



Project Controls Expo – 13th Oct 2015

Emirates Stadium, London

Planning, Scheduling Monitoring and Control

About the Speaker

Stephen Jones

Chairman of the APM Planning, Monitoring and Control Specific Interest Group. A Registered Project Professional, and a chartered Electrical Engineer. Project Management experience comes from the Nuclear Industry, currently Deputy Head of Project Management at Sellafield Ltd.

Sellafield is the largest and most complex Nuclear site in Europe

- Located in the County of Cumbria, North West England
- Functional support capability is provided by employees based at Risley, Warrington
- Nuclear build started at Sellafield in the late 1940's
- Location of Calder Hall – The world's first commercial scale Nuclear Power Station (1956-2003)



Single largest Nuclear construction site in the UK

- 250 active facilities on 1 ½ sq. miles / 700 acres
- Operations include
 - Decommissioning
 - Nuclear fuel reprocessing
 - Nuclear waste management
 - Construction
 - Delivery of major projects
- Total annual budget £1.9bn
- Employs 10,000+ people
- Recruits 64 Graduates and apprentices per year, 8 of which are my direct reports.



Topics

- Planning Verses Scheduling
- Network Diagrams
- Dependencies
- Critical Path
- Gantt Charts
- Resources
- Levelling and Smoothing
- Earned Value

Latest Book from APM



Available from
APM Website.

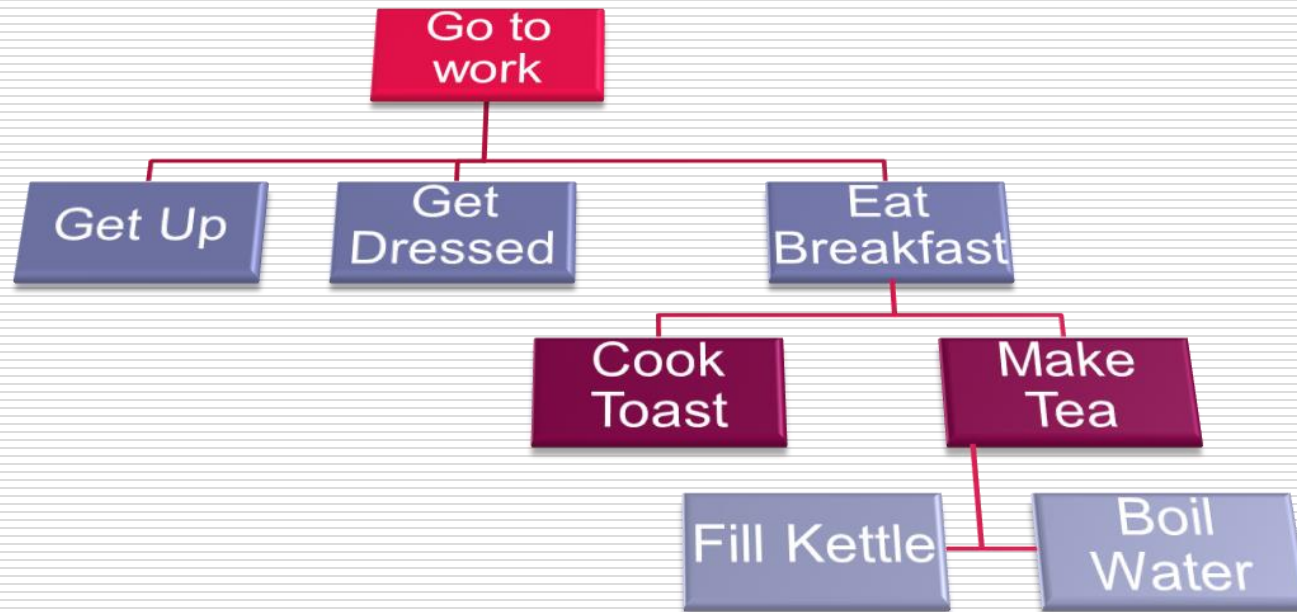
20% off today
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<https://www.apm.org.uk/Planning-Monitoring-Scheduling-Control>

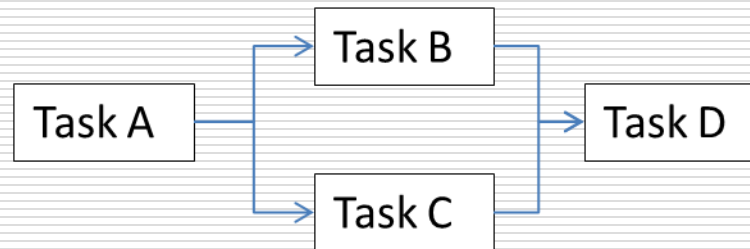
Planning or Scheduling?

- What is the difference between Planning and Scheduling?

Work Break Down Structure

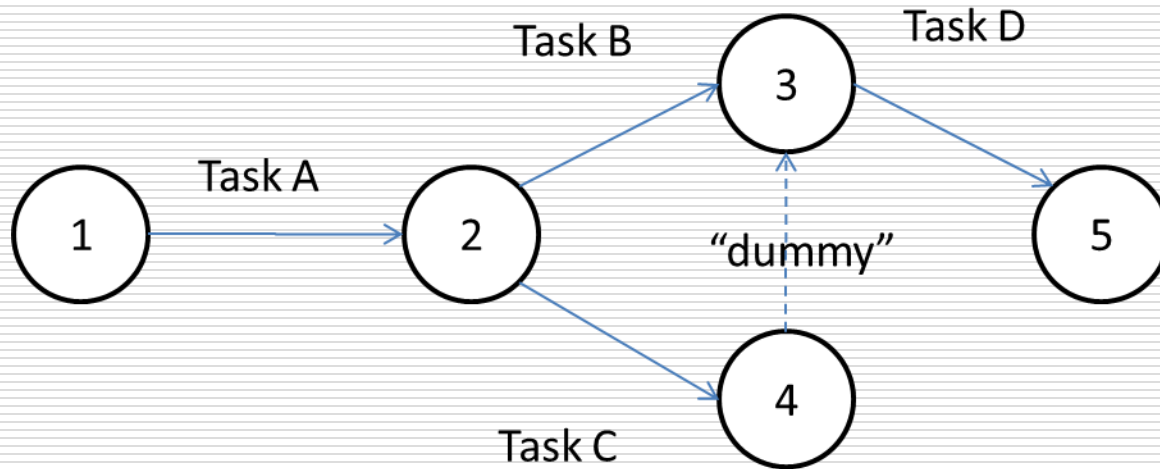


Network Diagrams



Activity on Node Network

Network Diagrams



Activity on Arrow Network

Dependencies

- Finish-to-Start (FS) relationship



- Activity 2 cannot start until Activity 1 has finished

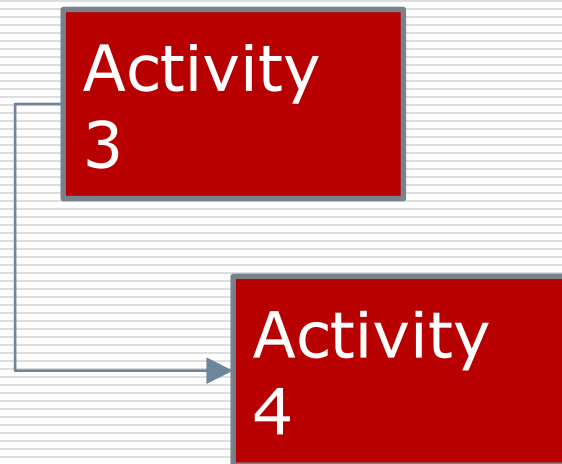
Example

- Can anyone give an example of two tasks with a Finish-to-Start relationship?

- For example. You cannot make a cup of tea, until the kettle has boiled.

Dependencies

- Start-to-Start (SS) relationship



- Activity 4 cannot start until Activity 3 has started

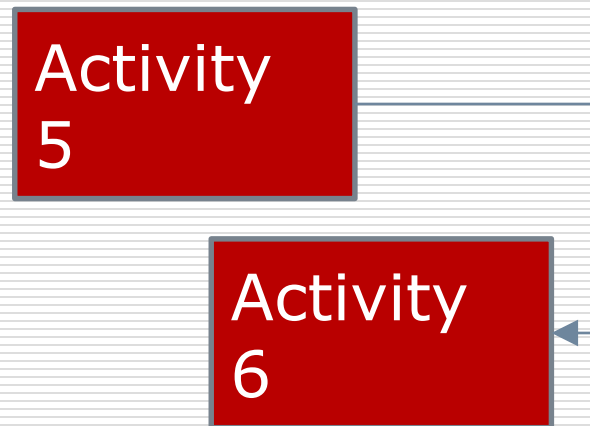
Example

- Can anyone give an example of two tasks with a Start-to-Start relationship?

- If activity 4 was lay pipeline, this can only start once (activity 3) the sections of pipe have started to arrive, it is not dependent on the delivery of the pipes being complete.

Dependencies

- Finish-to-Finish (FF) relationship



- Activity 6 cannot Finish until Activity 5 has Finished

Example

- Can anyone give an example of two tasks with a Finish-to-Finish relationship?

- If activity 6 was planning application, and activity 5 was site surveys, then you can start the planning application but it can not be completed until you have all the survey information.

Dependencies

- Start-to-Finish (SF) relationship



- This is rarely used. Activity 8 cannot finish until activity 7 has started

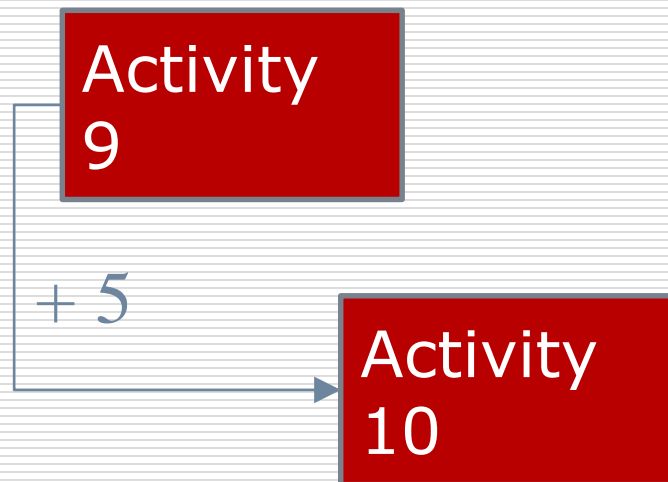
Example

- ❑ Can anyone give an example of two tasks with a Start-to-Finish relationship?

- ❑ If activity 7 and activity 8 were stand-by and duty pumps, the duty pump could not be stopped until the stand-by pump had been started. It is difficult to imagine planning to this level of detail, therefore should be avoided.

