Risk Management
Part II

Lecture 9 by Professor Vladimir Geroimenko

Module “Software Project Management“

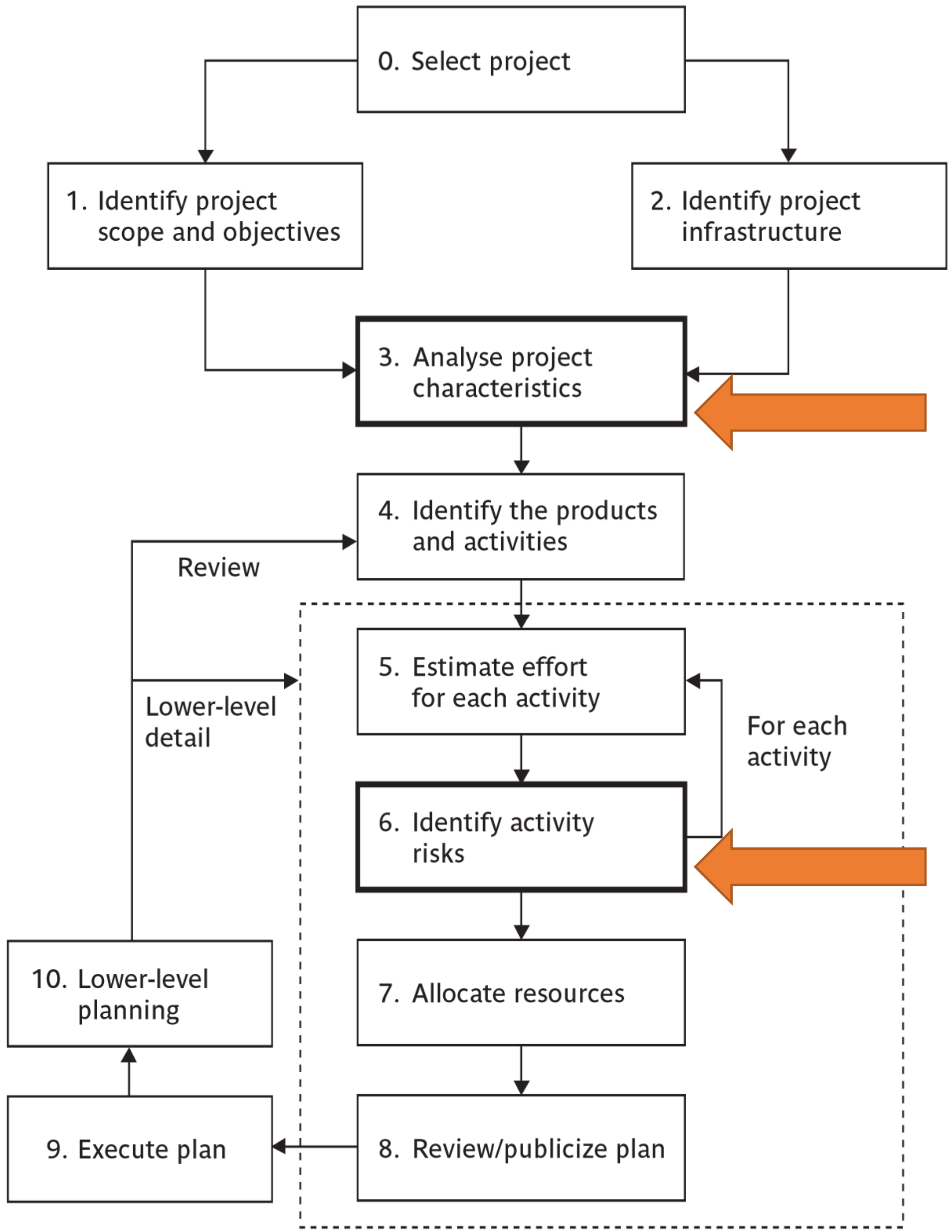
20 November 2016 - Teaching Week 9

Textbook reference: Chapter 7

Lecture Outline

- Using PERT to evaluate the effects of uncertainty
- Monte Carlo simulation
- Critical chain planning concepts

Managing risks in the Step Wise framework



Using PERT to evaluate the effects of uncertainty

- PERT stands for Program Evaluation and Review Technique
- PERT was developed in the USA for the Fleet Ballistic Missiles Program.
- PERT was developed in an environment of expensive, high-risk and state-of-the-art projects – this is that are similar to many today's large software projects.
- PERT was developed to take account of the uncertainty surrounding estimates of task durations.

The three PERT estimates

- PERT is very similar to CPM (Critical Path Method), however it requires not one but three estimates for each activity:
- **Optimistic time (a)** – the shortest time in which we could expect to complete the activity.
- **Most likely time (m)** – the time we would expect the task to take under normal circumstances.
- **Pessimistic time (b)** – the worst possible time, allowing for all reasonable eventualities.

The expected duration

PERT combines the three estimates (a, m and b) into a single **expected duration t_e** using the following formula:

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

a - optimistic time

m - most likely time

b - pessimistic time

Example: Calculating the expected durations

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	
A	5	6	8	?	
B	3	4	5	?	
C	2	3	3	?	
D	3.5	4	5	?	
E	1	3	4	?	
F	8	10	15	?	
G	2	3	4	?	
H	2	2	2.5	?	

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

Exercise: Expected durations (in weeks)

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	
A	5	6	8	?	
B	3	4	5	?	
C	2	3	3	?	
D	3.5	4	5	?	
E	1	3	4	?	
F	8	10	15	?	
G	2	3	4	?	
H	2	2	2.5	?	

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

Let's calculate this

Example: Expected durations (in weeks)

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	
A	5	6	8	?	
B	3	4	5	?	
C	2	3	3	?	
D	3.5	4	5	?	
E	1	3	4	?	
F	8	10	15	?	
G	2	3	4	3.00	
H	2	2	2.5	?	

