82121	0.82381	0.82639	0.82894	0.83147	0.83398	0.83646	0.83891
1.0	0.84134	0.84375	0.84614	0.84849	0.85083	0.85314	0.85543	0.85769	0.85993	0.86214
1.1	0.86433	0.86650	0.86864	0.87076	0.87286	0.87493	0.87698	0.87900	0.88100	0.88298
1.2	0.88493	0.88686	0.88877	0.89065	0.89251	0.89435	0.89617	0.89796	0.89973	0.90147
1.3	0.90320	0.90490	0.90658	0.90824	0.90988	0.91149	0.91308	0.91466	0.91621	0.91774
1.4	0.91924	0.92073	0.92220	0.92364	0.92507	0.92647	0.92785	0.92922	0.93056	0.93189
1.5	0.93319	0.93448	0.93574	0.93699	0.93822	0.93943	0.94062	0.94179	0.94295	0.94408
1.6	0.94520	0.94630	0.94738	0.94845	0.94950	0.95053	0.95154	0.95254	0.95352	0.95449
1.7	0.95543	0.95637	0.95728	0.95818	0.95907	0.95994	0.96080	0.96164	0.96246	0.96327
1.8	0.96407	0.96485	0.96562	0.96638	0.96712	0.96784	0.96856	0.96926	0.96995	0.97062
1.9	0.97128	0.97193	0.97257	0.97320	0.97381	0.97441	0.97500	0.97558	0.97615	0.97670
2.0	0.97725	0.97778	0.97831	0.97882	0.97932	0.97982	0.98030	0.98077	0.98124	0.98169
2.1	0.98214	0.98257	0.98300	0.98341	0.98382	0.98422	0.98461	0.98500	0.98537	0.98574
2.2	0.98610	0.98645	0.98679	0.98713	0.98745	0.98778	0.98809	0.98840	0.98870	0.98899
2.3	0.98928	0.98956	0.98983	0.99010	0.99036	0.99061	0.99086	0.99111	0.99134	0.99158
2.4	0.99180	0.99202	0.99224	0.99245	0.99266	0.99286	0.99305	0.99324	0.99343	0.99361
2.5	0.99379	0.99396	0.99413	0.99430	0.99446	0.99461	0.99477	0.99492	0.99506	0.99520
2.6	0.99534	0.99547	0.99560	0.99573	0.99585	0.99598	0.99609	0.99621	0.99632	0.99643
2.7	0.99653	0.99664	0.99674	0.99683	0.99693	0.99702	0.99711	0.99720	0.99728	0.99736
2.8	0.99744	0.99752	0.99760	0.99767	0.99774	0.99781	0.99788	0.99795	0.99801	0.99807
2.9	0.99813	0.99819	0.99825	0.99831	0.99836	0.99841	0.99846	0.99851	0.99856	0.99861
3.0	0.99865	0.99869	0.99874	0.99878	0.99882	0.99886	0.99889	0.99893	0.99896	0.99900
3.1	0.99903	0.99906	0.99910	0.99913	0.99916	0.99918	0.99921	0.99924	0.99926	0.99929
3.2	0.99931	0.99934	0.99936	0.99938	0.99940	0.99942	0.99944	0.99946	0.99948	0.99950
3.3	0.99952	0.99953	0.99955	0.99957	0.99958	0.99960	0.99961	0.99962	0.99964	0.99965
3.4	0.99966	0.99968	0.99969	0.99970	0.99971	0.99972	0.99973	0.99974	0.99975	0.99976
3.5	0.99977	0.99978	0.99978	0.99979	0.99980	0.99981	0.99981	0.99982	0.99983	0.99983
3.6	0.99984	0.99985	0.99985	0.99986	0.99986	0.99987	0.99987	0.99988	0.99988	0.99989
3.7	0.99989	0.99990	0.99990	0.99990	0.99991	0.99991	0.99992	0.99992	0.99992	0.99992
3.8	0.99993	0.99993	0.99993	0.99994	0.99994	0.99994	0.99994	0.99995	0.99995	0.99995
3.9	0.99995	0.99995	0.99996	0.99996	0.99996	0.99996	0.99996	0.99996	0.99997	0.99997
4.0	0.99997	0.99997	0.99997	0.99997	0.99997	0.99997	0.99998	0.99998	0.99998	0.99998

