Software Project Management

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Project Scheduling cont…

What is PERT and how does it work?

- PERT (Program Evaluation and Review Technique) is a variation of CPM:
  - incorporates uncertainty about duration of tasks.
- Gantt charts can be derived automatically from PERT charts.
- Gantt chart representation of schedule is helpful in planning the utilization of resources,
  - while PERT chart is more useful for monitoring the timely progress of activities.

Program Evaluation and Review Technique (PERT)

- The activity durations computed using an activity network are only estimated duration.
- It is therefore not possible to estimate the worst case (pessimistic) and best case (optimistic) estimations using an activity diagram.
- Since, the actual durations might vary from the estimated durations,
  - the utility of the activity network diagrams are limited.
- The CPM can be used to determine the duration of a project,
  - but does not provide any indication of the probability of meeting that schedule.

Program Evaluation and Review Technique (PERT)

- PERT charts are a more sophisticated form of activity chart.
- Project managers know that there is considerable uncertainty about how much time a task would exactly take to complete.
- The duration assigned to tasks by the project manager are after all only estimates.

Program Evaluation and Review Technique (PERT)

- Therefore, in reality the duration of an activity is a random variable with some probability distribution.
- In this context, PERT charts can be used to determine the probabilistic times for reaching various project milestones, including the final milestone.

Program Evaluation and Review Technique (PERT)

- PERT charts, like activity networks consist of a network of boxes and arrows.
- The boxes represent activities and the arrows represent task dependencies.
- A PERT chart represents the statistical variations in the project estimates assuming these to be normal distribution.

Program Evaluation and Review Technique (PERT)

- PERT allows for some randomness in task completion times, and therefore provides the capability to determine
  - the probability for achieving project milestones based on the probability of completing each task along the path to that milestone.

Program Evaluation and Review Technique (PERT)

- Each task is annotated with three estimates:
  - **Optimistic (O):** the best possible case task completion time.
  - **Most likely estimate (M):** Most likely task completion time.
  - **Worst case (W):** The worst possible case task completion time.

Program Evaluation and Review Technique (PERT)

- The optimistic (O) and worst case (W) estimates represent the extremities of all possible scenarios of task completion.
- The most likely estimate (M) is the completion time that has the highest probability.
- The three estimates are used to compute the expected value of the standard deviation.

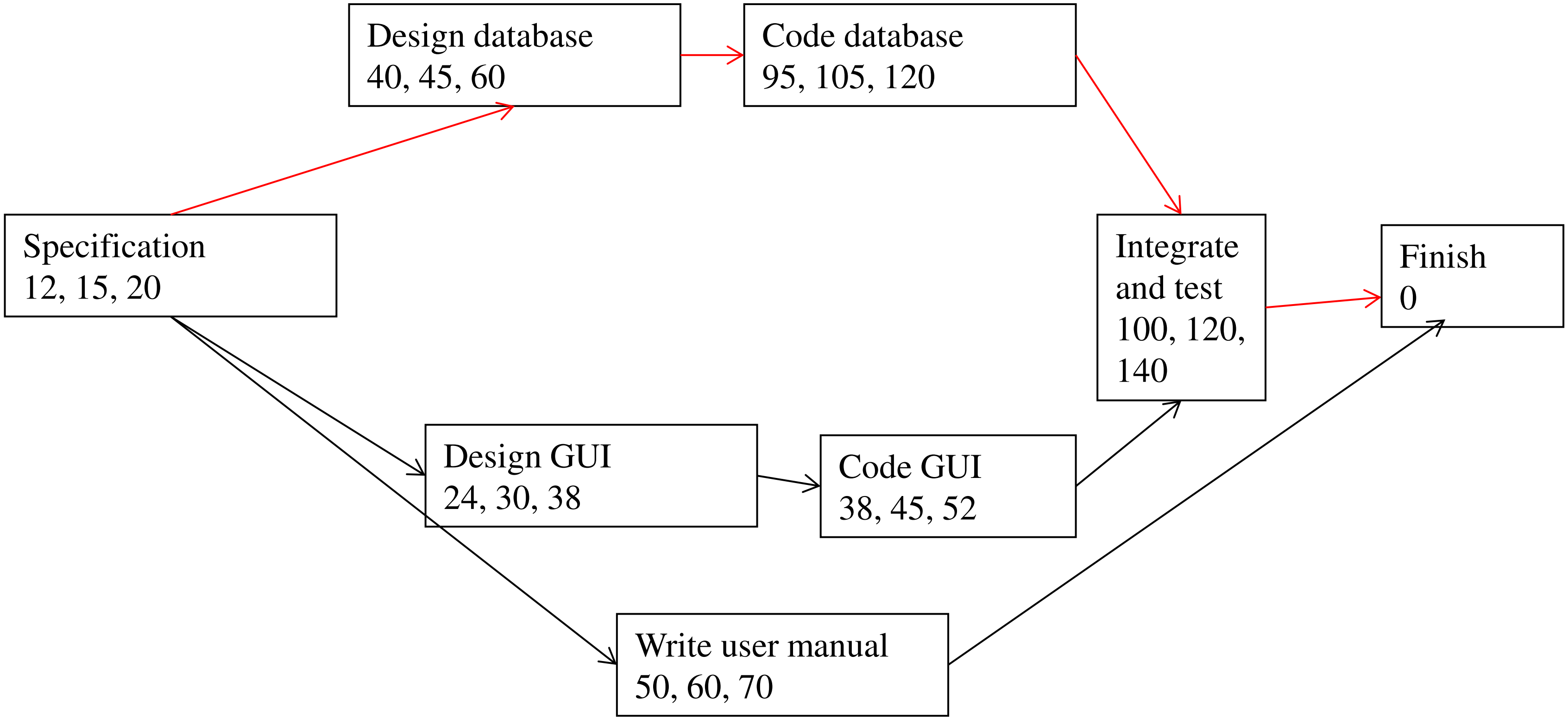
Program Evaluation and Review Technique (PERT)