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

$$3.00 = \frac{2 + 4 * 3 + 4}{6}$$

Example: Expected durations (in weeks)

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	
A	5	6	8	6.17	
B	3	4	5	4.00	
C	2	3	3	2.83	
D	3.5	4	5	4.08	
E	1	3	4	2.83	
F	8	10	15	10.50	
G	2	3	4	3.00	
H	2	2	2.5	2.08	

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

$$3.00 = \frac{2 + 4 * 3 + 4}{6}$$

The standard deviation

- The standard deviation is a quantitative measure of the degree of uncertainty of an activity duration estimate.
- The activity standard deviation **can be used as a ranking measure** of the degree of uncertainty or risk for each activity.
- PERT calculates **standard deviation s** using the following formula:

$$s = \frac{b - a}{6}$$

a - optimistic time

b - pessimistic time

Example: Calculating standard deviations

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	s St deviation
A	5	6	8	6.17	?
B	3	4	5	4.00	?
C	2	3	3	2.83	?
D	3.5	4	5	4.08	?
E	1	3	4	2.83	?
F	8	10	15	10.50	?
G	2	3	4	3.00	?
H	2	2	2.5	2.08	?

$$s = \frac{b - a}{6}$$

Example: Standard deviations

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	s St deviation
A	5	6	8	6.17	0.50
B	3	4	5	4.00	0.33
C	2	3	3	2.83	0.17
D	3.5	4	5	4.08	0.25
E	1	3	4	2.83	0.50
F	8	10	15	10.50	1.17
G	2	3	4	3.00	0.33
H	2	2	2.5	2.08	0.08

$$s = \frac{b - a}{6}$$

Exercise: Rank the risks of the activities

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	s St deviation
A	5	6	8	6.17	0.50
B	3	4	5	4.00	0.33
C	2	3	3	2.83	0.17
D	3.5	4	5	4.08	0.25
E	1	3	4	2.83	0.50
F	8	10	15	10.50	1.17
G	2	3	4	3.00	0.33
H	2	2	2.5	2.08	0.08

More Risky
?
?
?
?
?
?
Less Risky

Exercise: Rank the risks of the activities

Activity	a Optimistic	m Most likely	b Pessimistic	t_e Expected	s St deviation
A	5	6	8	6.17	0.50
B	3	4	5	4.00	0.33
C	2	3	3	2.83	0.17
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F	8	10	15	10.50	1.17
G	2	3	4	3.00	0.33
H	2	2	2.5	2.08	0.08