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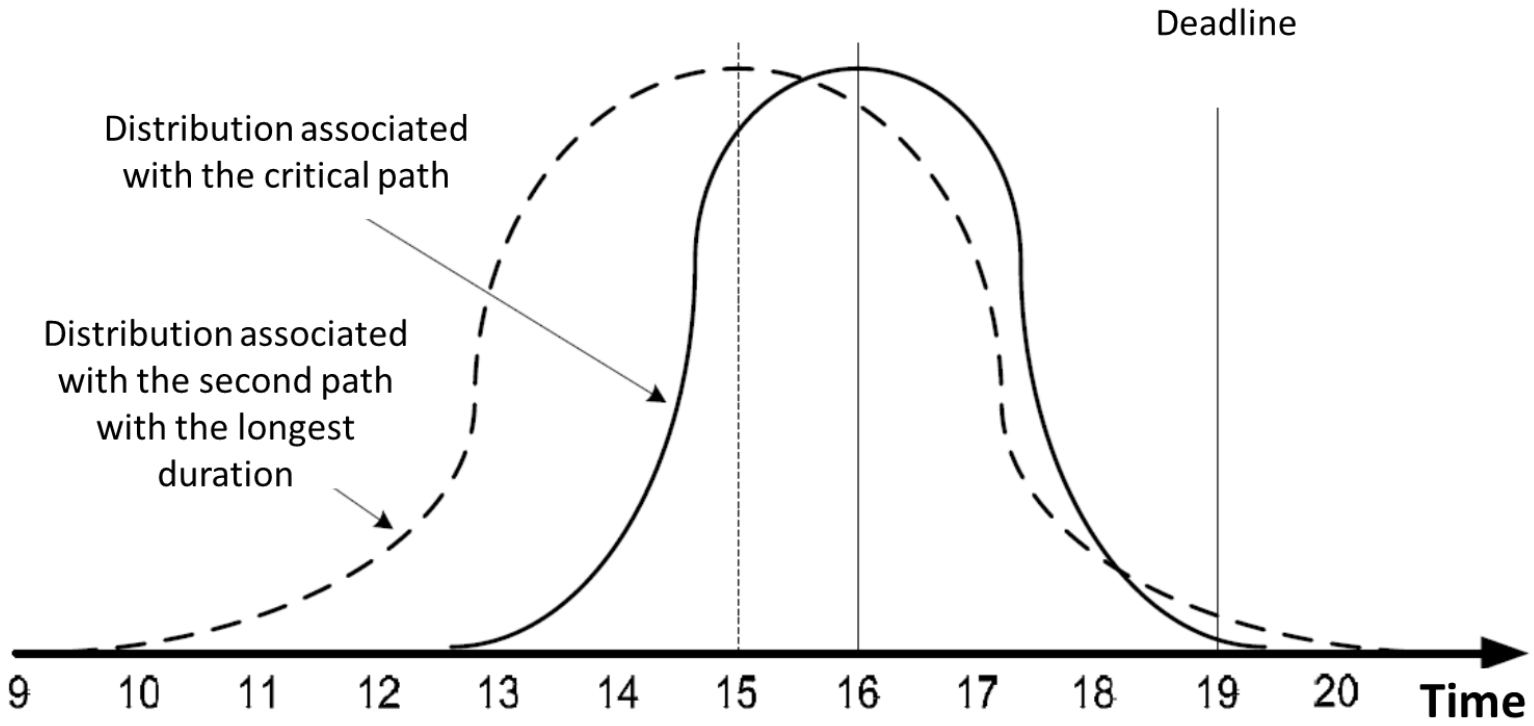
Standard Normal Distribution



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Commitment Method Cost / Time