Lag and Lead

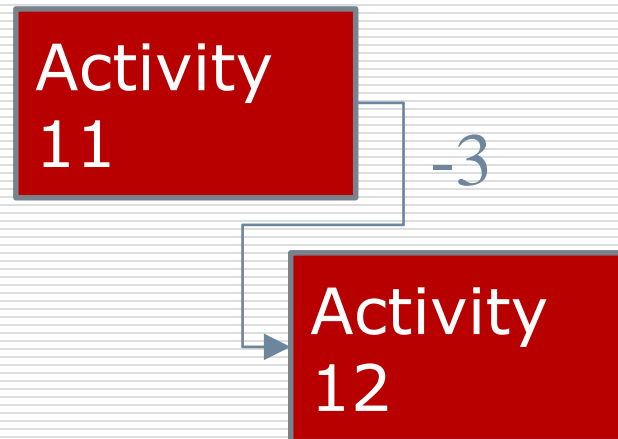
□ Lag



- Activity 10 can only start 5 days after Activity 9 starts

Lag and Lead

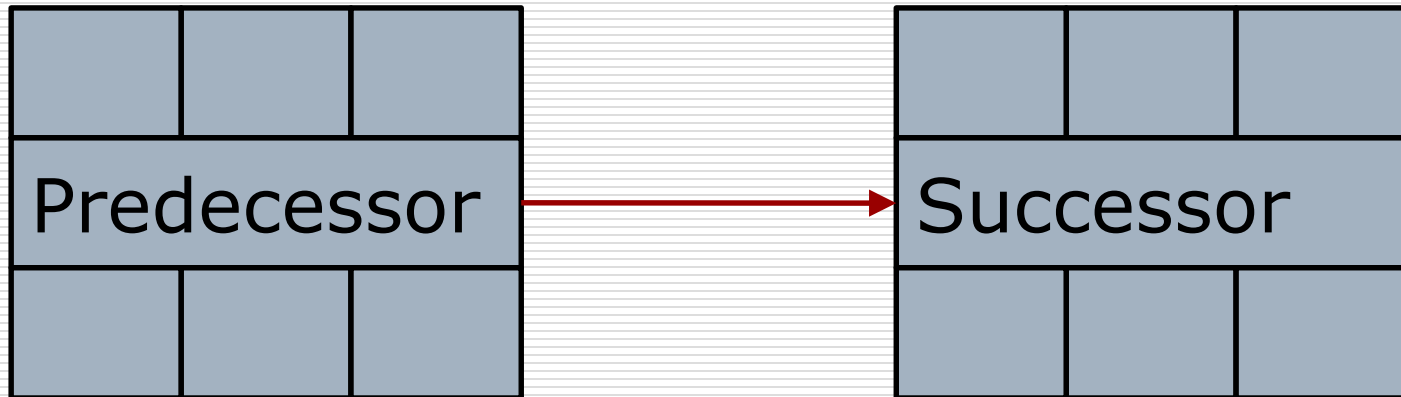
- Lead is a negative lag



- Activity 12 can start 3 days before Activity 11 finishes

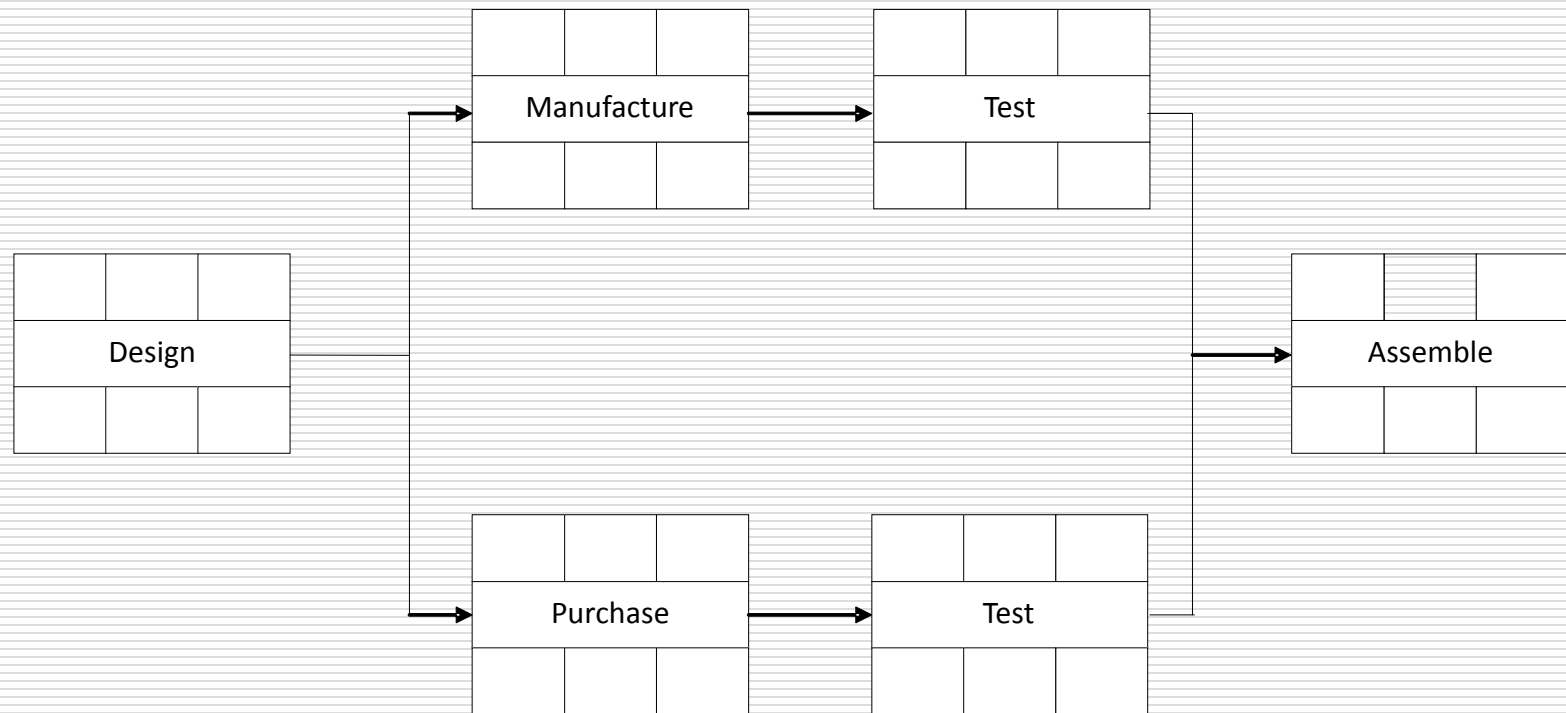
Creating a Network

- All activities should have a predecessor and successor



- With the exception of the first and last

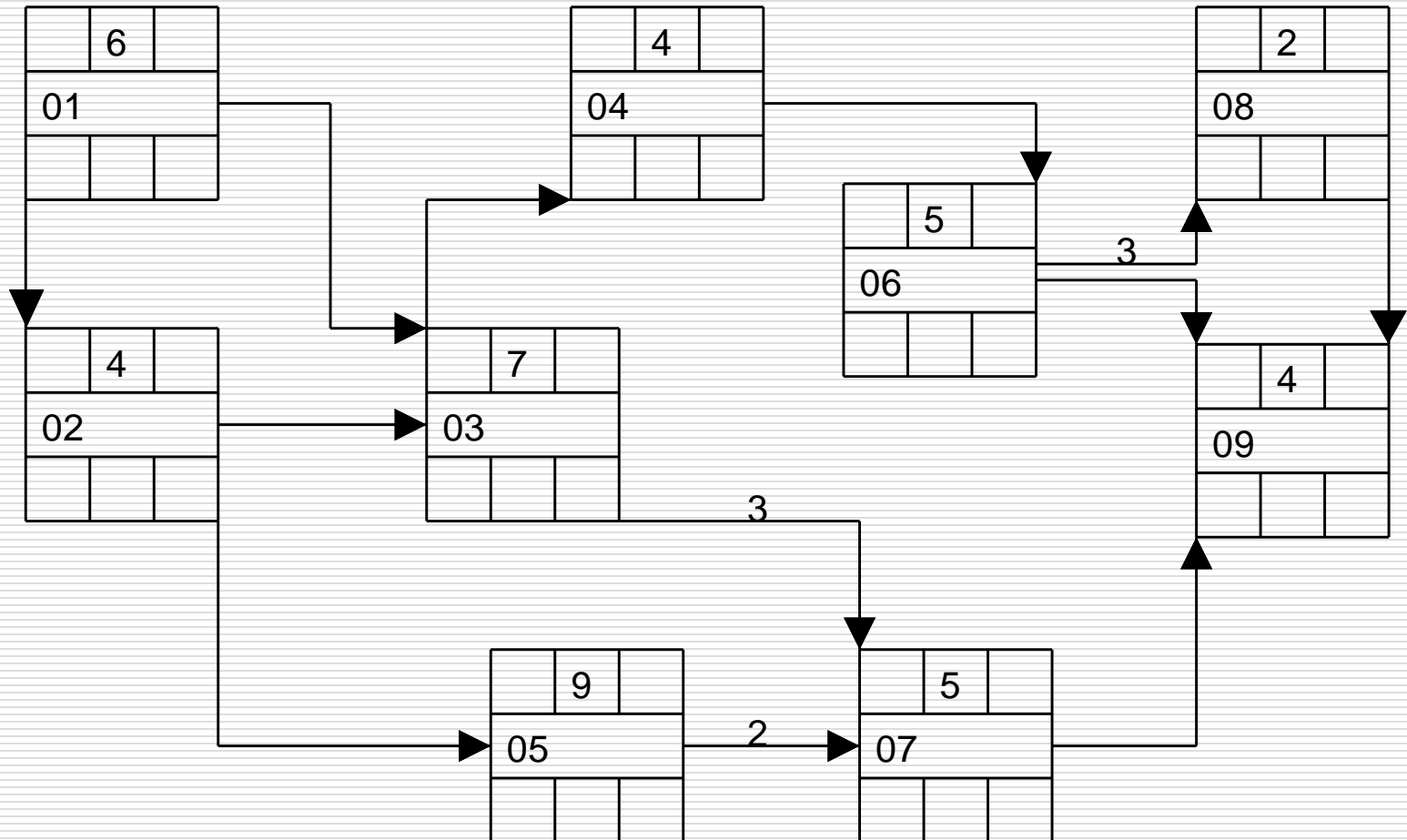
Example of Network



Exercise 1 – Draw the network

ID	Predecessor	Dur.
Activity 1	-	6
Activity 2	Activity 1 (Start-to-Start)	4
Activity 3	Activity 1 and Activity 2	7
Activity 4	Activity 3 (Start-to-Start)	4
Activity 5	Activity 2	9
Activity 6	Activity 4 (Finish-to-Finish)	5
Activity 7	Activity 3 + 3 Days Lag, and Activity 5 + 2 days Lag	5
Activity 8	Activity 6 + 3 Days Lag	2
Activity 9	Activity 6, and Activity 7, and Activity 8 (Finish-to-Finish)	4

Answer to Exercise 1



Which day does the project start?

Day One

Or

Day Zero

In all scheduling software Day zero does not exist.

For teaching purposed Day Zero is used, then
converted to Day One

The book acknowledges both, but Day one is correct

Network Analysis

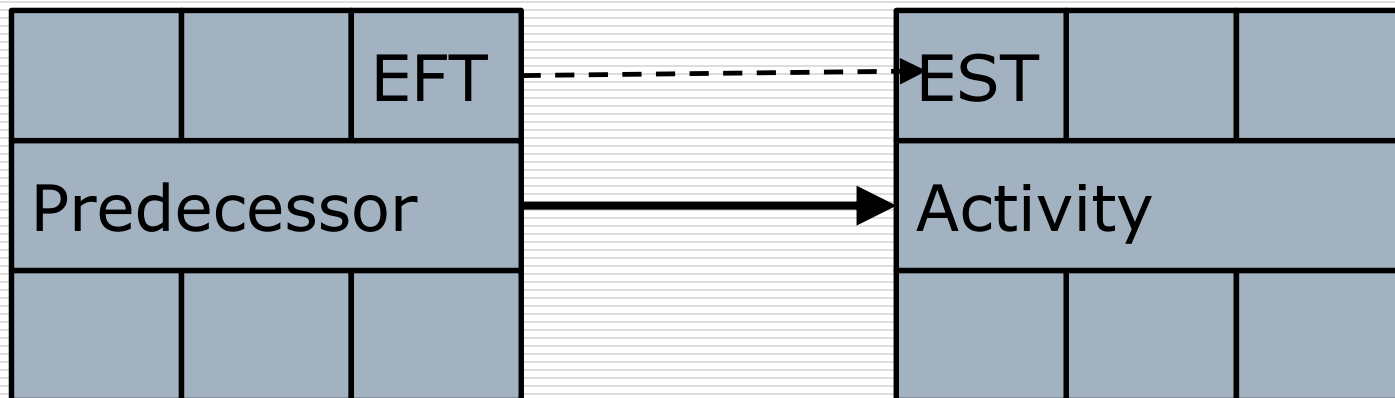
- British Standard for the representation of a Network Node (BS4335)

EST= Earliest Start
Dur. = Duration
EFT = Earliest Finish
LST = Latest Start
TF = Total Float
LFT = Latest Finish

EST	Dur.	EFT
ID Description		
LST	TF	LFT

Earliest Start Time (EST)

- The earliest time by which an activity can start EST is equal to the EFT of preceding activities



Earliest Finish Time (EFT)

- The earliest time by which an activity can finish

$$\text{EFT} = \text{EST} + \text{Duration}$$

EST	Dur.	EFT
Activity		

Latest Start Time (LST)