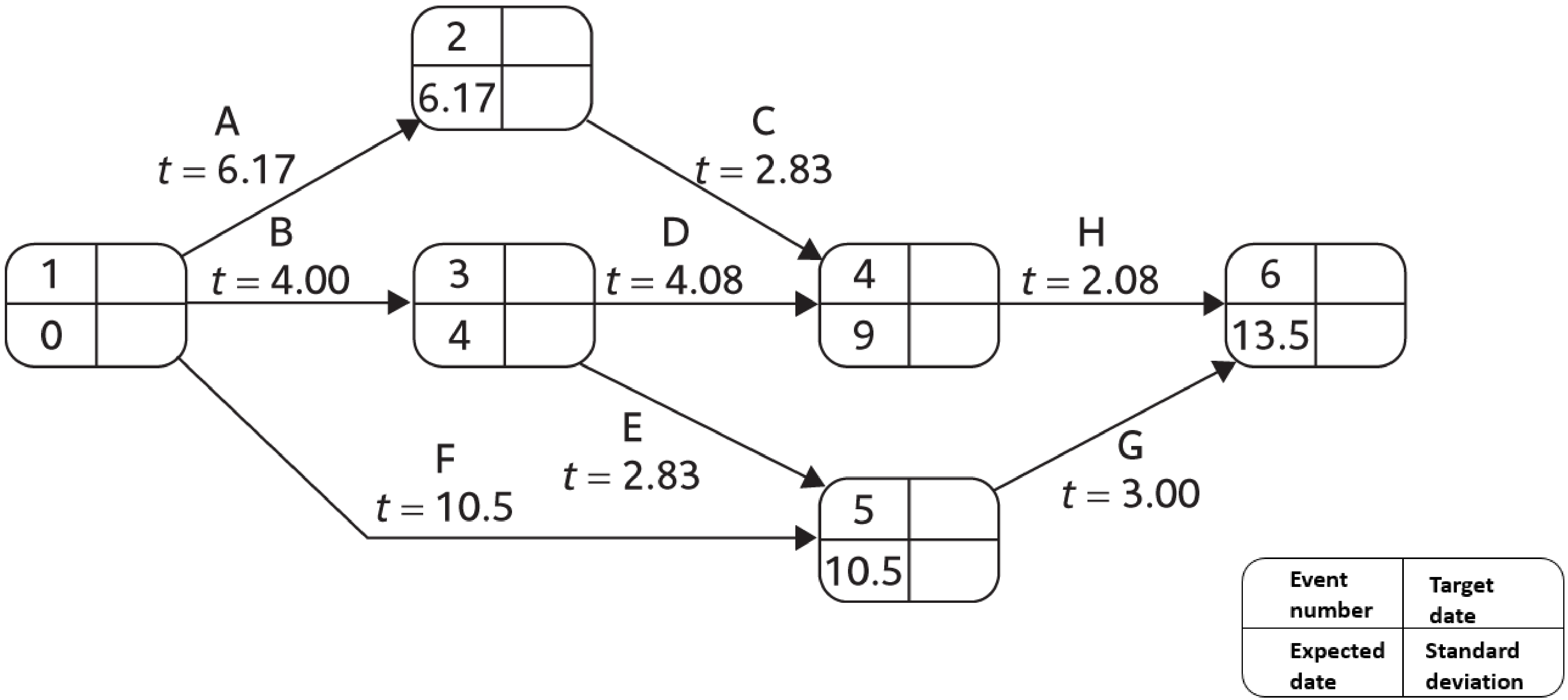
More Risky
F
A, E
B, G
D
C
H
Less Risky

Using expected durations

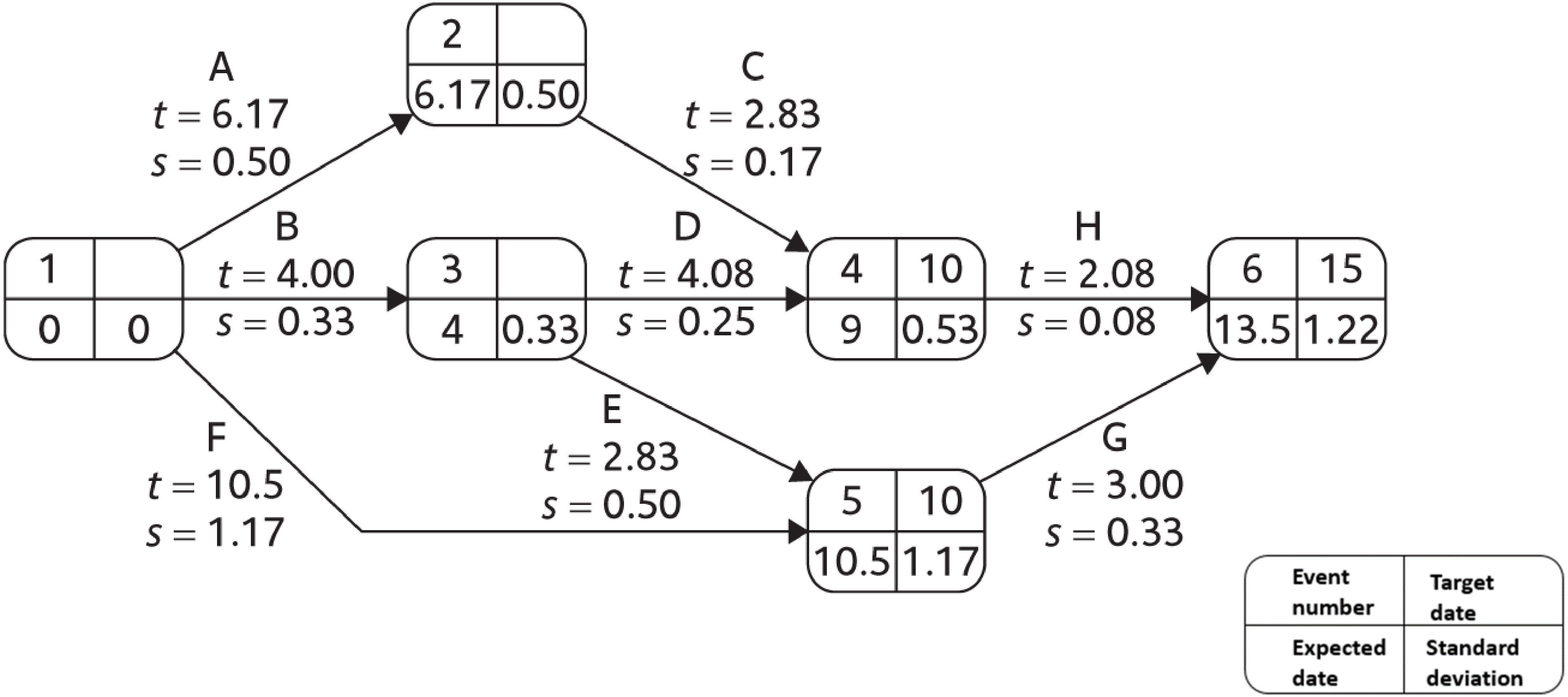
- The expected durations are used to carry out **a forward pass** through a network, using the same technique as CPM.
- Unlike the CPM approach, the PERT method does not indicate *the earliest date* by which we could complete the project but ***the expected date: “We expect to complete the project by …”***
- Next slide – The PERT network after the forward pass (as an activity-on-arrow network):

Event number	**Target date**
Expected date	**Standard deviation**

The PERT network after the forward pass



The PERT network with calculated event standard deviations and three target dates



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**:

1. Calculate the standard deviation of each project event;
2. Calculate the **z value** for each event that has a target date;
3. Convert z values to probabilities;

$$z = \frac{T - t_e}{s}$$

T is the target date

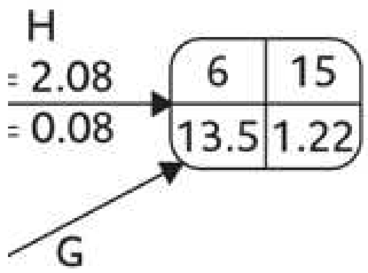
$\mathbf{t_e}$ is the expected date

Calculating the z value: an example

$$z = \frac{T - t_e}{s}$$

The z value for event 6 (= completing the project by week 15):