- The entire distribution lies between the interval *(M-3*ST)* and *(M+3*ST)*,
  - where *ST* is the standard deviation.
- Thus, the standard deviation for a task is *ST=(W-O)/6*.
- The mean estimated time *ET=(O+4M+W)/6*.

Program Evaluation and Review Technique (PERT)

- Since all possible completion times between the minimum and maximum duration for every task has to be considered
  - there can be many critical paths,
    - depending on the various permutations of the estimates for each task.
- This makes critical path analysis in PERT charts very complex.

Program Evaluation and Review Technique (PERT)



PERT

- PERT was developed to take account of the uncertainty surrounding estimates of task durations.
- It was developed in an environment of expensive, high risk and state-of-the-art projects
  - Not that dissimilar to many of today's large software projects.

Estimates in PERT

- Most likely time
  - The time we would expect the task to take under normal circumstances.
  - We shall identify this by the letter *m or M*.
- Optimistic time
  - The shortest time in which we could expect to complete the activity, barring outright miracles.
  - We shall use the letter *a* or O, for this.
- Pessimistic time
  - The worst possible time, allowing for all reasonable eventualities but excluding 'acts of God and warfare'.
  - We shall call this *b or P*.

Estimates in PERT

- PERT then combines these three estimates to form a single expected duration, t_e or ET, using the formula

  t_e= (a+4m+b)/6 (t_e, a, m & b correspond to ET, O, M & P respectively).
- The expected durations are used to carry out a forward pass through a network, using the same method as the CPM technique.
- In this case, however, the calculated event dates are not the earliest possible dates but the dates by which we expect to achieve those events.

PERT event labelling convention

Event number	Target date
Expected date	Standard Deviation

Activity standard deviations

- A quantitative measure of the degree of uncertainty of an activity duration estimate may be obtained by calculating the standard deviation *s* of an activity time using the formula
  - $s=(b-a)/6$
- The activity standard deviation is proportional to the difference between the optimistic and pessimistic estimates, and can be used as a ranking measure of the degree of uncertainty of risk for each activity.