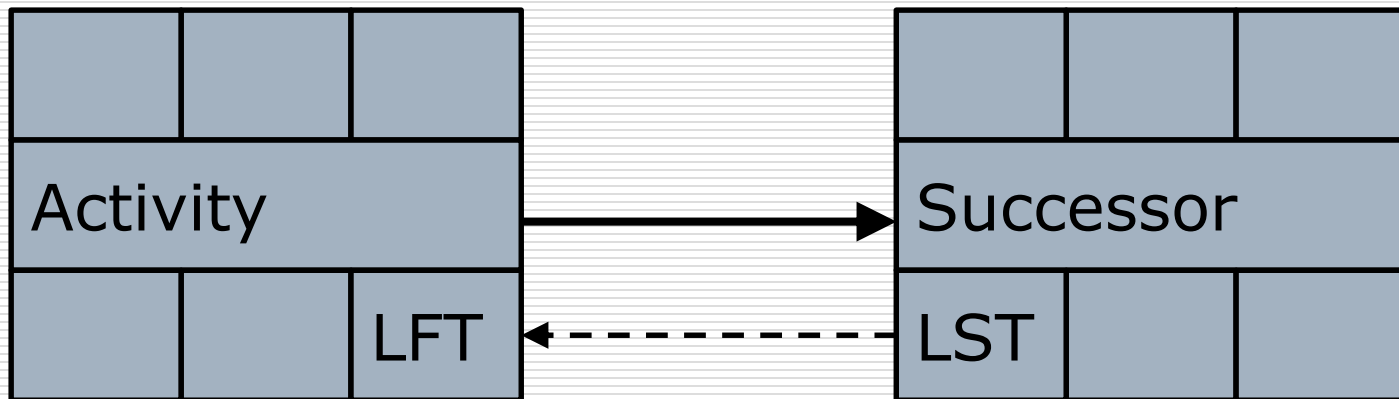
- The latest time by which an activity can start

$$\text{LST} = \text{LFT} - \text{Duration}$$

	Dur.	
Activity		
LST		LFT

Latest Finish Time (LFT)

- The latest time by which an activity can finish LFT is equal to the LST of succeeding activities



Forward Pass

- Early Finish = Early Start + Duration

EST	Dur.	EFT
ID Description		
LST	TF	LFT

$$0 + 8 = 8$$

0	8	8
Activity A		

8

$$8 + 6 = 14$$

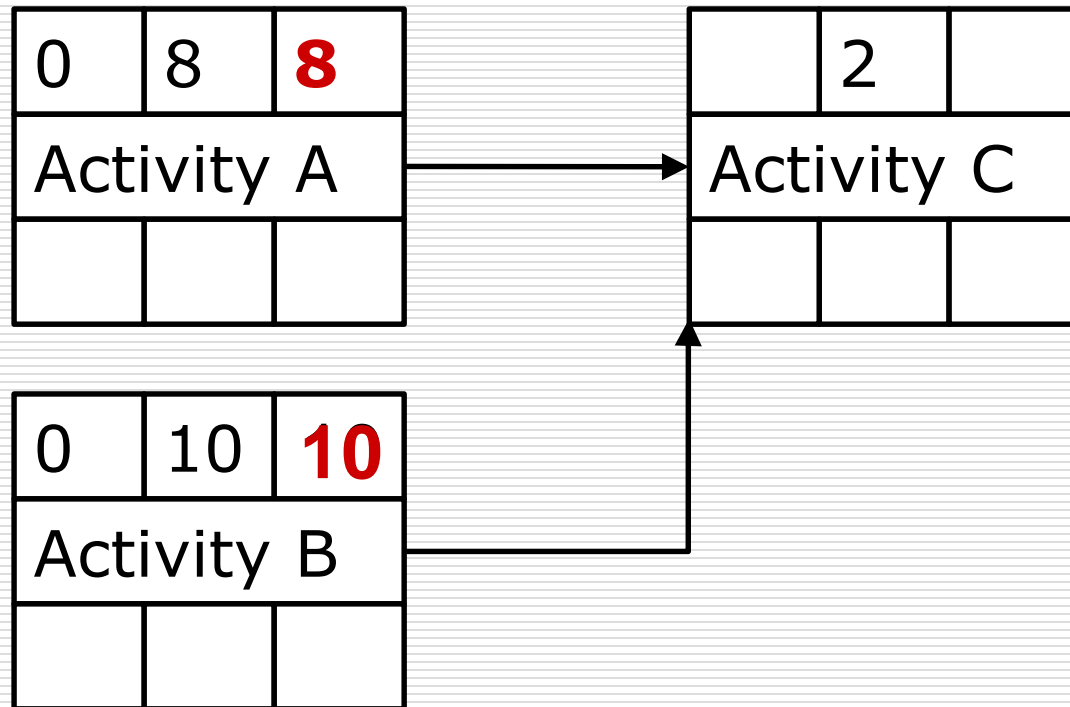
	6	14
Activity B		

$$14 + 7 = 21$$

14	7	21
Activity C		

Assumes Finish to Start links with no lag

If there are multiple Predecessors?



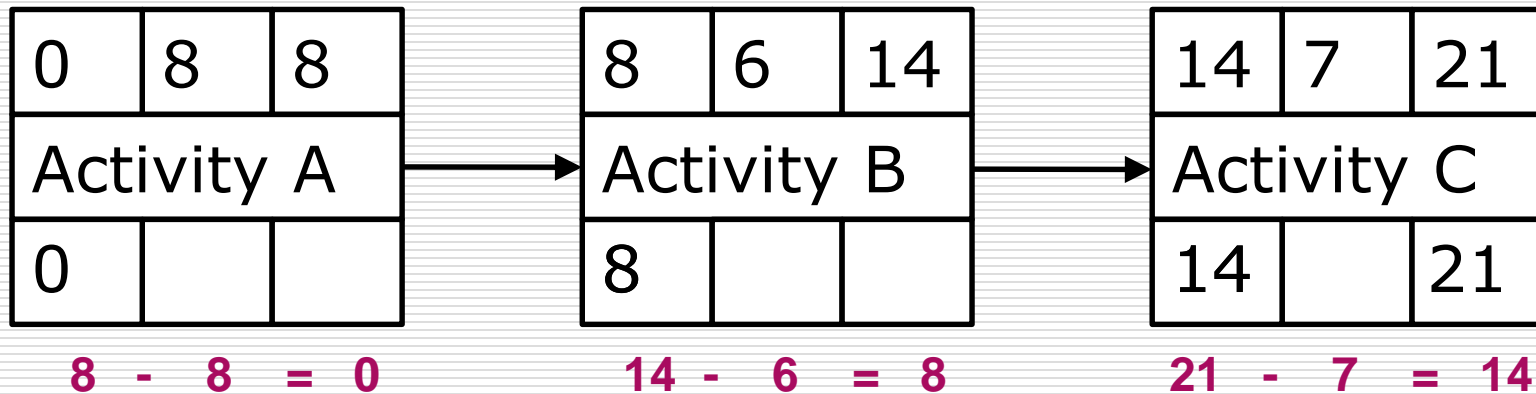
EST	Dur.	EFT
ID Description		
LST	TF	LFT

- Big Steps Forward

Backward Pass

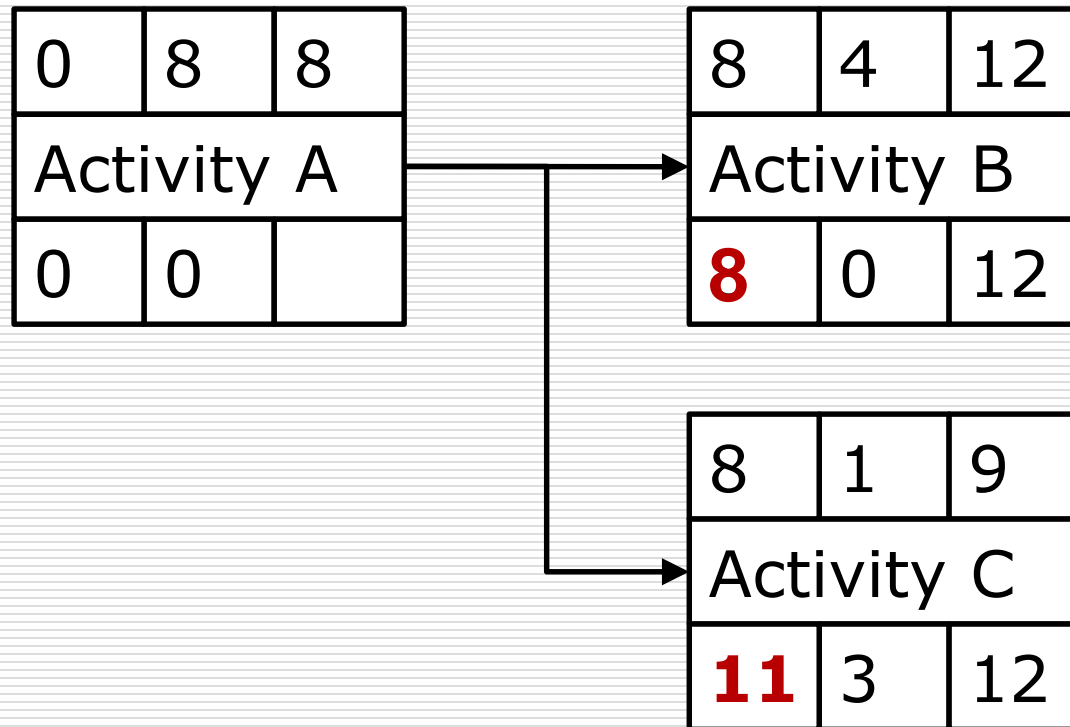
- Late Start = Late Finish – Duration

EST	Dur.	EFT
ID Description		
LST	TF	LFT



Assumes Finish to Start links with no lag

If there are multiple Successors?



EST	Dur.	EFT
ID Description		
LST	TF	LFT

- Little Steps Back

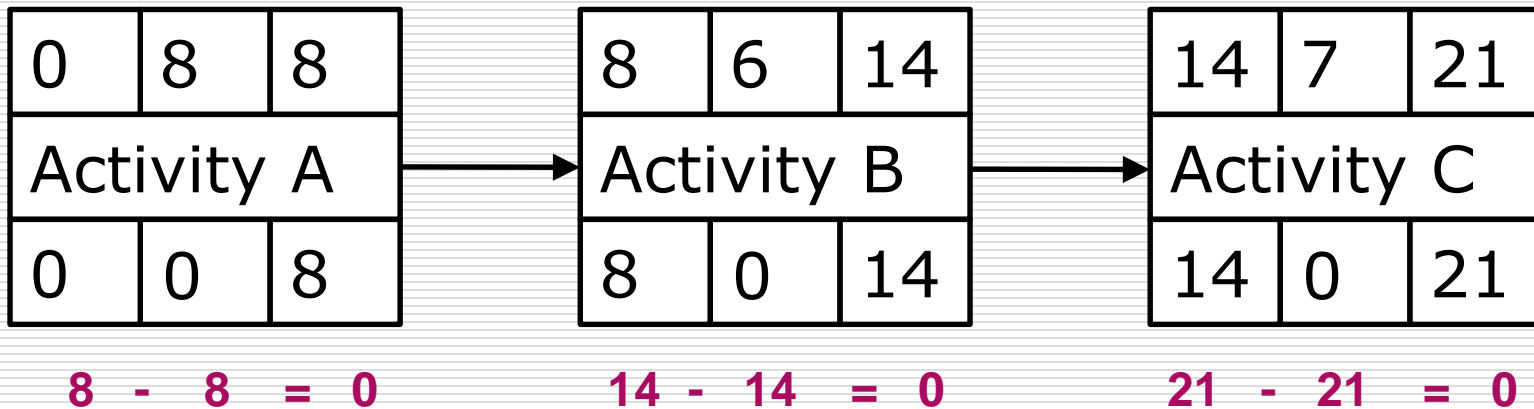
Total Float – also known as Slack

- Float is amount of time an activity can be delayed (or extended) without affecting the total project duration, i.e. the end date.