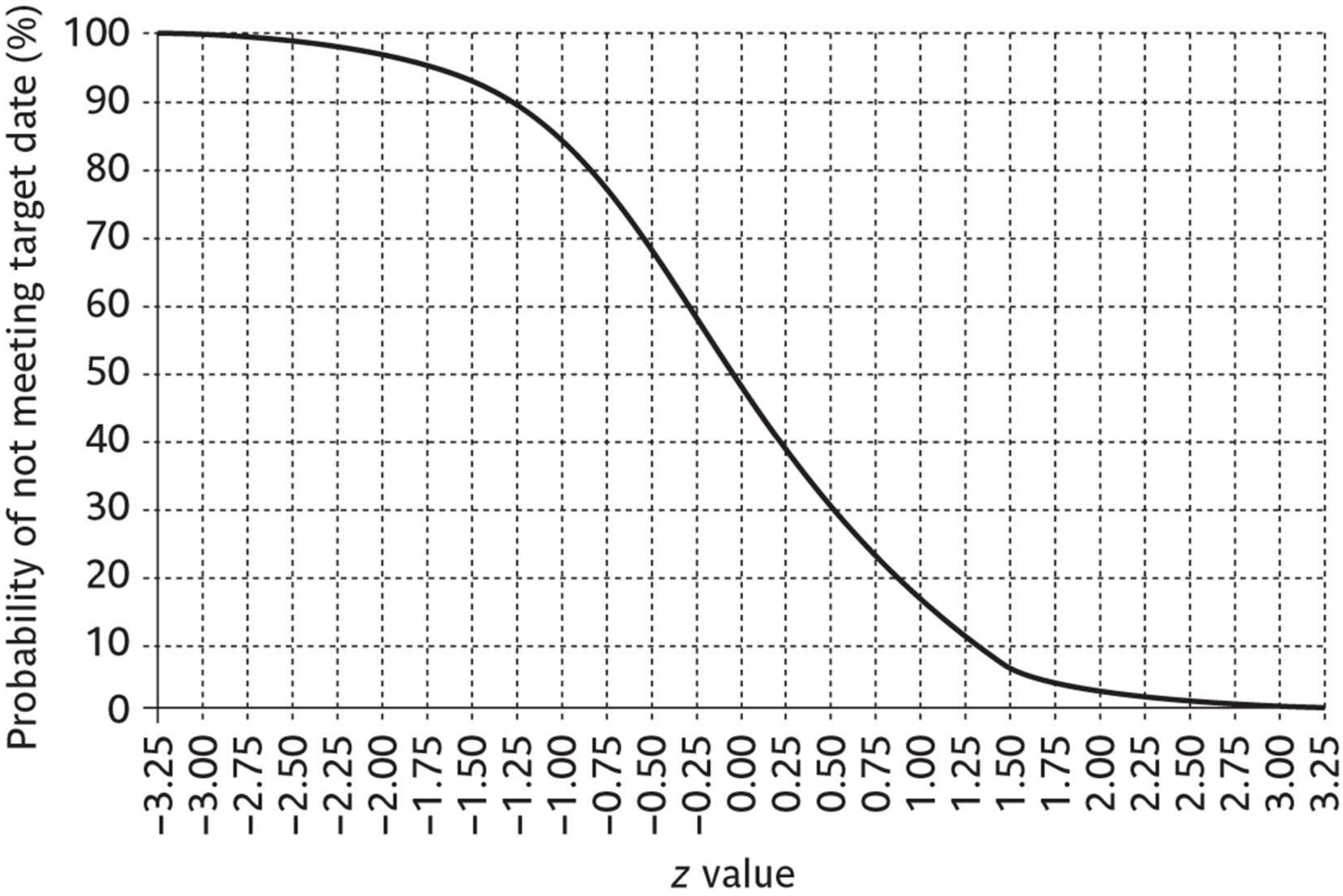
$$\frac{15 - 13.5}{1.22} = 1.23$$



Event number	Target date
Expected date	Standard deviation

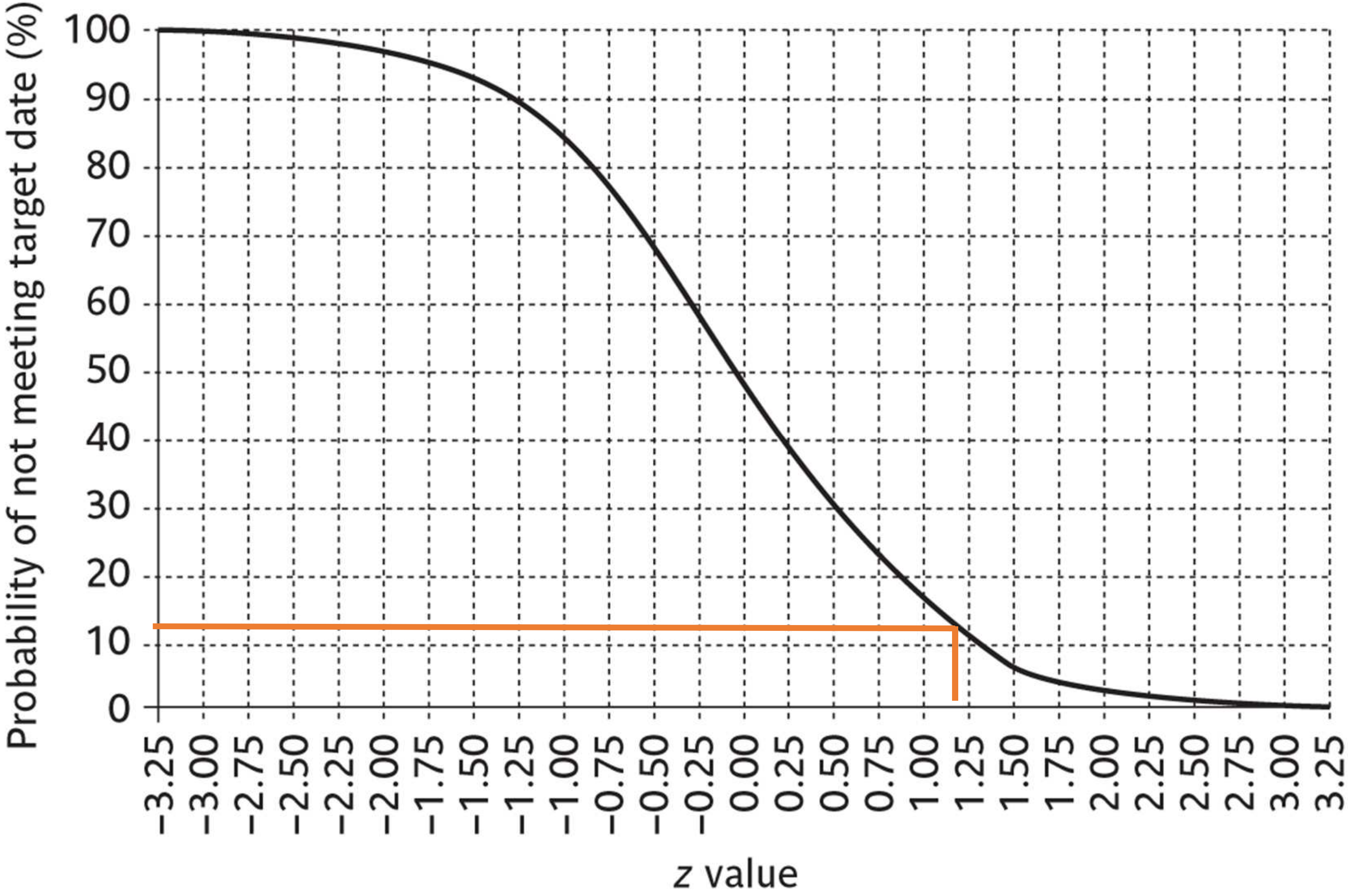
Converting z values to probabilities

A z value can be converted to the probability of not meeting the target date by using the following graph.



For z = 1.23 (in our example)

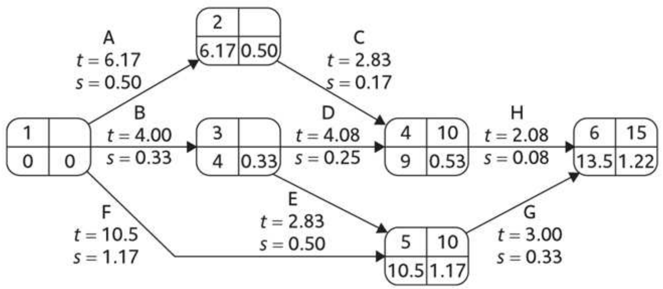
The probability of not meeting the target date is approx. 12%. The probability of meeting is ca. 88%

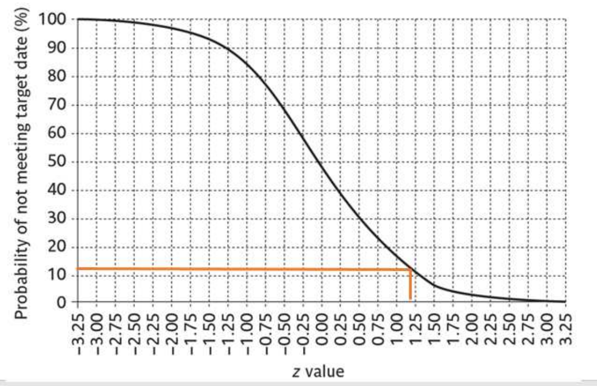


Summary: The advantages of PERT

- PERT focuses on uncertainty of forecasting.
- PERT can calculate the standard deviation for each activity and to rank them according to their degree of risk. Using this ranking: F have grater uncertainty, C – no big concern
- PERT allows to calculate the probability of meeting / not meeting of any set target.

