Project Scheduling

Network Techniques

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Background

- Schedule is the conversion of a project action plan into an operating timetable.
- It serves as the basis for monitoring and controlling project activities
- The schedules are typically based on the previously determined action plan or work breakdown structures (WBS).

Forming a Network

- The basic approach of all scheduling techniques is to form a network of activity and event relationship
- These graphically portrays the sequential relation between the tasks in a project
- The tasks that must precede or follow other tasks are then clearly identified in time as well as function

Advantages of a Network

- Denotes the time when specific individuals must be available for work on a given task
- Aids in ensuring that proper communication takes place between departments and functions
- Denotes an expected project completion date
- Denotes **critical activities**, that if delayed, will delay the project completion date

Advantages of a Network

- Identifies activities with **slack** that can be delayed for specified periods without penalty or from which resources may be temporarily borrowed without harm.
- Determines the dates on which tasks may be started, or must be started if the project is to stay on schedule
- Illustrates which tasks must be coordinated to avoid resource or timing conflicts

Network Techniques – PERT and CPM

- The most common approach to project scheduling is the use of network techniques such as **Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM).**
- Both methods identify a project critical path, whose activities could not be delayed, and also indicate the activities with slack (or float).
- PERT is best suited for research and development-related projects.
- CPM is best suited for construction and development related projects.

Critical Path Method (CPM)

- CPM uses deterministic activity time estimates and was designed to control both the time and cost aspects in a project.
- In CPM activities can be crashed or expedited at extra cost to speed up the completion date.

Terminology

- Activity - A specific task or set of tasks, that are required by a project which use resources and take time to complete
- Event - The result of completing one or more activities. An identifiable end state occurring at a particular time. Use no resources

Terminology

- Network - The combination of all activities and events. define the project and activity precedence relationships
- Path - The series of connected activities (or intermediate events between any two events) in a network
- Critical - Activities , events or paths which if delayed will delay the completion of the project.

Activity on Arrow (AOA) and Activity on Node (AON) Networks

- In AOA, arrows represent activities while nodes stands for events
- In AON, nodes represents activities with arrows to show the preceding relationships

Basis of Time Estimates

- These time estimate are expressions of the risks associated with the time required for each activity.
- Methods used for Time Estimating
  1. Time Study Approach
  2. Previous Project Data
  3. Guesstimating Approach

1. Time Study Approach

- In this approach the time **T** for completing an activity is,

$$T = \frac{Q}{p \times n}$$

where,

Q= total quantity of work

p= productivity factor (output per man day)

n = normal size of the crew

2. Previous Project Data

- Data from recently completed projects are used without consideration of Q, p and n.
- Past data from projects of similar cost, complexity are also used
- Data from foreign projects can also be used if local data is not available.

3. Guesstimating Approach

- In this approach experienced project personnel are asked to guess project activity durations
- More often than not, this is the only approach used in a project for estimating time duration.
- Often estimators make three estimates
    - Optimistic time (To)
    - Most likely time (Tm)
    - Pessimistic time (Tp)

Guesstimating Approach- cont.

- All possible times for a specific activity might be represented by a statistical distribution.
- The most likely time (Tm) for the activity is the mode of this distribution.
- The optimistic time (To) is determined such that the actual time required by the activity will be 'To' or greater about 99% of the time. ('To' is the Shortest time; therefore 99% of the time, actual time will be higher than 'To')
- The pessimistic time ('Tp') is determined such that about 99% of the time the activity will have a duration of 'Tp' or less. ('Tp' is the Longest time; therefore 99% of the time, actual time will be lesser than 'Tp')

Guesstimating Approach- cont.

- The expected time 'Te'

$$Te = (To + 4Tm + Tp) / 6$$

- The above formula for calculating expected time is based on Beta- Statistical distribution.
- If for a particular activity the time taken is known with certainty, then To = Tm = Tp.

Guesstimating Approach- cont.