Calculating Float

- Total Float = Late Finish – Early Finish

EST	Dur.	EFT
ID Description		
LST	TF	LFT



Assumes Finish to Start links with no lag

Free Float

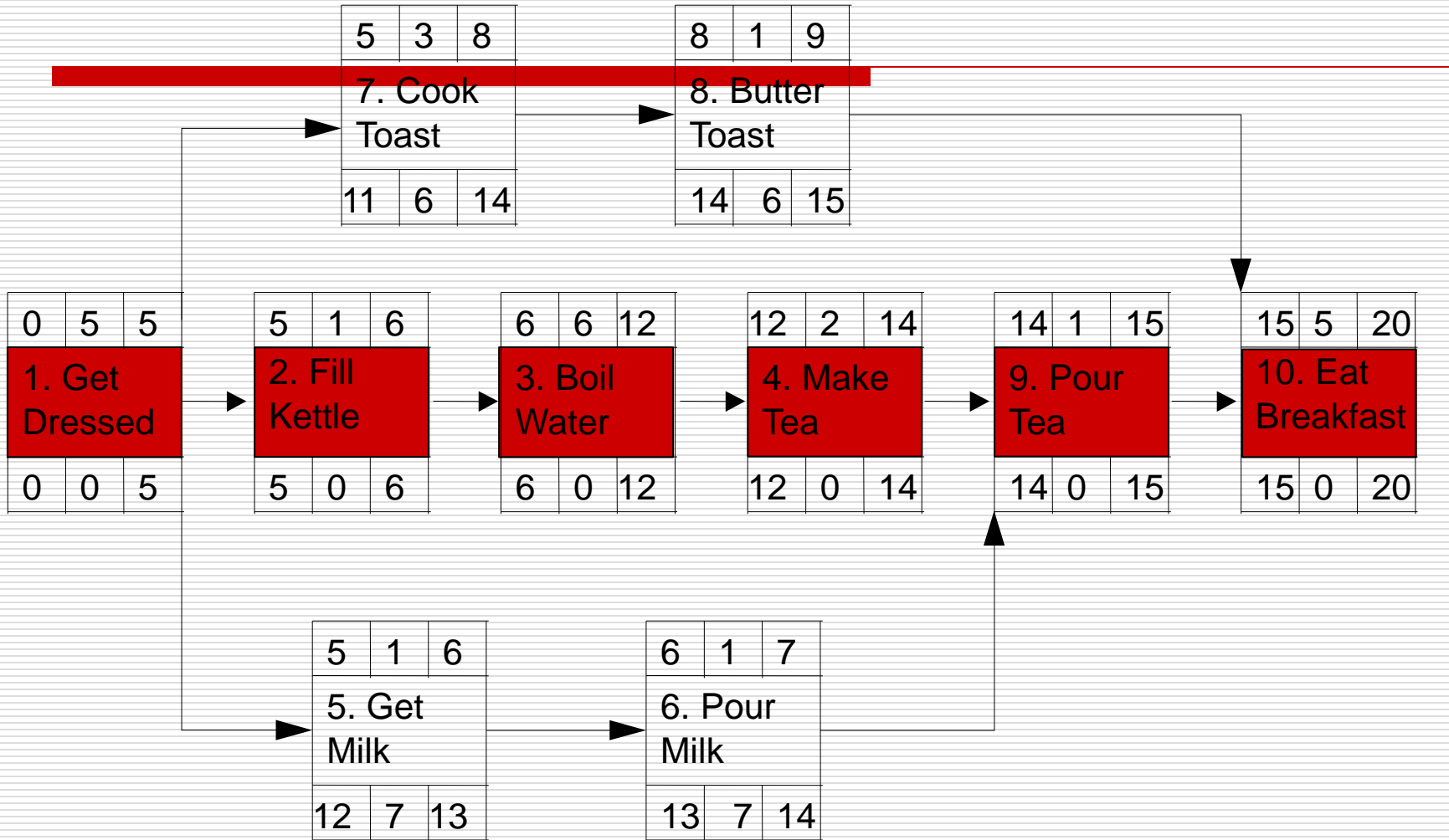
- The amount of time an activity can be delayed or extended without delaying the start of the next or succeeding activity

$$\text{Early Finish Time} \text{ less } \text{Early Start Time} \text{ less } \text{Duration}$$

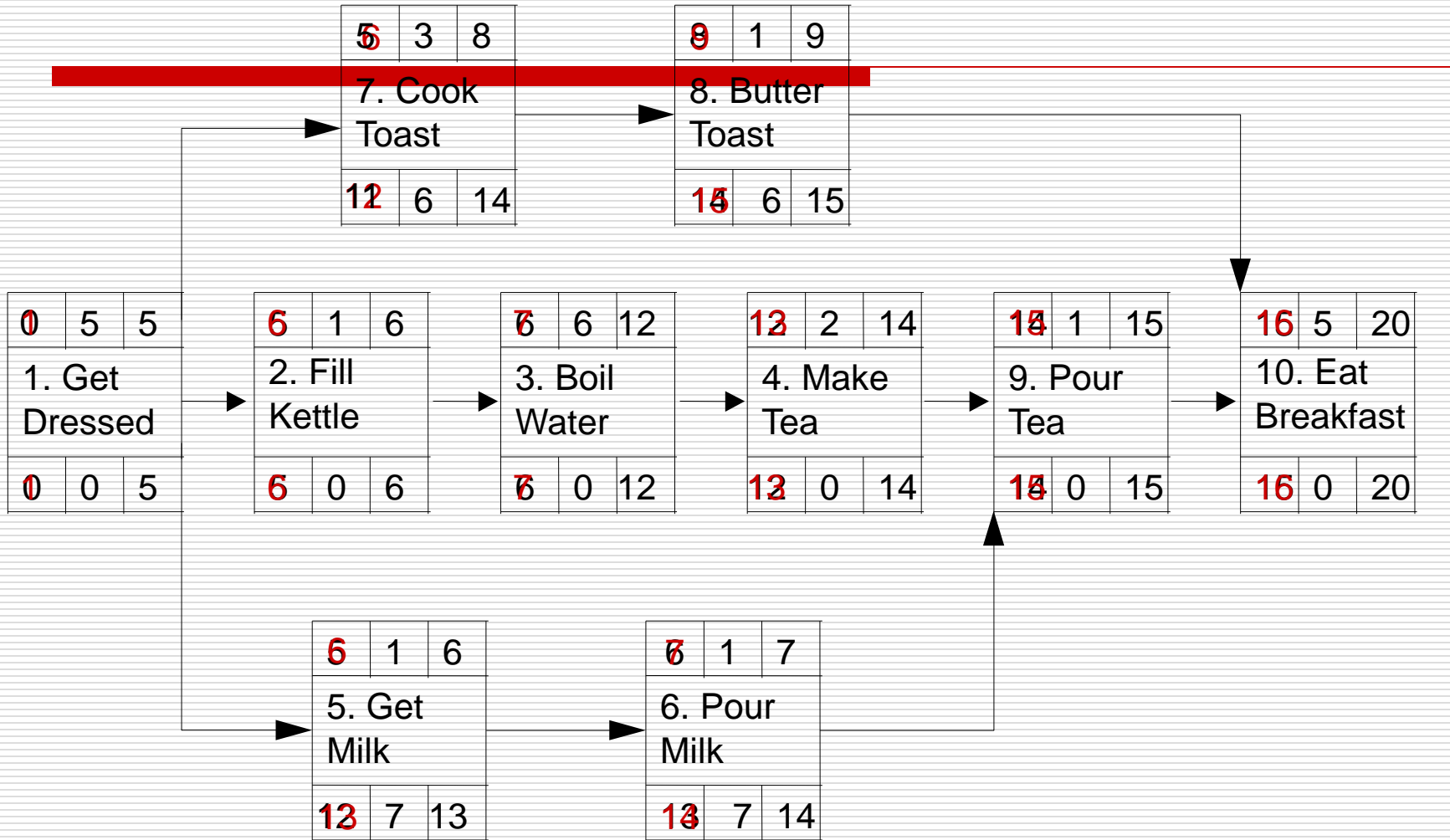
Critical Path

- The **critical path** is the path through activities with minimum float. This is normally zero float
- It is the **longest** route through the activity network
- There may be more than one critical path
- Any delays in critical activities will cause the project to be delayed