Example

Activity Label	Activity Name
A	Hardware Selection
B	System configuration
C	Install hardware
D	Data migration
E	Draft office procedures
F	Recruit staff
G	User training
H	Install and test

Example cont…

Activity Label	Optimistic (a)	**Activity duration (weeks),** Most Likely (m)	Pessimistic (b)	Precedents
A	5	6	8	---
B	3	4	5	---
C	2	3	3	A
D	3.5	4	5	B
E	1	3	4	B
F	8	10	15	---
G	2	3	4	E,F
H	2	2	2.5	C,D

Expected Time Estimates (t_e)

Activity	Activity duration (weeks)			
	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Expected $t_e=(a+4m+b)/6$
A	5	6	8	(5+4*6+8)/6= 6.17
B	3	4	5	(3+4*4+5)/6= 4
C	2	3	3	(2+4*3+3)/6= 2.83
D	3.5	4	5	(3.5+4*4+5)/6= 4.08
E	1	3	4	(1+4*3+4)/6= 2.83
F	8	10	15	(8+4*10+15)/6= 10.5
G	2	3	4	(2+4*3+4)/6= 3
H	2	2	2.5	(2+4*2+2.5)/6= 2.08

Activity Deviation (s)

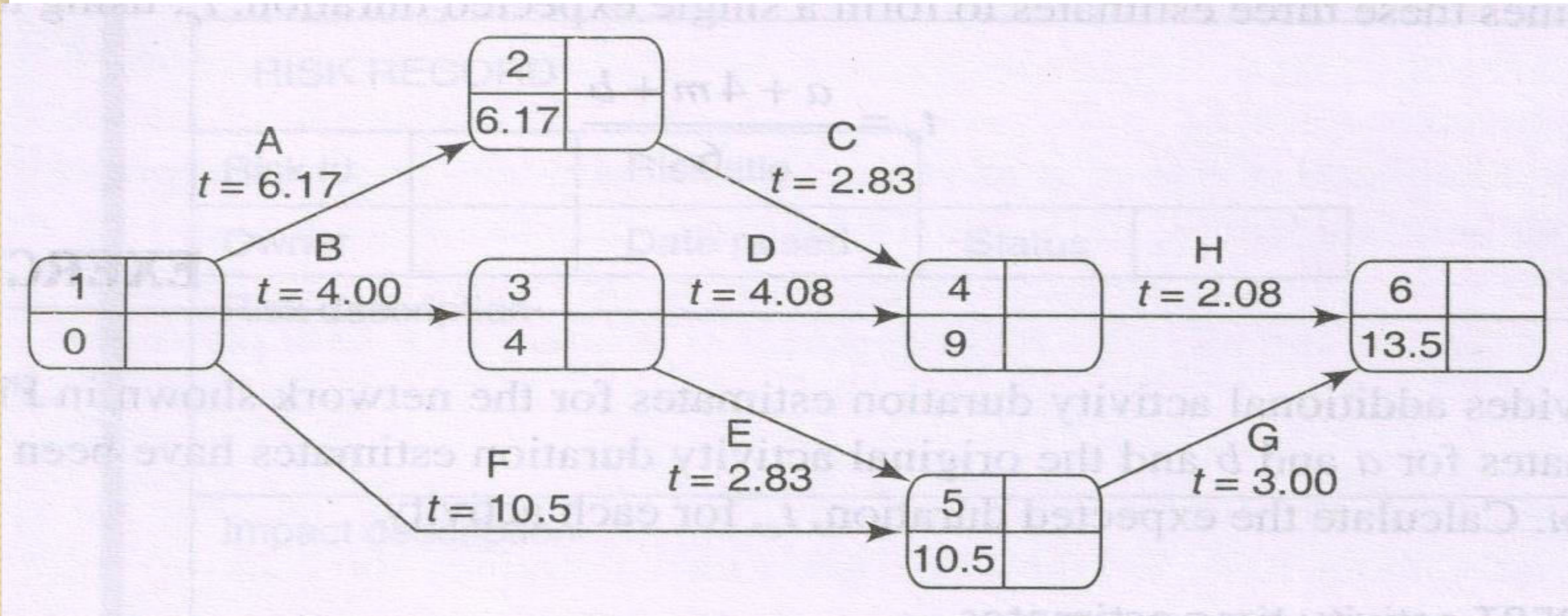
Activity	Optimistic (a)	Pessimistic (b)	Standard deviation s=(b-a)/6
A	5	8	(8-5)/6= 0.5
B	3	5	(5-3)/6= 0.33
C	2	3	(3-2)/6= 0.17
D	3.5	5	(5-3.5)/6= 0.25
E	1	4	(4-1)/6= 0.5
F	8	15	(15-8)/6= 1.17
G	2	4	(4-2)/6= 0.33
H	2	2.5	(2.5-2)/6= 0.08