Cost-per-activity model

Calculation of project duration

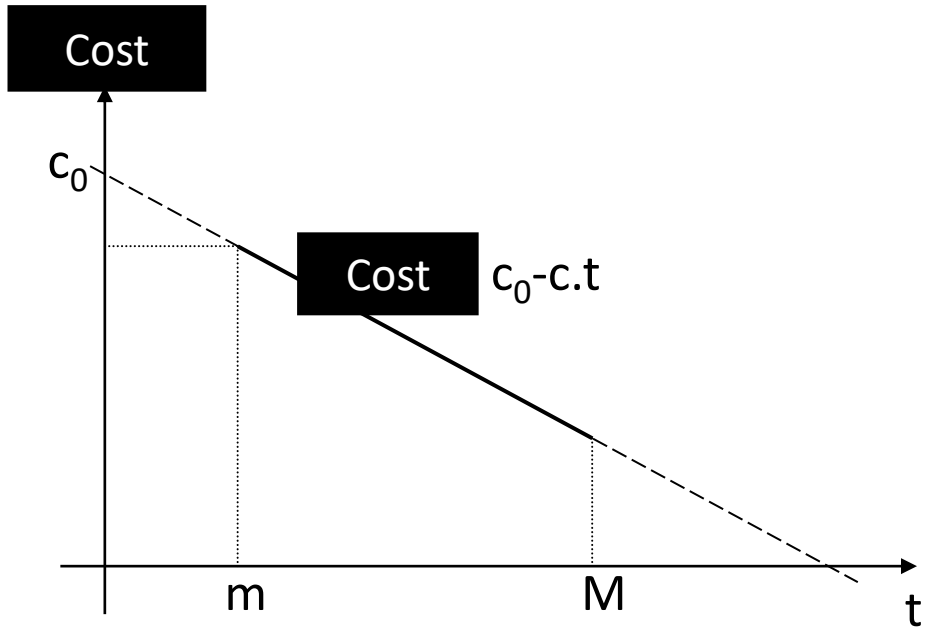
Relationship of time to cost

Universidade do Minho

Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry

Commitment Method Cost / Time
Generic cost model per activity

- It is assumed that:
- The duration of each activity is a linear function of the costs associated with carrying out the activity.
- Each activity has a minimum possible duration (m) and a maximum possible duration (M).



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Method Commitment Cost / Time
Calculation of project duration

- Determine the minimum cost of project duration.
- Consider a fixed cost of 45 Currency Units (UM) per day for the duration of the project.

Activity	Precedence	M	m	c	c_0	Cost
A	-	3	1	40	140	140-40t
B	A	7	3	10	110	110-10t
C	A	4	2	40	180	180-40t
D	C	5	2	20	130	130-20t

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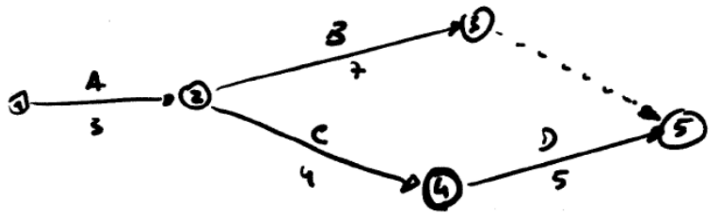
Example

Example

Activity	Precedence	M	m	C	Co	Cost
A	-	3	1	40	140	140 - 40t
B	A	7	3	10	110	110 - 10t
C	A	4	2	40	180	180 - 40t
D	C	5	2	20	130	130 - 20t

Indirect cost

45 um/dia



Duration = 12 dias

CP = A, C, D

Cost = 45 x 12 + (140 - 40.3) + (110 - 10.7) + (180 - 40.4) + (130 - 20.5) =

= 650

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Example

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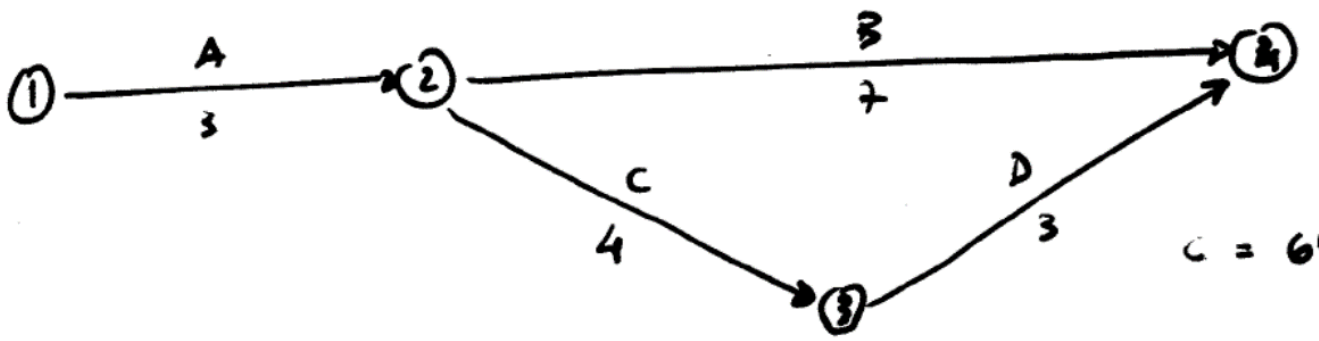
Reduction Hypothesis