More Risky
F
A, E
B, G
D
C
H
Less Risky

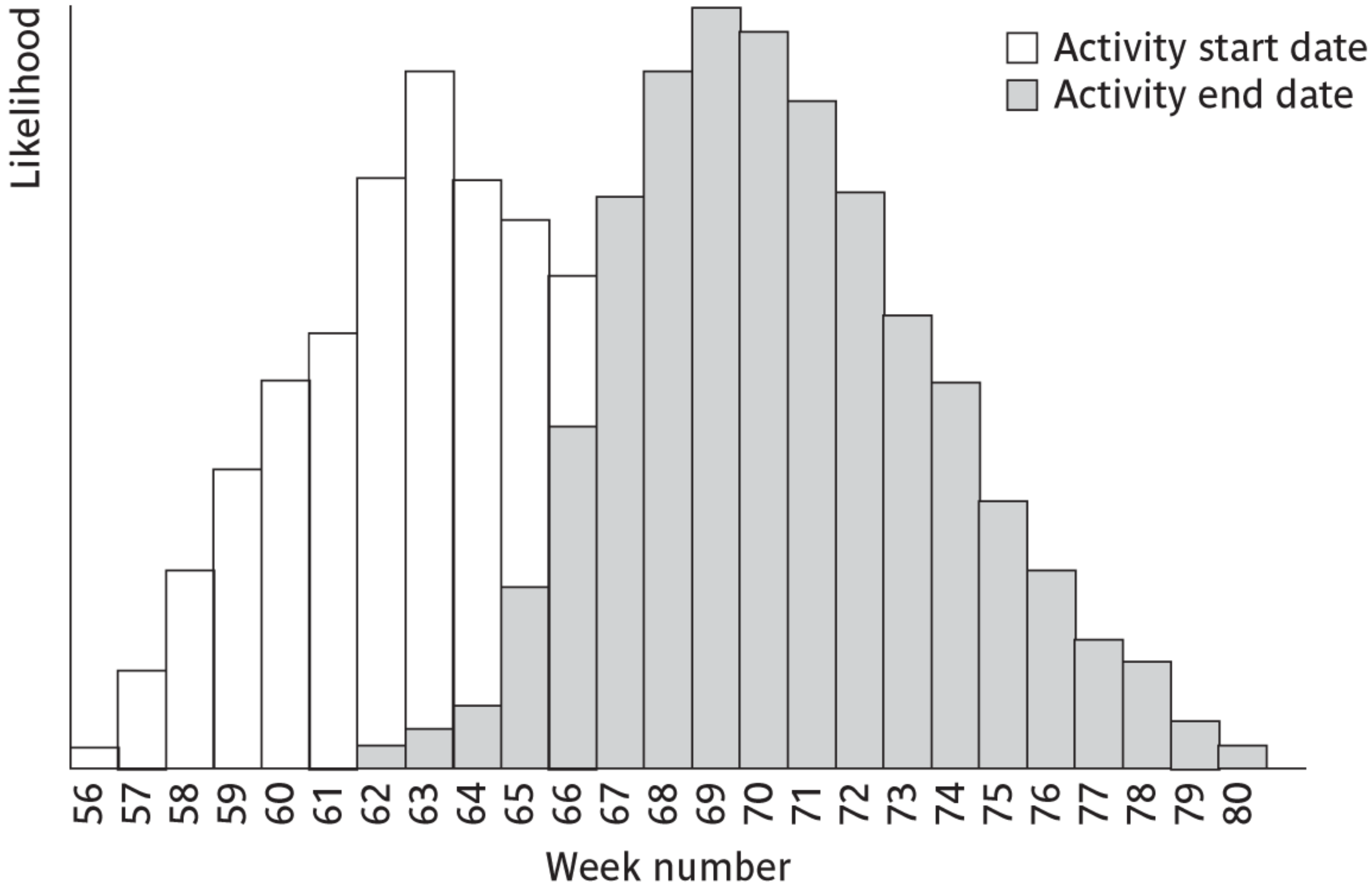




Monte Carlo simulation

- An alternative to the PERT technique.
- Based on calculating activity completion times for a project network **a large number of times**, each time selecting estimated activity times **randomly** from a set of estimates for each activity.
- Historic data from previous similar project can be used.
- The results can be displayed as a graph.
- There are a number of packages available for carrying out Monte Carlo simulation.