- The variance

$$s^2 = ((Tp - To)/6)^2$$

- The standard deviation

$$s = (Tp - To)/6$$

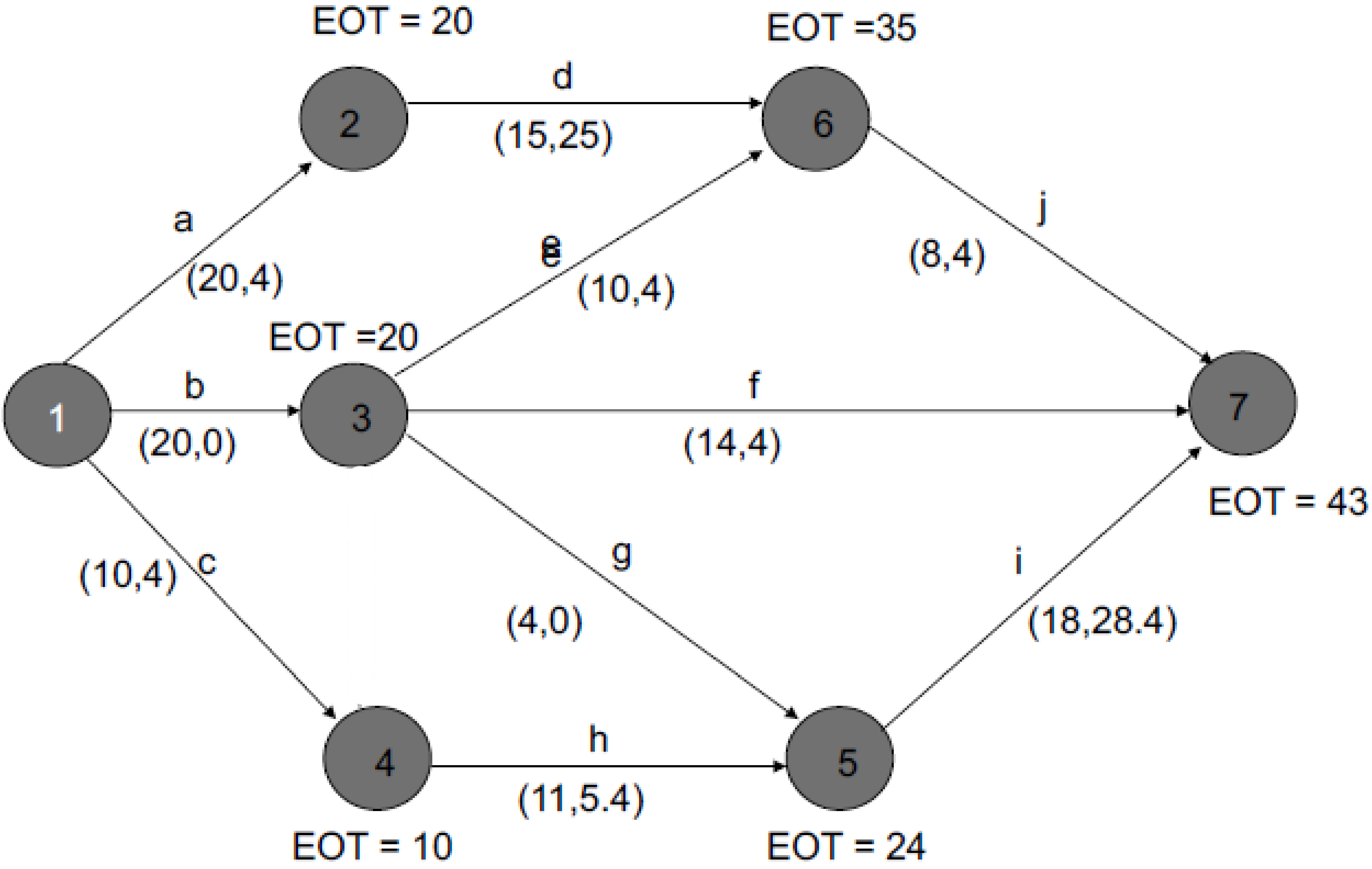
Example

Activity	Immediate Predecessor	To	Tm	Tp
a	-	10	22	22
b	-	20	20	20
c	-	4	10	16
d	a	2	14	32
e	b	8	8	20
f	b	8	14	20
g	b	4	4	4
h	c	2	12	16
i	g,h	6	16	38
j	d,e	2	8	14

Example – cont.