A - 2 dias - 40 un/dia

C - 2 dias - 40 un/dia

D - 2 dias - 20 un/dia ←



CP ≡ A,B ou A,C,D

Duration = 10

C = 650 - 45.2 + 20.2 = 60

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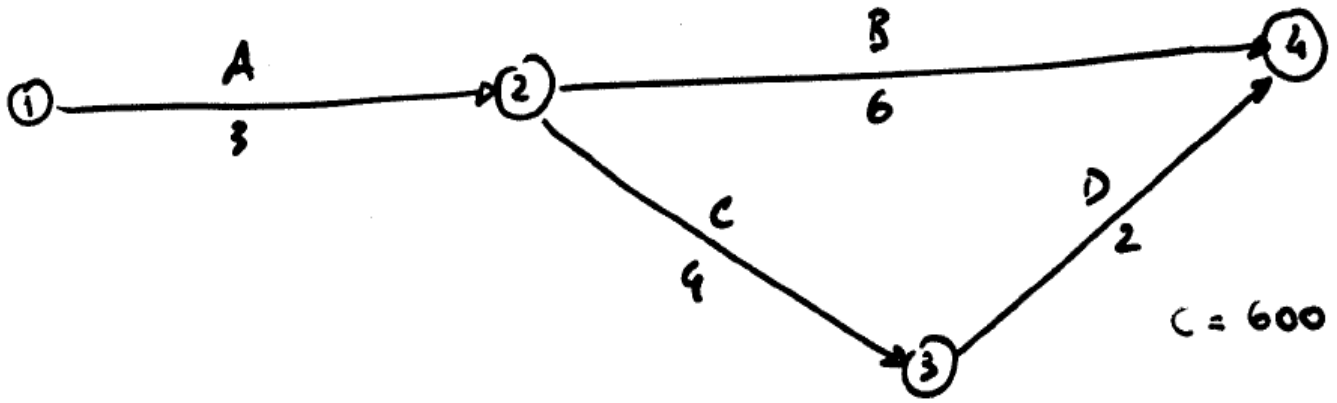
Example

Hip.

A - 2 dias - 40 un/dia

B, C - 2 dias - 50 un/dia

B, D - 1 dia - 30 un/dia ←



CP = A, B ou A, C, D

Dur = 9

C = 600 - 45 + 30 = 585

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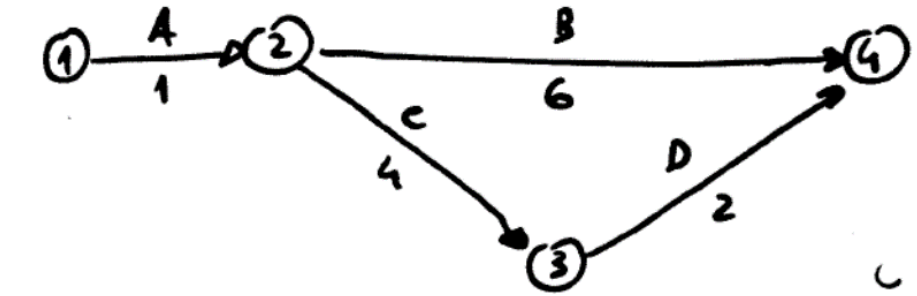
Example

Hip.

A - 2 dias - 40 un/dia ← ÓPTIMO

B,C - 2 dias - 50 un/dia

higher than the indirect cost of the project



CP ≡ A, B ou A, C, D

Dur. ≡ 7

C = 585 - 45.2 + 40.2 = 575 un

Minimum project cost

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More information

See recommended bibliography

- Kerzner, H. (2009). Project management : a systems approach to planning, scheduling, and controlling. New Jersey, USA: John Wiley & Sons.
- PMI-PMBOK. (2013). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide) (5th ed.). Pennsylvania, USA: Project Management Institute (PMI).*

WWW ?...

- Project Management Institute
  - http://www.pmi.org/
- International Project Management Association
  - http://www.ipma.ch/Pages/default.aspx
- Association for Project Management
  - http://www.apm.org.uk/
- Project Management Forum
  - http://www.pmforum.org/

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MSIE 4.0

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Thank You

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