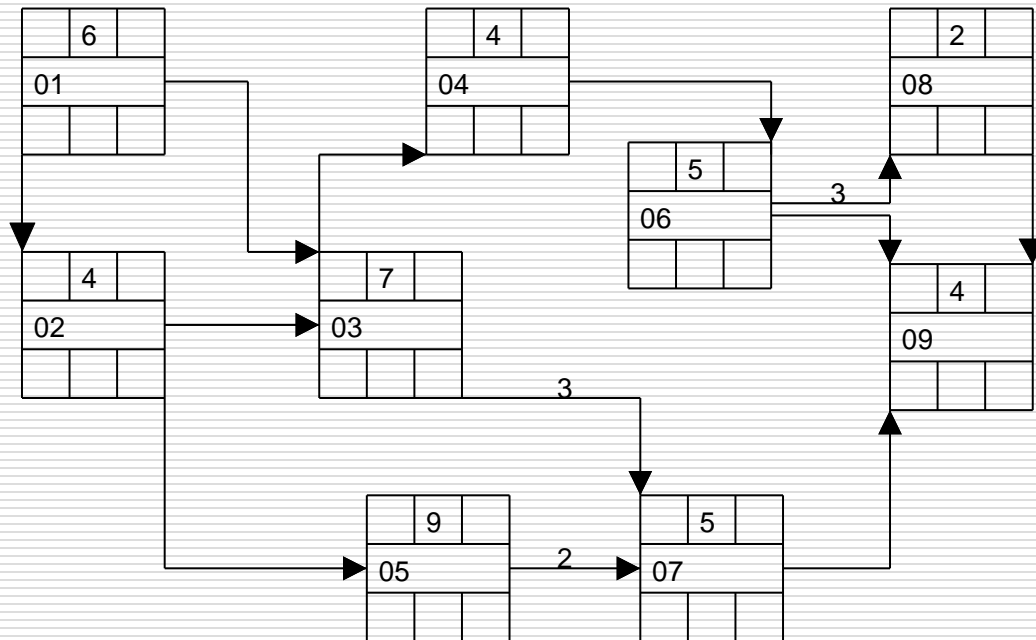
Critical Path Example



Start on Day 1



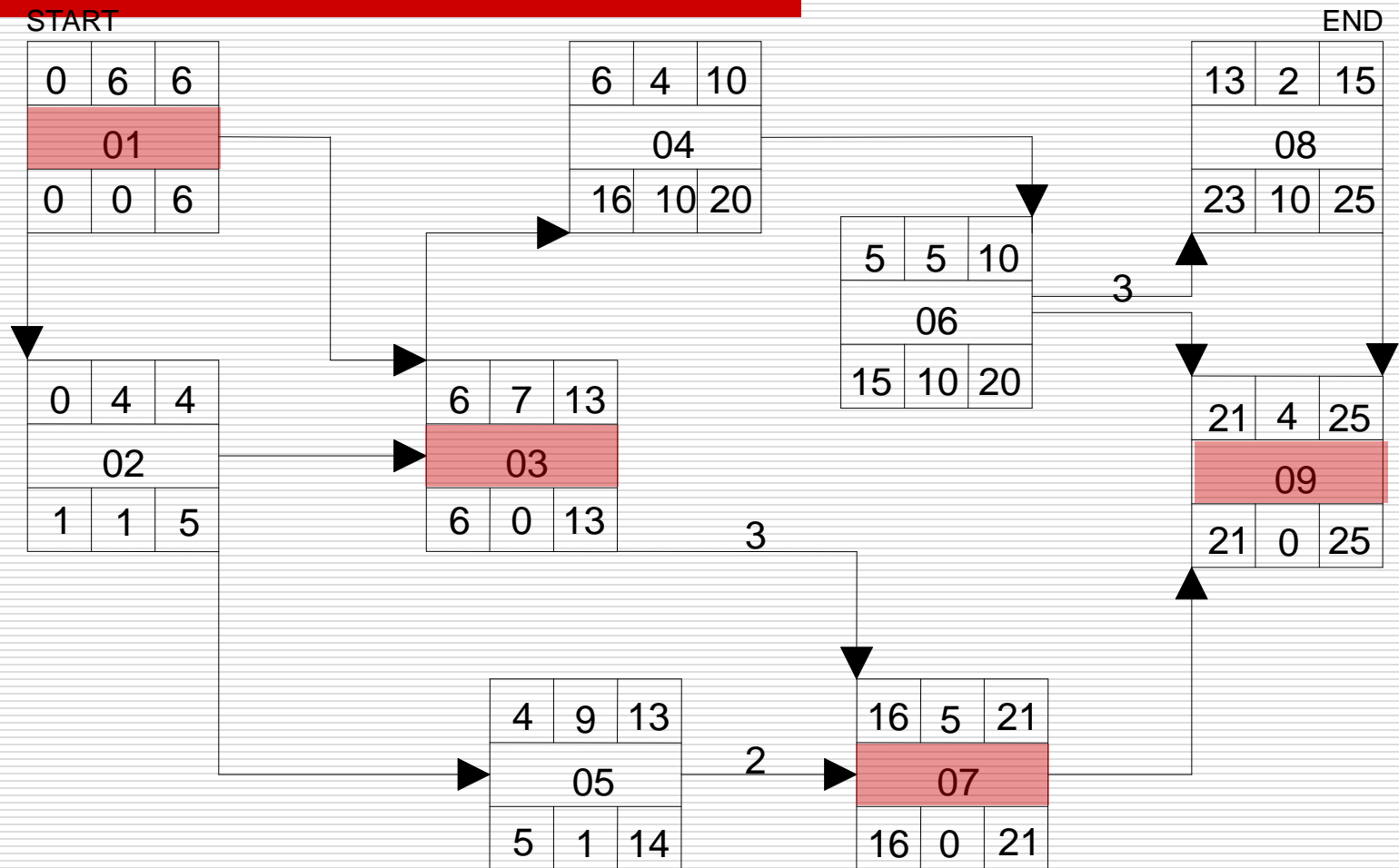
Exercise 2 – Full Analyse the Network



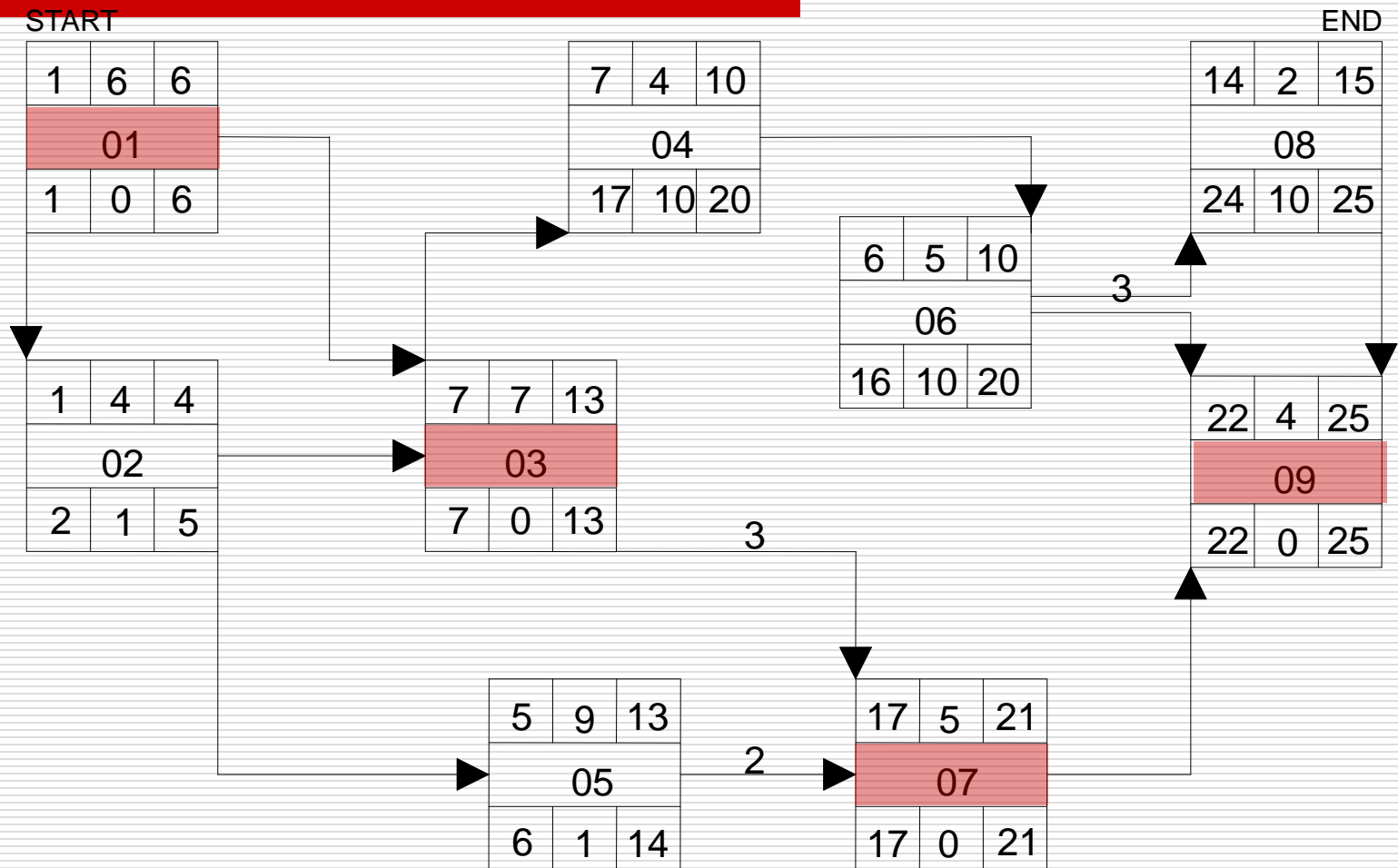
Fully Analyse
this network

Identify the
Critical Path

Answer – Day 0



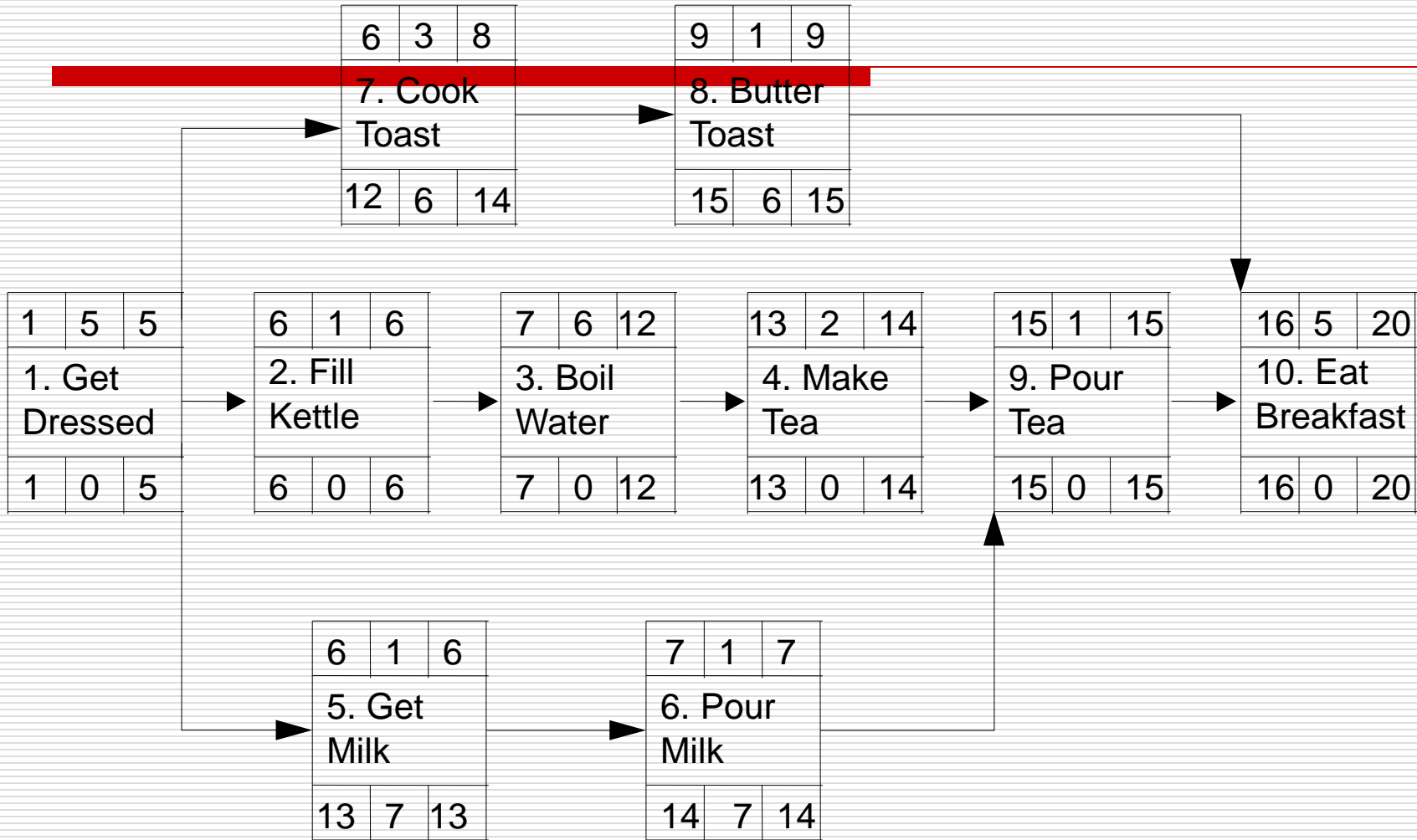
Answer – Day 1



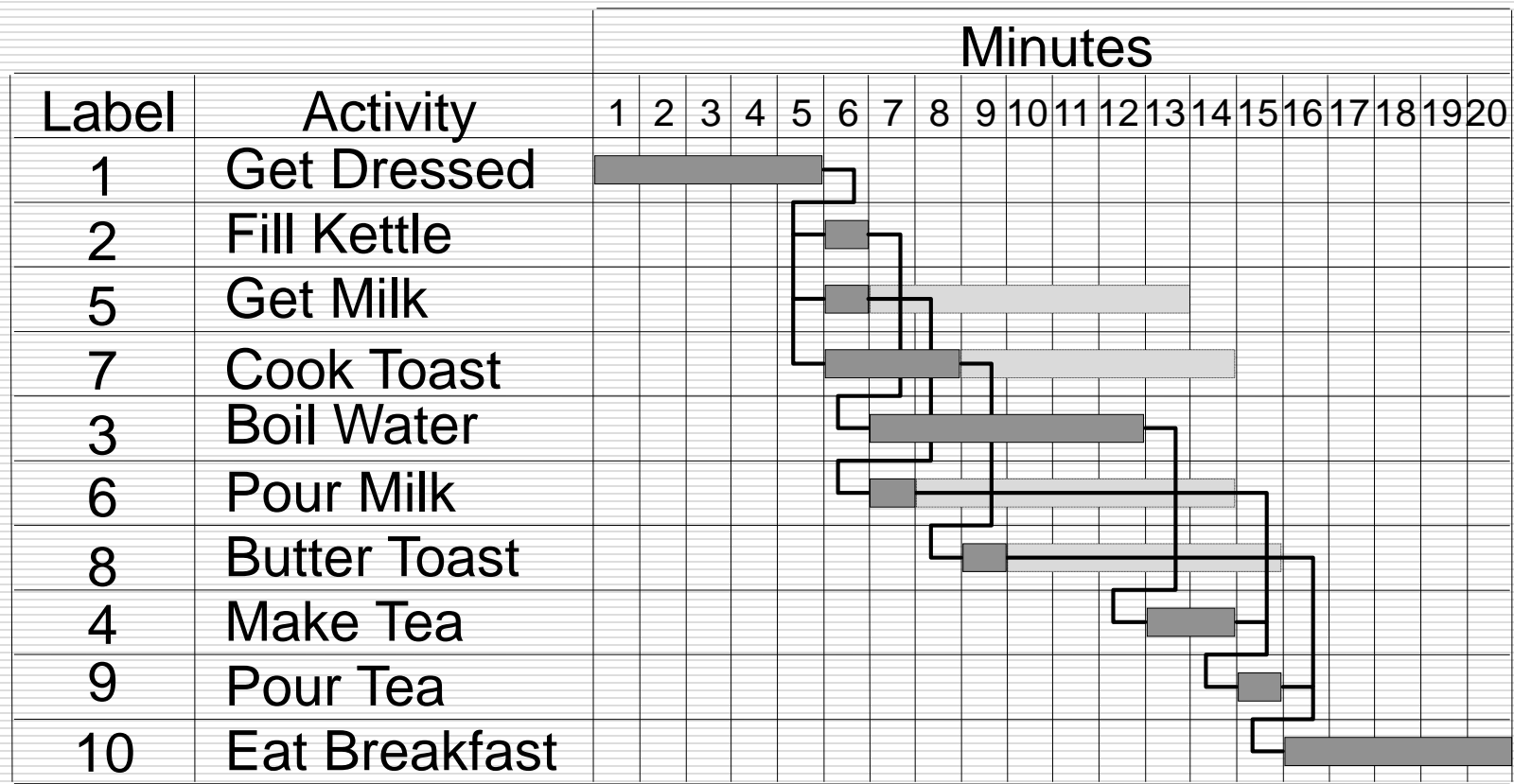
Gantt Charts

- ❑ A Gantt Chart is a simple form of Bar Chart
- ❑ Bar length indicates duration
- ❑ Tasks are usually positioned at earliest dates showing any float at the end
- ❑ Shown with or without logic connections
- ❑ Can be rolled up into summary tasks and can show milestones