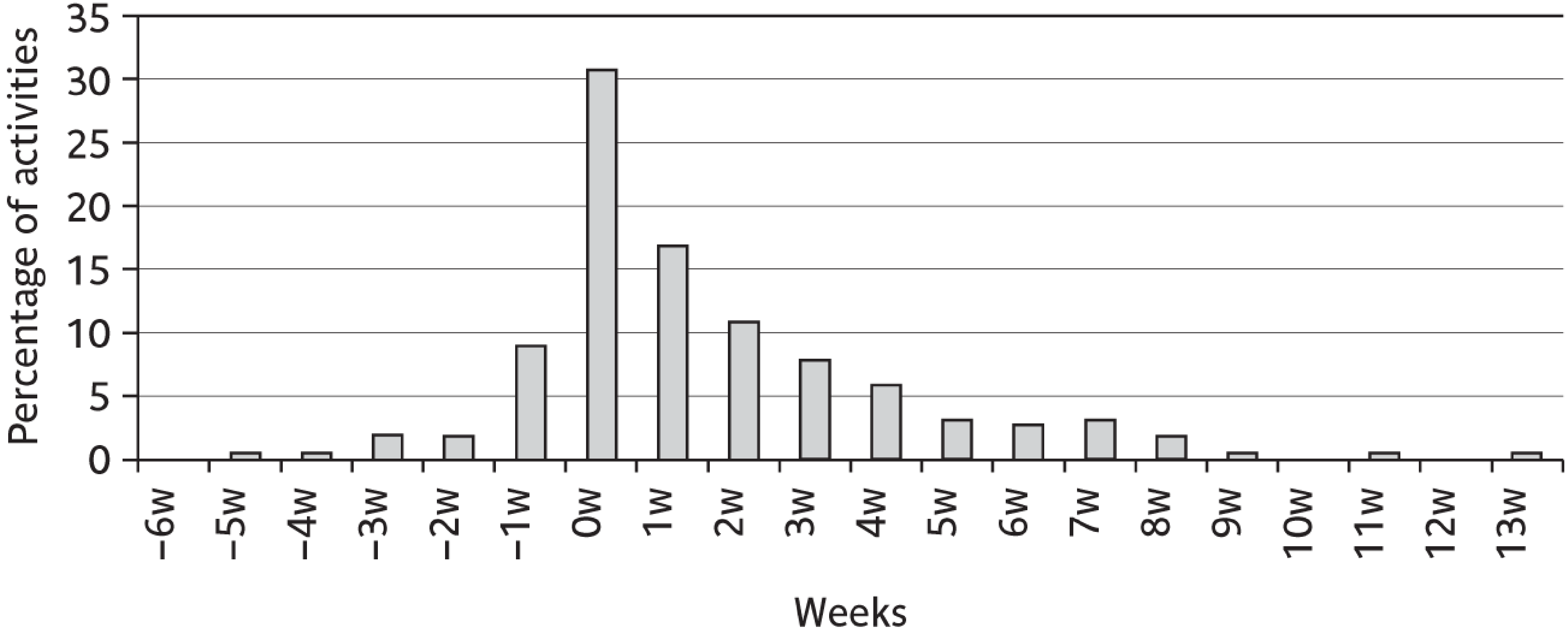
Monte Carlo simulation



Critical chain – The main idea

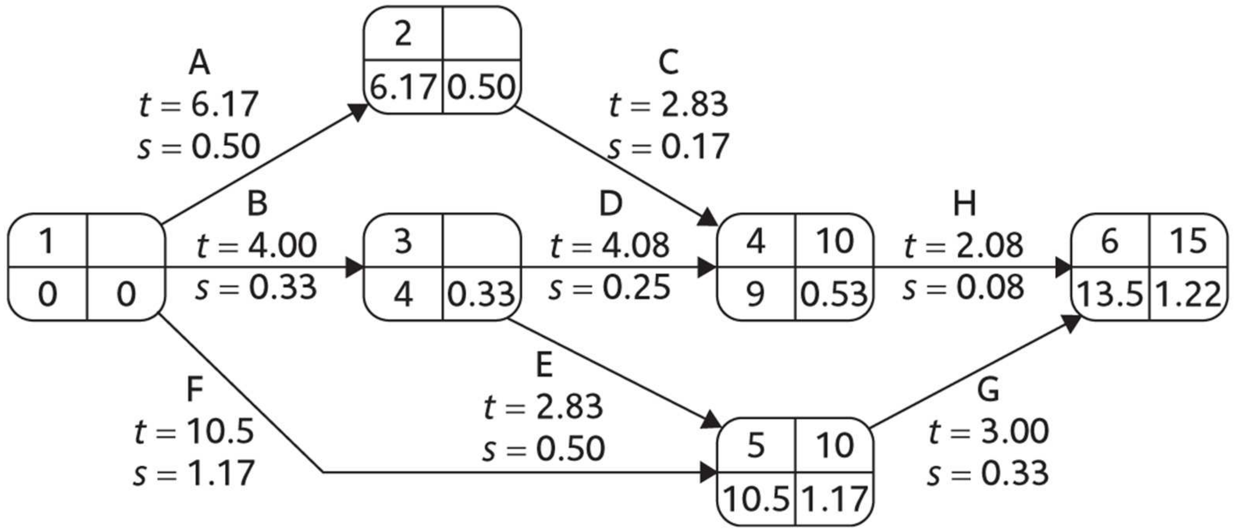
- The project manager is forced to focus on the activities where the actual durations exceed the target (i.e. that can be late)
- Activities which are actually completed **before** the target date are likely to be overlooked.
- But these early completions, properly handled, could allow the meet the target completion date if the later activities are delayed.

Percentage of activities early or late (van Genuchten, 1991)