Expected Time Estimates (t_e) & SD (s)

Activity	Activity duration (weeks)				
	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Expected Time (t_e)	Standard Deviation (s)
A	5	6	8	6.17	(8-5)/6= 0.5
B	3	4	5	4	(5-3)/6= 0.33
C	2	3	3	2.83	(3-2)/6= 0.17
D	3.5	4	5	4.08	(5-3.5)/6= 0.25
E	1	3	4	2.83	(4-1)/6= 0.5
F	8	10	15	10.5	(15-8)/6= 1.17
G	2	3	4	3	(4-2)/6= 0.33
H	2	2	2.5	2.08	(2.5-2)/6= 0.08

Example

- In the following PERT network, we expect the project to take 13.5 weeks.
- The network is obtained after forward pass.



The likelihood of meeting targets

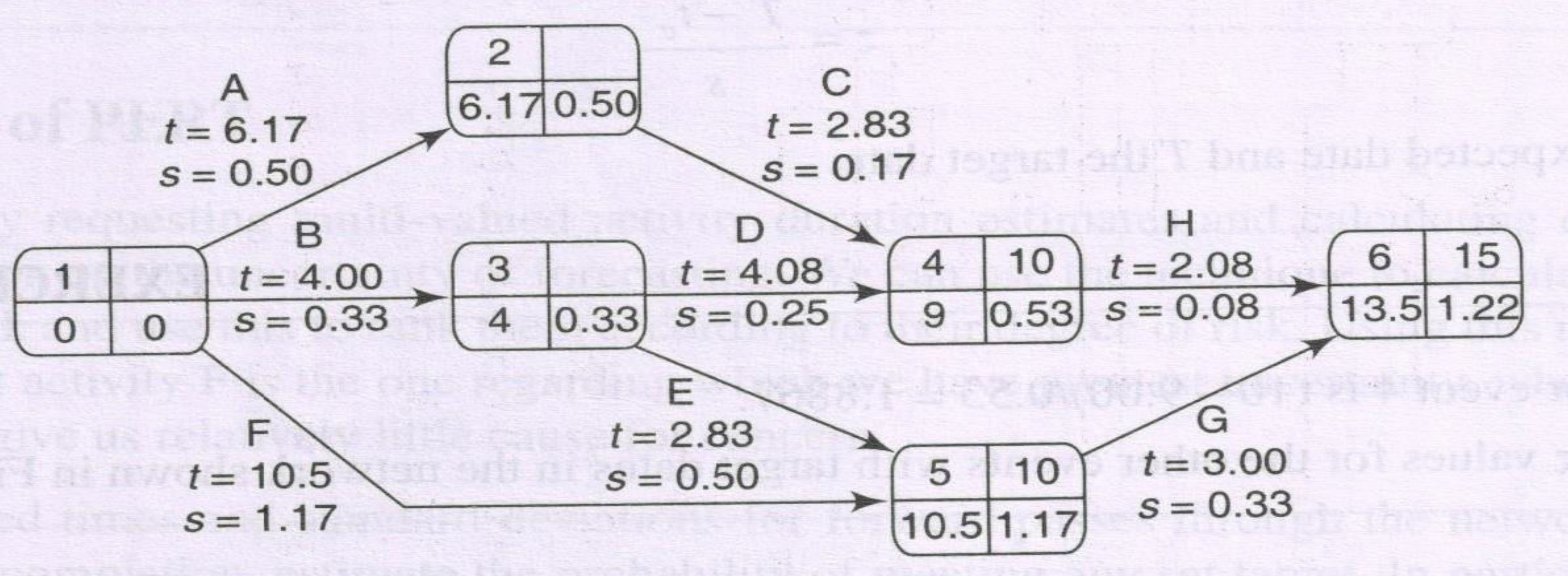
- The main advantage of the PERT technique is that
  - it provides a method for estimating the probability of meeting or missing target dates.
- There might be only a single target date, the project completion,
  - but we might wish to set additional intermediate targets.