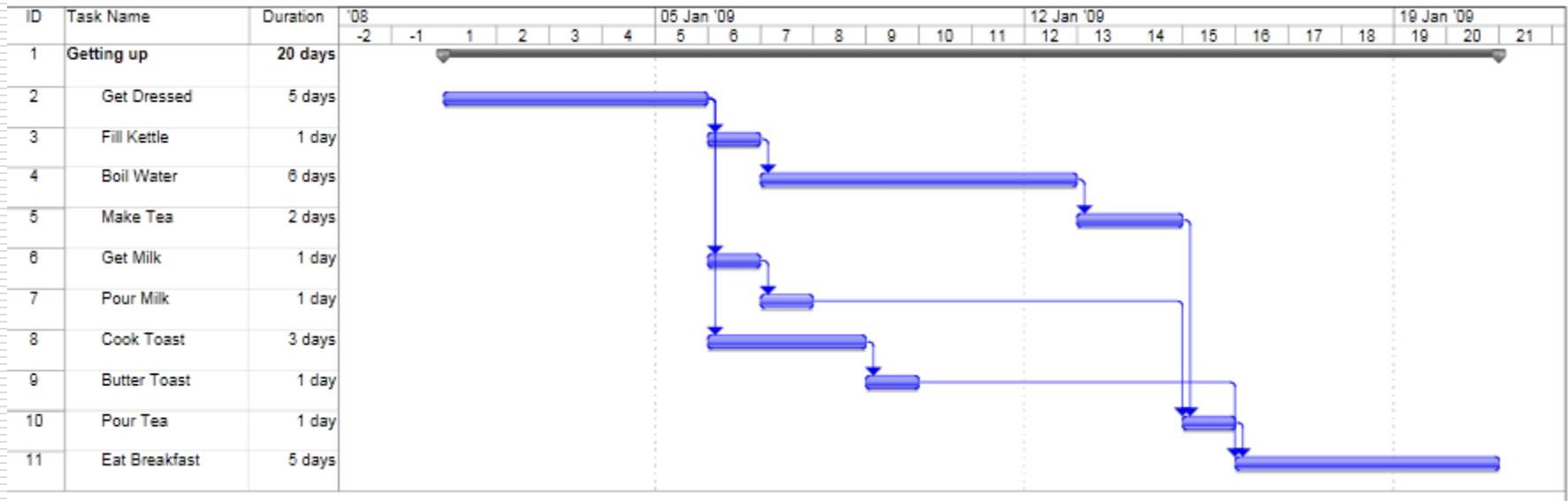
Getting Up Example



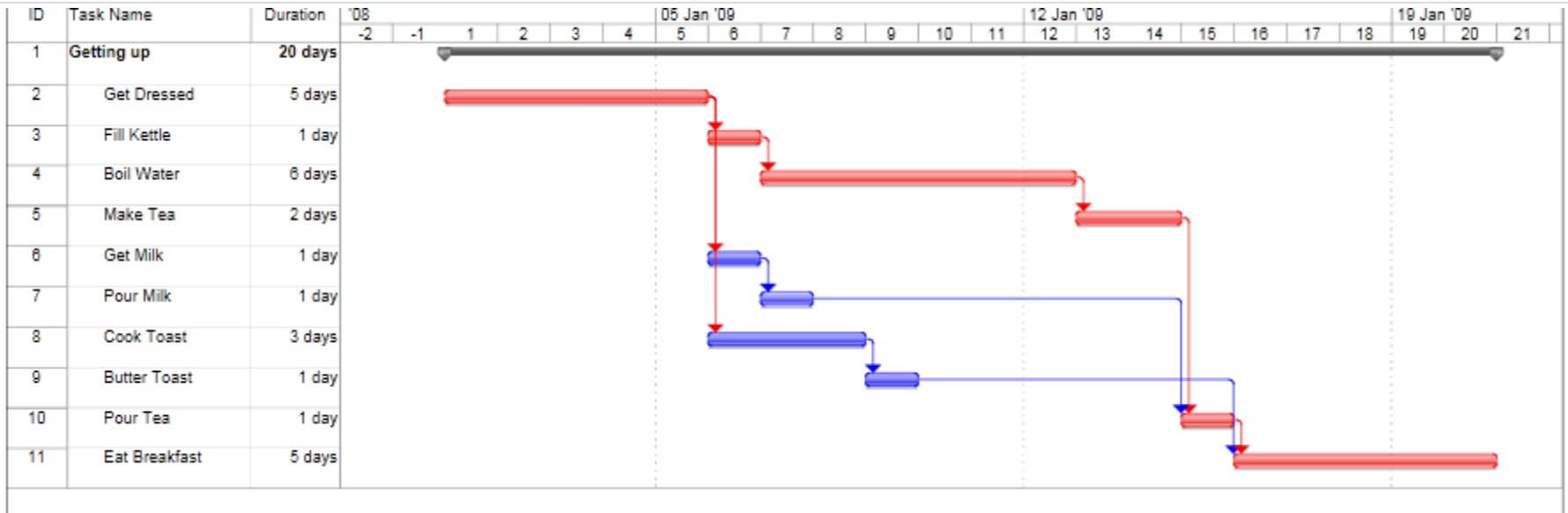
Getting Up Gantt



Gantt Chart in MS Project

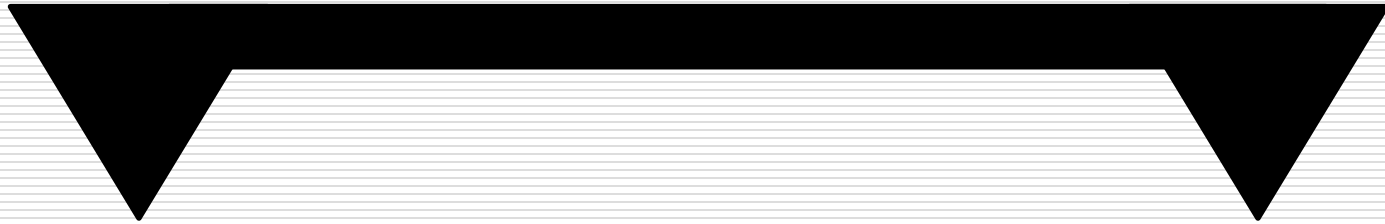


Gantt Chart with Critical Path



Summary Bars

- Summary Bar or Hammock

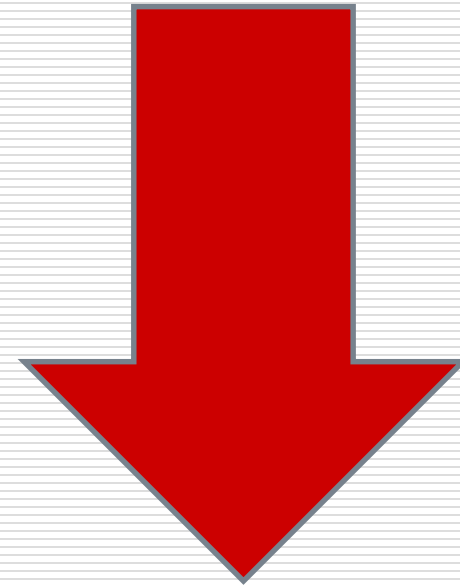


- Expand and contract linked activities

Constraints

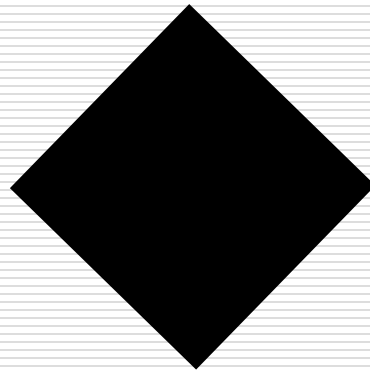
Types of Date Constraint

- Must Start on
- Must Finish on
- Start no later than
- Finish no later than
- Start no earlier than
- Finish no earlier than
- As Late As Possible



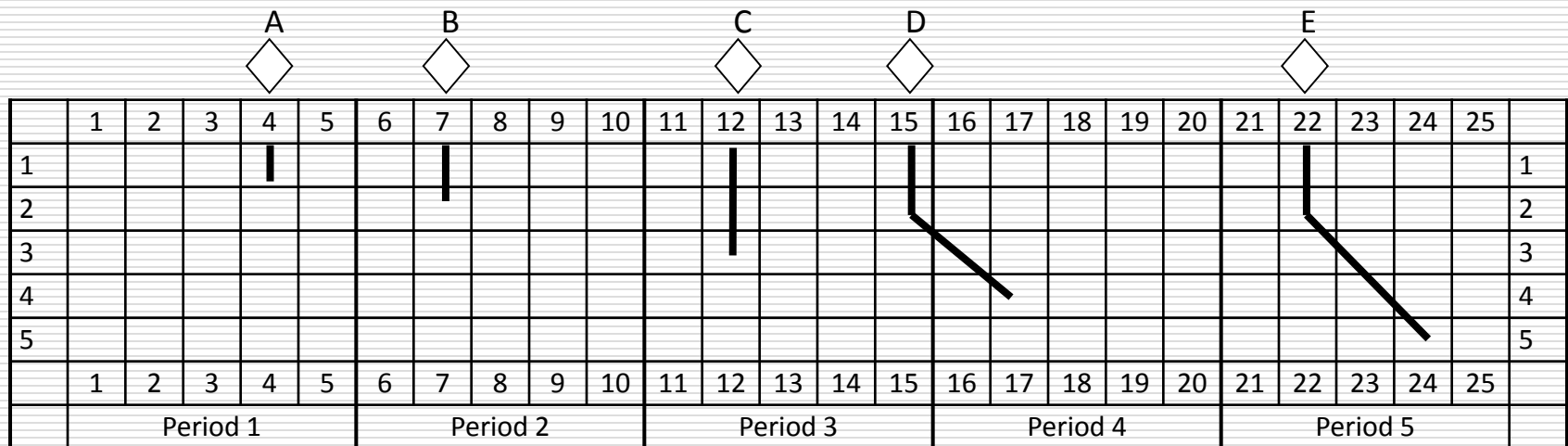
Milestones

- Milestones are shown as a diamond shape



- Milestone are used to record the anticipated date an activity

Milestone Chart



Progress lines will remain straight until the completion dates are reached. If work deviates from schedule, the progress line will slope to show the revised estimated completion date

Level of Effort

- General support Activities
- Project Manager
- Planner
- Scheduler

Level of effort should be used sparingly

These activities should be clearly identified

Resources

This section will cover

- Resource histogram
- Levelling
- Smoothing

Resource

	day																	
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	2	2	2	2														
B					4	4	4	4	4	4								
C					4	4	4	4	4									
D											5	5	5					
E											2	2	2	2	2			
F										4	4	4	4	4				
G																3	3	3