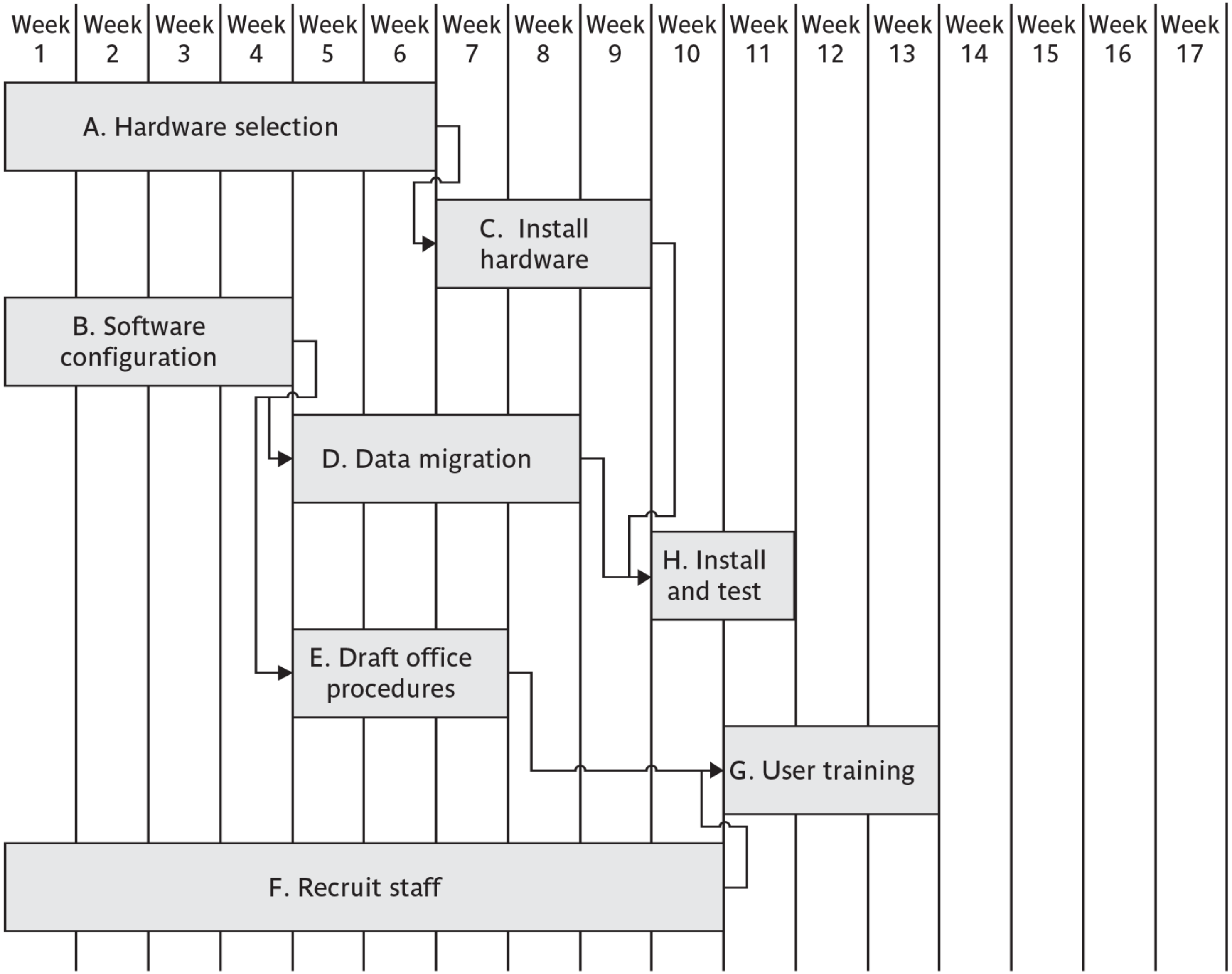
An example

For example, let's rework our previous example



as a **Gantt chart** (see next slide)

Gantt chart - “traditional” planning approach



Critical chain approach

A problem with estimates of task duration:

- Estimators tend to add a safety zone to take account of possible difficulties
- Developers work to the estimate + safety zone, so time is lost
- **No advantage is taken of opportunities where tasks can finish early – and provide a buffer for later activities**

Critical chain approach (cont.)

An answer to this:

1. Ask the estimators for two estimates
   - Most likely duration: 50% chance of meeting this
   - Comfort zone: additional time needed to have 95% chance
2. Schedule all activities suing most likely values and starting all activities on latest start dates

Most likely and comfort zone estimates

Activity	Most likely	Plus comfort zone	Comfort zone
A	6	8	2
B	4	5	1
C	3	3	0
D	4	5	1
E	3	4	1
F	10	15	5
G	3	4	1
H	2	2.5	0.5

TABLE 7.8 Most likely and comfort zone estimates (days)

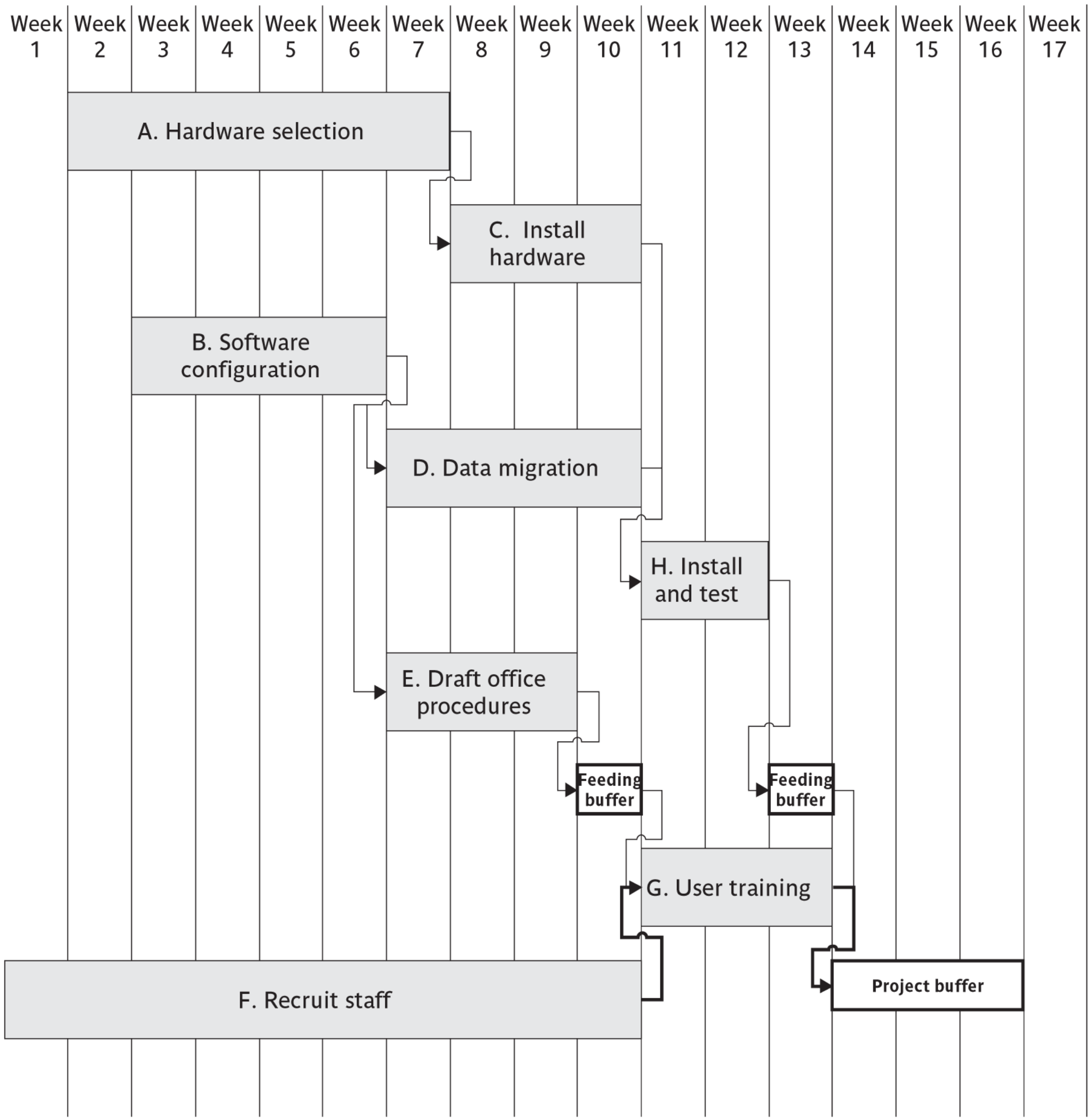
Critical chain (cont.)