The likelihood of meeting targets

- Suppose that we must complete the project within 15 weeks at the outside.
- We expect it will take 13.5 weeks but it could take more or perhaps less.
- In addition, suppose
  - that activity C must be completed by week 10,
    - as it is to be carried out by a member of staff who is scheduled to be working on another project, and
  - that event 5 represents the delivery of intermediate products to the customer,
    - which must take place by week 10.

The likelihood of meeting targets

- These three target dates are shown on the PERT network below.



The likelihood of meeting targets

- The PERT technique uses the following three-step method for calculating the probability of meeting or missing a target date:
  - Calculate the standard deviation of each project event.
  - Calculate the z value for each event that has a target date.
  - Convert z values to probabilities.

Calculating the standard deviation of each project event

- Standard deviations for the project events can be calculated by carrying out a forward pass using the activity standard deviations.
- To add two standard deviations
  - Add their squares and then find the square root of the sum.
- One practical outcome of this is that
  - the contingency time to be allocated to a sequence of activities as a whole would be less than the sum of the contingency allowances for each of the component activities.

Event Standard Deviation

Event	Event Standard Deviation
1	0
2	$\sqrt{(0.5)^2}=0.5$
3	$\sqrt{(0.33)^2}=0.33$
4	$\max\{\sqrt{(0.33)^2+(0.25)^2}, \sqrt{(0.5)^2+(0.17)^2}\} = \max\{\sqrt{0.1089+0.0625}, \sqrt{0.25+0.0289}\} = \max\{\sqrt{0.1714}, \sqrt{0.2789}\} = \max\{0.41, 0.53\} = 0.53$
5	$\max\{\sqrt{(1.17)^2}, \sqrt{(0.33)^2+(0.5)^2}\} = \max\{1.17, \sqrt{0.1089+0.25}\} = \max\{1.17, \sqrt{0.3589}\} = \max\{1.17, 0.6\} = 1.17$
6	$\max\{\sqrt{(0.53)^2+(0.08)^2}, \sqrt{(1.17)^2+(0.33)^2}\} = \max\{\sqrt{0.2809+0.0064}, \sqrt{1.3689+0.1089}\} = \max\{\sqrt{0.2873}, \sqrt{1.4778}\} = \max\{0.54, 1.22\} = 1.22$

Calculating the z values

- The z value is calculated for each node that has a target date.
- It is equivalent to the number of standard deviations between the node's expected and target dates.
- It is calculated using the formula
  - $z=(T-t_e)/s$
    - where t_e is the expected date and T the target date.