Activity	Immediate Predecessor	To	Tm	Tp	Te	s^2	s
a	-	10	22	22	20	4.0	2.0
b	-	20	20	20	20	0.0	0.0
c	-	4	10	16	10	4.0	2.0
d	a	2	14	32	15	25.0	5.0
e	b	8	8	20	10	4.0	2.0
f	b	8	14	20	14	4.0	2.0
g	b	4	4	4	4	0.0	0.0
h	c	2	12	16	11	5.4	2.3
i	g,h	6	16	38	18	28.4	5.3
j	d,e	2	8	14	8	4.0	2.0

Example – cont.



Slack or Float

- For any event

  EOT = Earliest Occurrence Time

  LOT = Latest Occurrence Time

- For any Activity

  EST = Earliest Start Time

  LST = Latest Start Time

Slack or Float = LST - EST

Uncertainty of Project Completion Time

- One of the duties of the project manager is to determine the probability that the project will be completed by the suggested deadline
- That is to find the completion time associated with a predetermined level of risk.

Uncertainty of Project Completion Time

$$Z = (D - Tc)/\ S$$

where

D = Desired Project Completion time

Tc = The critical path time

s^2 = The variance of the path

Z = The number of standard deviations of normal distribution

Example – cont.

If the PM has committed that the project be completed in 50 days what is his chance of completing on time?

D = 50

Tc = 43

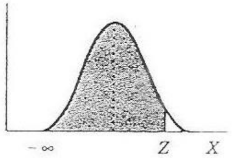
s^2 = 33

Z = (50 – 43) / 5.745

= 1.22 standard deviations

- The probability associated with Z = 1.22 from Normal Distribution tables is 0.8888
- The probability that the project be completed in 50 days is 88.88%.

Table 8-4. Cumulative (Single Tail) Probabilities of the Normal Probability Distribution (Areas under the Normal Curve from $-\infty$ to Z)



Example: the area to the left of $Z = 1.34$ is found by following the left Z column down to 1.3 and moving right to the .04 column. At the intersection read .9099. The area to the right of $Z = 1.34$ is $1 - .9099$ .0901. The area between the mean (dashed line) and $Z = 1.34 = .9099 - .5 = .4099$.

z	00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8880
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9932	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

Example – cont.

What deadline is consistent with 95% probability of on time completion?

Look in the Normal probability chart and find 0.9500

Find the corresponding Z value

Z = 1.645

also,

Tc = 43 (same)

s^2 = 33 (same)

Z = (D – Tc)/ S

Solving for D,

D = 52.45

- Thus, there is 95% chance that project will be finished in 52.45 days.

Example – cont.

As D → Tc ; Z → 0

From the tables for Z =0 the probability of project completion on time is 50%

The implication is that if the PM wants a reasonable chance of meeting the project deadlines there must be some slack in the project schedule.

Example – cont.

Non Critical Paths b-g-i

The variance of this path = 0 + 0 + 28.4 = 28.4

Which is slightly less than the variance of the critical path (33)

The path time is 42 days (20+4+18)

For D = 50 Z = (50 - 42)/5.33 = 1.5

Thus, there is 93.3% chance that this path will get completed in 50 days and the probability is higher than that for the critical path (88.8).

Example – cont.

Non Critical Paths c-h-i

The path time = 10 + 11 + 18 = 39

The total path variance is 37.8

Now for D = 50

Z = (D - T)/S = (50 - 39)/6.18 = 1.79

The corresponding probability is 96.33 %.

Thus, we have a 96.33% chance of this non critical path to allow the project to be on time.

Example – cont.

Non Critical Paths c-h-i

If the desired completion time D = 43 (Critical time)

Z= (43-39)/6.18 = 0.65

Thus the chance of non critical path c-h-i being on time is 74%

Example 2

The estimates for optimistic, most probable and pessimistic completion times for a project having 13 activities are given in the Table 1. (Durations are given in months)

a. Draw the network
b. Calculate all expected activity times and variances
c. Determine the critical path and the critical time for project completion
d. What is the probability that the project can be completed within the critical time?
e. Calculate the probability that the project will be completed in 46 months.

Activity	Predecessors	Optimistic	Most Probable	Pessimistic
A	-	12	14	16
B	-	8	10	12
C	-	6	7	8
D	A	12	13	14
E	A	8	9	9
F	C	7	8	8
G	C	11	13	14
H	B,F	9	10	11
I	B,F	14	14	16
J	G,I	9	11	12
K	E,H	8	10	11
L	E,H	9	9	10
M	D,L	10	11	12

Table 1