3. Identify *the critical chain* – same a critical path but **resource constraints** also taken into account.
4. Put **a project buffer** at the end of the critical chain with duration 50% of sum of comfort zones of the activities on the critical chain.

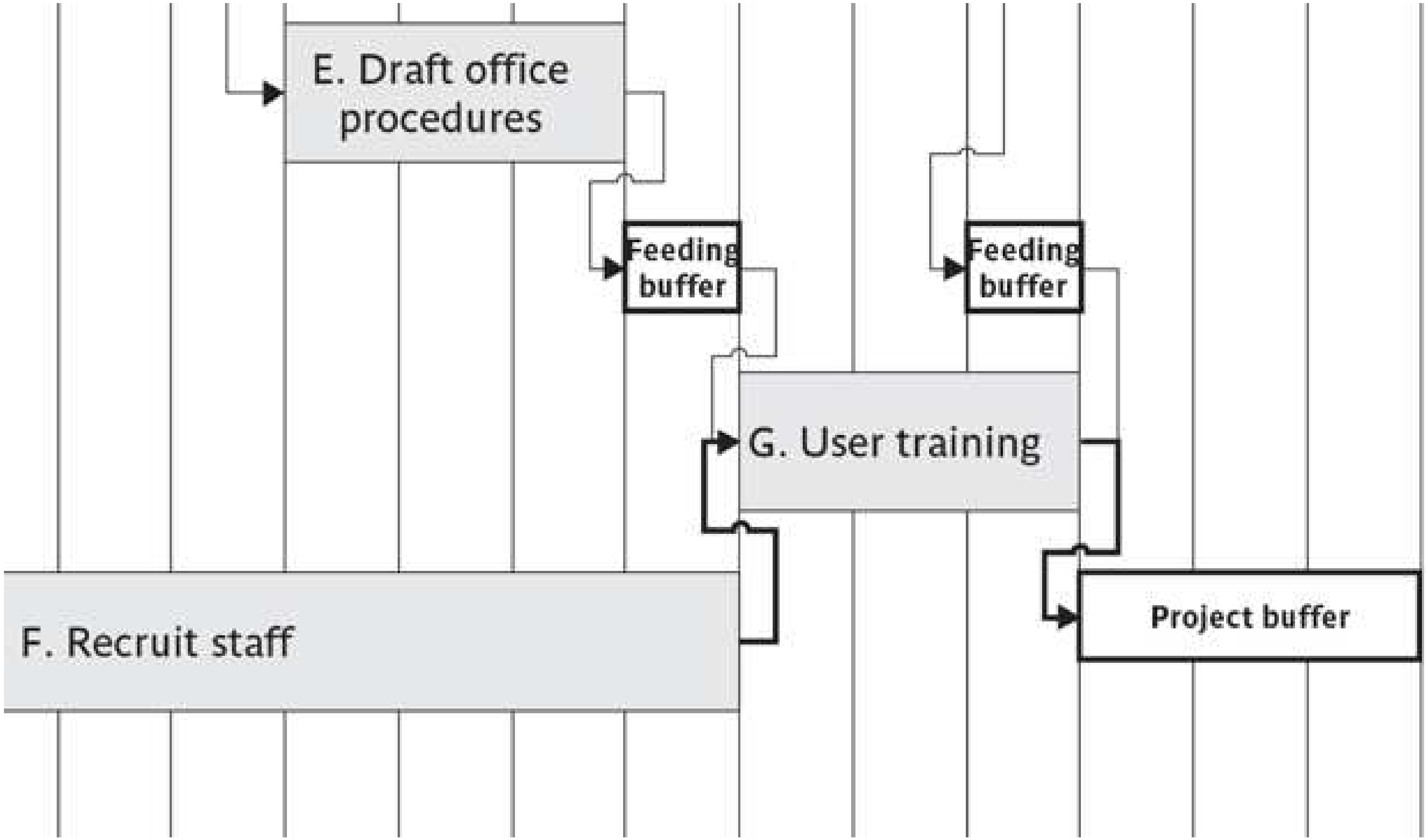
Critical chain (cont.)

5. Where subsidiary chains of activities *feed into critical chain*, add **a feeding buffer**
6. Duration of feeding buffer 50% of sum of comfort zones of activities in the feeding chain
7. Where there are parallel chains, take the longest and sum those activities

Gantt chart - critical chain planning approach



A closer look: critical chain

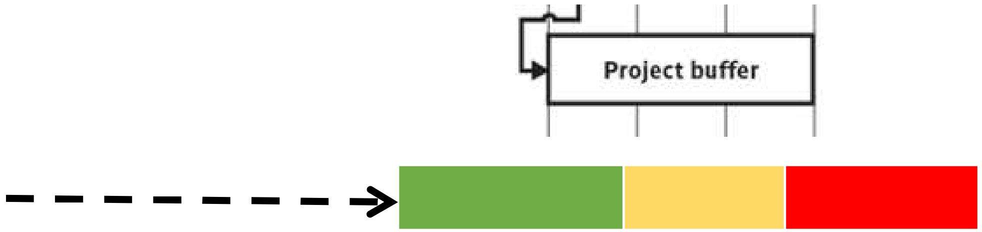


Executing the critical chain-based plan

- No chain of tasks is started earlier than scheduled, but once it has started is finished as soon as possible
- This means the activity following the current one starts as soon as the current one is completed, even if this is early – **the relay race principle**

Executing the critical chain-based plan

Buffers are divided into three zones of 33% each:



- **Green**: No action required if the project moves into this zone
- **Amber**: An action plan is formulated if the project moves into this zone
- **Red**: The action plan above is executed if the project moves into this zone

Summary: Two Lectures on Risk Management

- Project risks
  - What causes project risks
- Risk Management Framework
  - Risk identification
  - Risk assessment
  - Risk reduction strategies
  - Risk monitoring
- Estimation techniques
  - Risk Exposure
  - Qualitative measures
- PERT
- Monte Carlo simulation
- Critical chain planning

Thank you for your attention

Any questions, please?