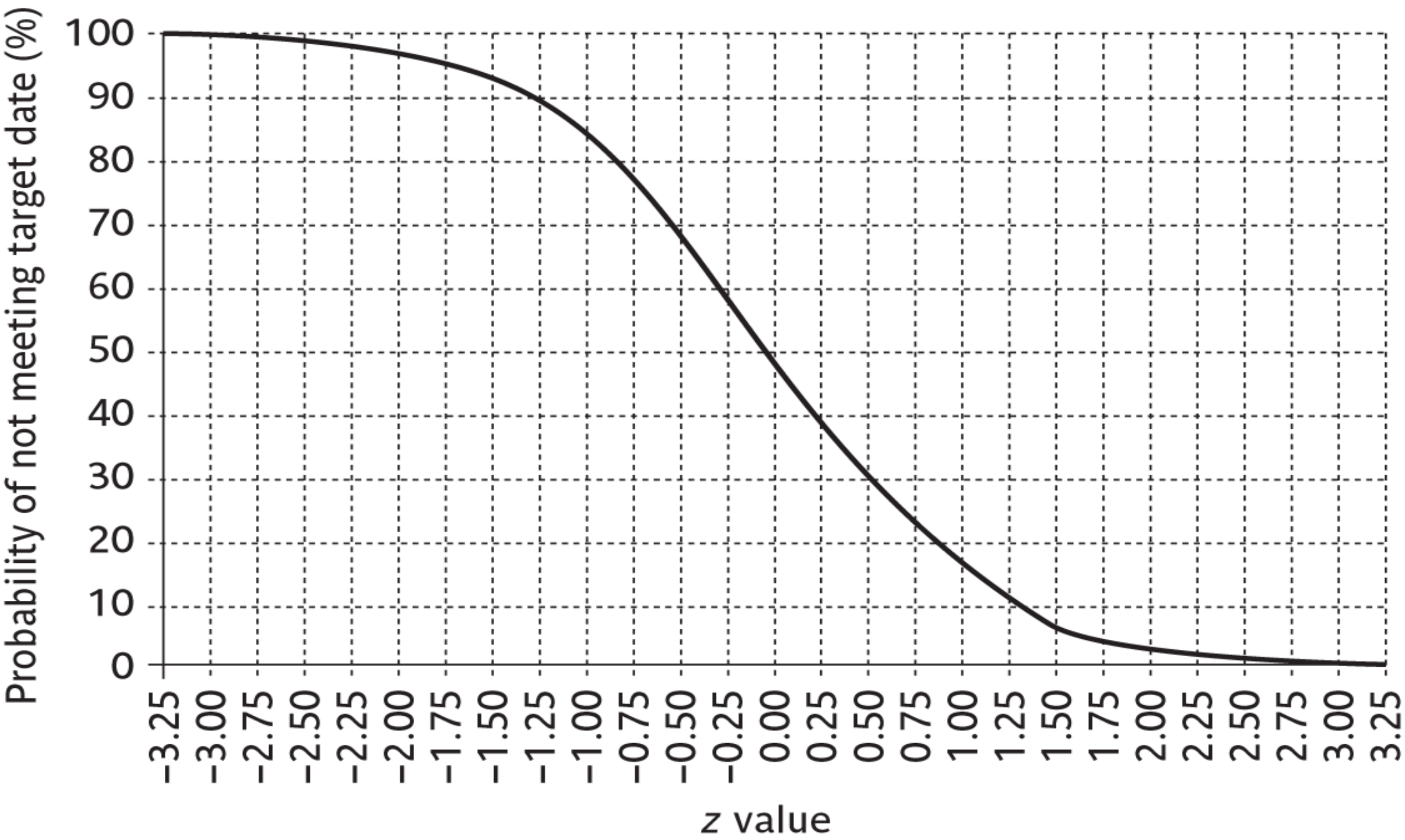
z Values for different events

- Event 4
  - Target date is 10
  - $z=(T-t_e)/s=(10-9)/0.53=1/0.53=1.89$
- Event 5
  - Target date is 10.
  - $z=(T-t_e)/s=(10-10.5)/1.17= - 0.5/1.17= - 0.43$
- Event 6
  - Target date is 15
  - $z=(T-t_e)/s=(15-13.5)/1.22=1.5/1.22=1.23$

Converting z values to probabilities

- A *z* value may be converted to the probability of not meeting the target date by using the shown graph.
- This graph is the equivalent of tables of *z* values, also known as standard deviation, which may be found in most statistics textbooks.

Converting z values to probabilities



Probabilities

- Event 4
  - $\Phi(1.89)=0.97$
  - So, there is a probability of 97% risk of meeting the target date.
  - Or, there is a probability of 3% risk of not meeting the target date.
- Event 5
  - $\Phi(-0.43)=1-\Phi(0.43)=1-0.67=0.33$
  - There is a probability of 33% risk of meeting the target date.
  - There is a probability of 67% risk of not meeting the target date.

Probabilities

- Event 6
  - $\Phi(1.23)=0.89$
  - There is a probability of 89% risk of meeting the target date.
  - There is a probability of 11% risk of not meeting the target date.

Normal Table

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.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	.8830
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	.9922	.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

Advantages of PERT

- PERT focuses attention on the uncertainty of forecasting
    - By requesting multi-valued activity duration estimates and calculating expected dates.
- The technique can be used to
    - calculate the standard deviation for each task and
    - rank them according to their degree of risk.

Advantages of PERT

- Using this ranking, it can be seen that, for example, that
  - activity F is the one regarding which we have greatest uncertainty, whereas
  - activity C should , in principle, give us relatively little cause for concern.

Advantages of PERT

- If we use the expected times and standard deviations for forward passes through the network,
  - we can, for any event or activity completion,
    - estimate the probability of meeting any set target.
- In particular, by setting target dates along the critical path,
  - we can focus on those activities posing the greatest risk to the project's schedule.

Summary

- We have discussed PERT.
- Solved some examples on PERT.

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Thank you