Resource

12																		
11											F	F	F					
10											F	F	F					
9											F	F	F					
8					C	C	C	C	C	F	F	F	F					
7					C	C	C	C	C	F	E	E	E					
6					C	C	C	C	C	F	E	E	E	F				
5					C	C	C	C	C	F	D	D	D	F				
4					B	B	B	B	B	B	D	D	D	F				
3					B	B	B	B	B	B	D	D	D	F		G	G	G
2	A	A	A	A	B	B	B	B	B	B	D	D	D	E	E	G	G	G
1	A	A	A	A	B	B	B	B	B	B	D	D	D	E	E	G	G	G
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	day																	



Exercise 3 – Gantt Charts

Using the network from Exercise 2

The following activities require the use of a certain numbers of carpenters:

- Activity 01 3 Carpenters
- Activity 03 3 Carpenters
- Activity 04 4 Carpenters
- Activity 05 7 Carpenters
- Activity 06 6 Carpenters

(all other activities use zero carpenters)

- Draw a Gantt Chart and the associate resource histogram**

Exercise 3 - Answer

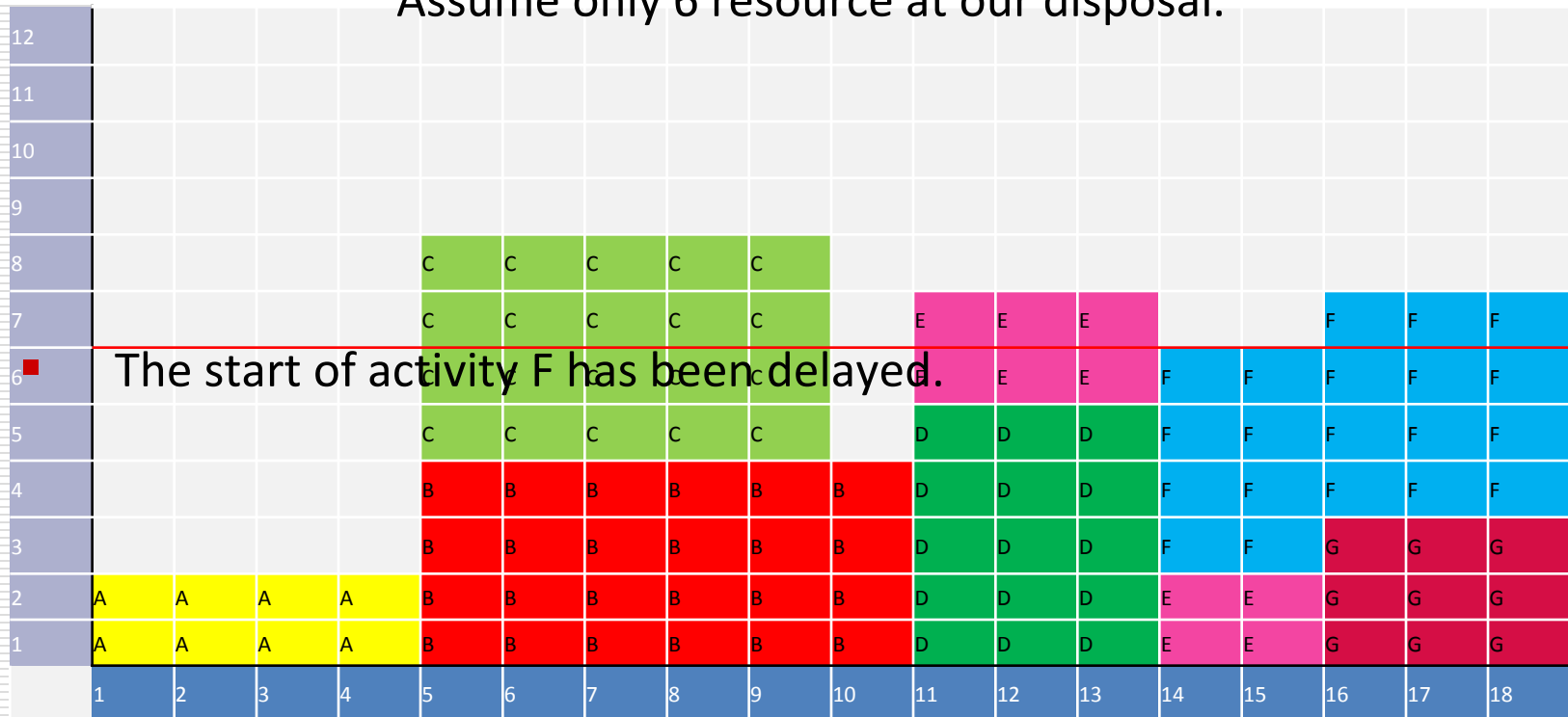
Activity label	Weeks																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
01	3	3	3	3	3	3																			
02	0	0	0	0																					
05					7	7	7	7	7	7	7	7													
06						6	6	6	6	6															
03							3	3	3	3	3	3	3												
04							4	4	4	4															
08														0	0										
07																	0	0	0	0	0				
09																						0	0	0	0
Resources																									

Smoothing

- Assuming Time is limited
- It allows the activity to be arranged with their float
- No Change to Project Duration
- Over demand may not be removed requiring additional resource

Example of Smoothed Histogram

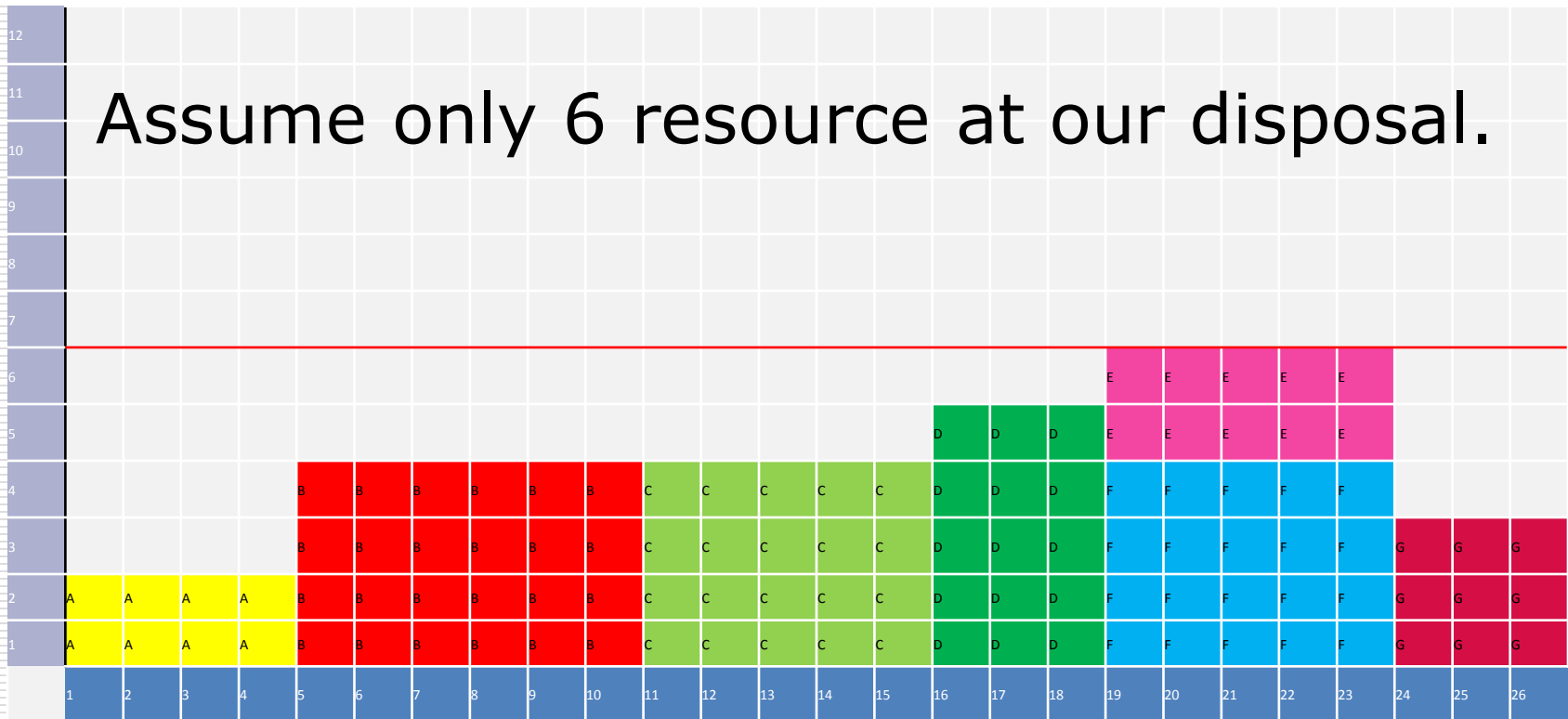
Assume only 6 resource at our disposal.



Levelling

- Assumes resources are limited
- It allows the activity start times to be delayed
- Over demand is removed
- Duration of the project may increase

Example of Levelled Histogram



- All over demand has been removed

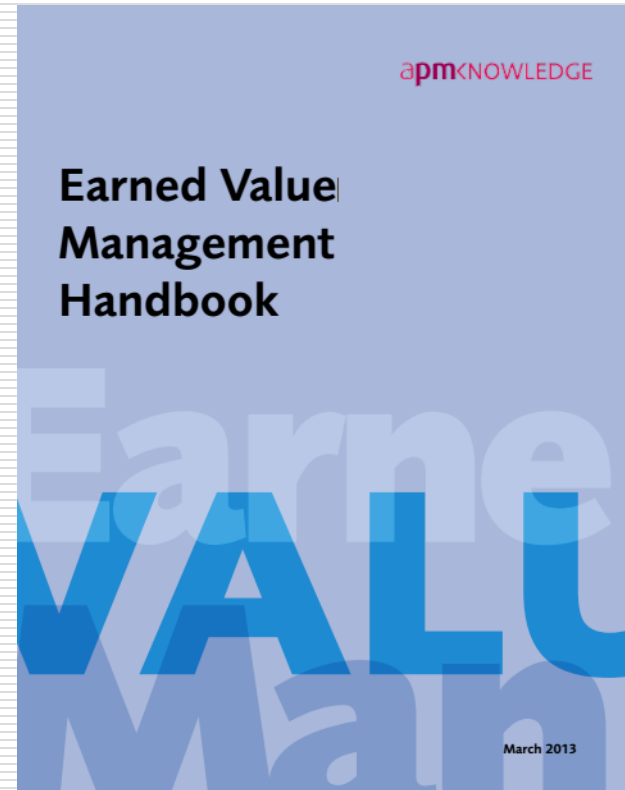
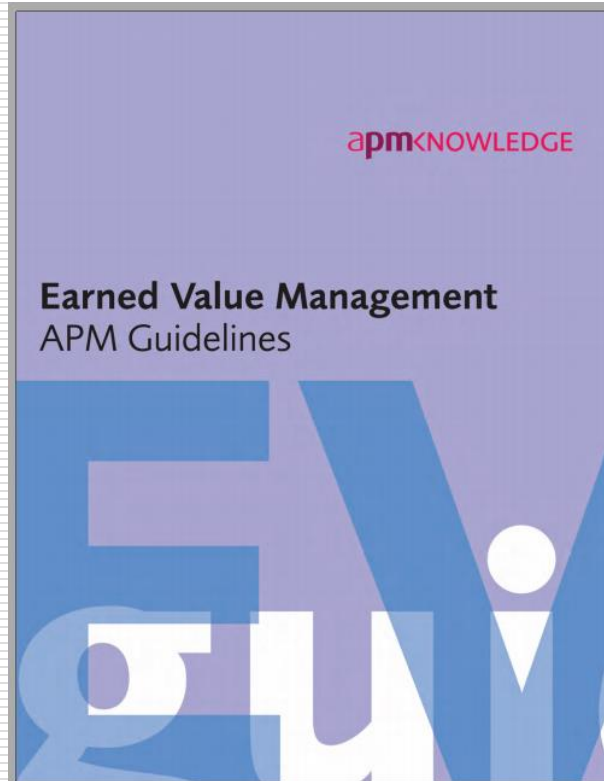
Exercise 4 – Smoothing

Using the network from Exercise 2

Assuming there are only 10 Carpenters available at any one time, smooth the resources so the project is completed in the minimum time

- Draw a Gantt Chart and the associate smoothed resource histogram**

Earned Value



Available on APM Website – free PDF for full members.

Earned Value

- ❑ What is Earned Value (EV)
- ❑ Budget Cost of Work Performed (BCWP)
- ❑ It is the value of the work actually done at a given point in time. It takes the work that has been done and the budget for each task and indicates what portion of the budget should have been spent to achieve it

Actual Cost

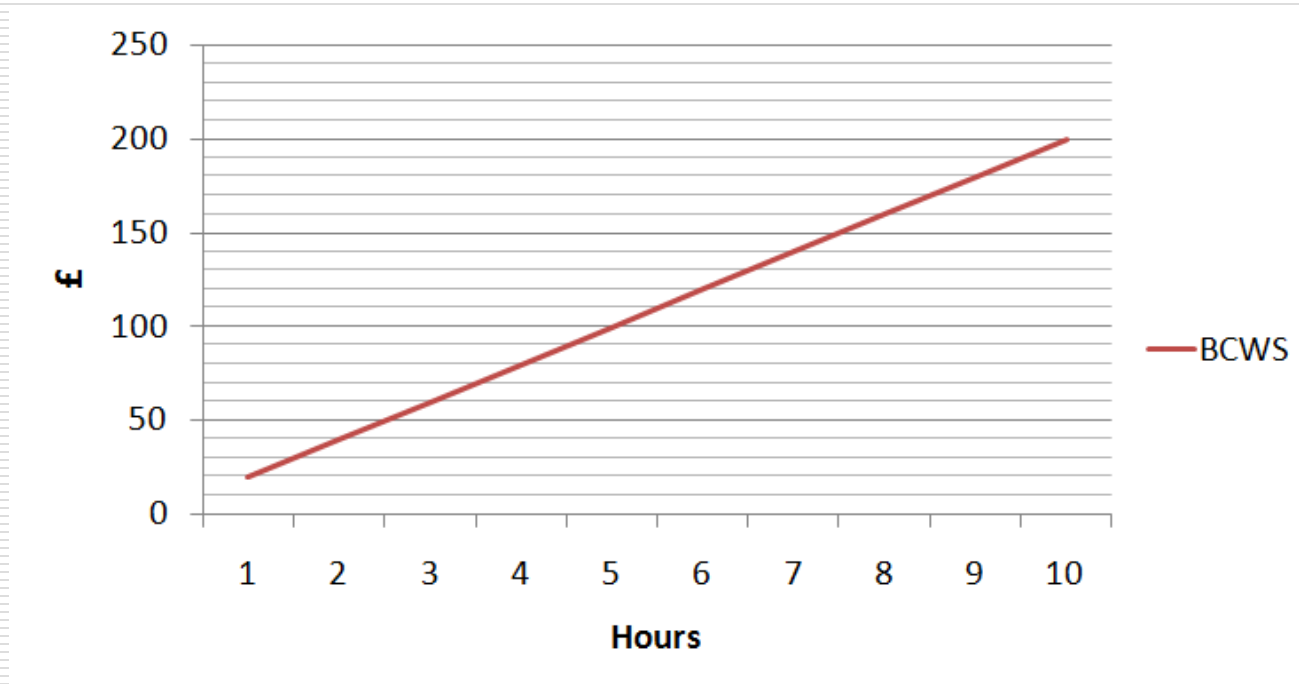
- ❑ The Actual Cost of Work Performed(ACWP) is the cost of the work done.
- ❑ It is the amount reported as actually expended in completing the work accomplished within a given time period

Planned Value

- Budgeted Cost of Work Scheduled (BCWS)
- It is the value of the work that should have been done at a given point in time.
- It indicates the budget at a given point.

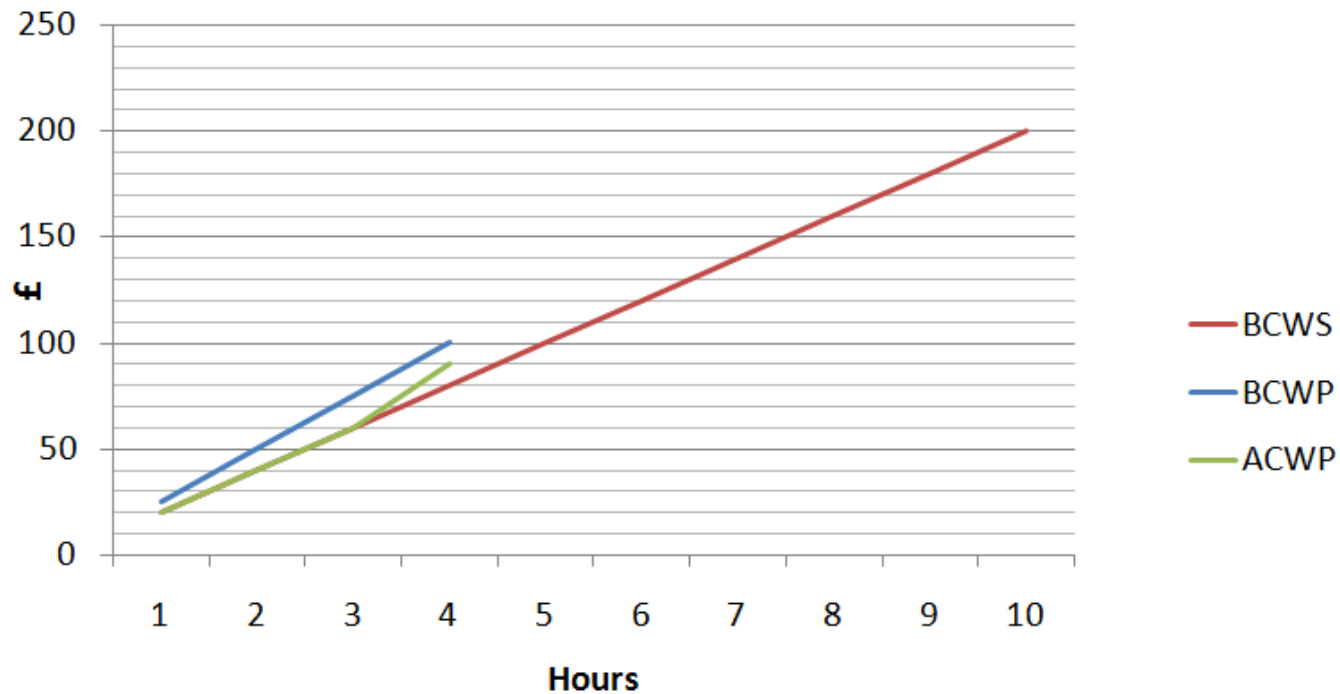
Example

- A builder estimates to build a wall will require 100 bricks at £1 each. The builder can lay 10 bricks per hour. The builder charges £10 per hour



Example

- ❑ After 4 hours the builder has laid 50 bricks
- ❑ Earned Value = £100, Actual = £90



Schedule Performance Index

- SPI measures progress against the plan.
- Greater than 1.0 is good (ahead of plan)
- Less than 1.0 is bad (behind plan)
- Equals 1.0 when we are on plan
- $SPI = BCWP / BCWS$
- Schedule Variance = $BCWP - BCWS$

Example

In our example

- ❑ Earned Value (BCWP) = £100
- ❑ Planned value (BCWS) = £80
- ❑ $SPI = BCWP / BCWS$
- ❑ $SPI = 1.25$
- ❑ The builder is ahead of schedule
- ❑ $SV = 100 - 80 = +20$

Cost Performance Index

- CPI is a ratio of the value of work to actual cost incurred.
- Greater than 1.0 is good (under budget)
- Less than 1.0 is bad (over budget)
- Equals 1.0 when we are on budget
- $CPI = BCWP / ACWP$
- $Cost\ Variance = BCWP - ACWP$

Example

In our example, after 4 hours the cost will be £40 for labour plus £50 for brick = £90

- ❑ Earned Value (BCWP) = £100
- ❑ Actual cost (ACWP) = £90
- ❑ $CPI = BCWP / ACWP$
- ❑ $CPI = 1.11$
- ❑ The cost is under budget
- ❑ $CV = 100 - 90 = +10$

EAC

- Estimate at Completion
- A forecast of the cost required to complete the project based on current progress
- $EAC = \text{Budget at Completion} / CPI$
- $EAC = £200 / 1.11$
- $EAC = £180$ (should finish under budget)

Estimated Duration

- ❑ A forecast of the time required to complete the project based on current progress
- ❑ Estimated Duration = Planned Duration / SPI
- ❑ In our example = 10 hours / 1.25
- ❑ Estimated Duration = 8 hours
- ❑ Should finish ahead of schedule

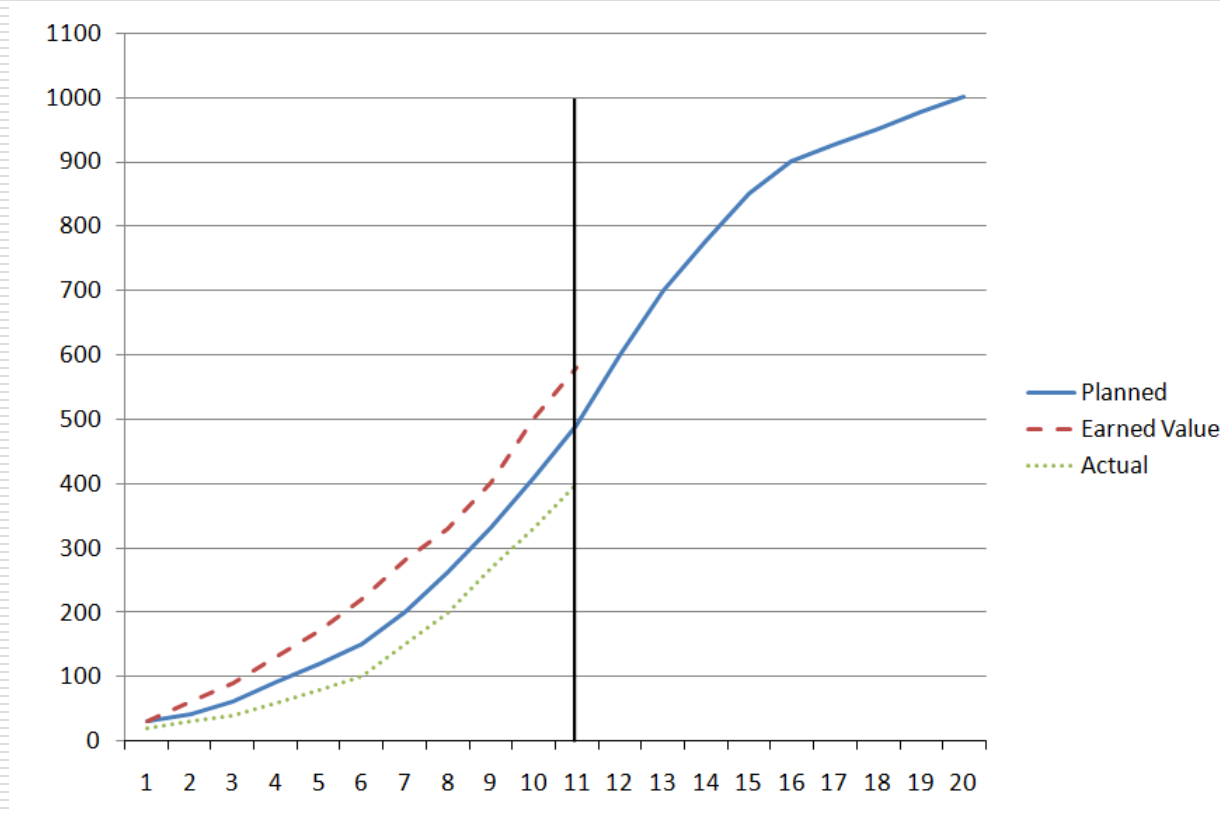
Summary

- ❑ BAC = budget at Completion
- ❑ Earned Value EV = %complete x BAC
- ❑ Cost Variance CV = BCWP – ACWP
- ❑ Schedule Variance SV = BCWP – BCWS
- ❑ Cost Performance Index CPI = BCWP/ ACWP
- ❑ Schedule Performance Index SPI = BCWP/ BCWS
- ❑ EAC = Total Budget / CPI
- ❑ Est. time at completion = Planned duration / SPI

Benefits of Earned Value Analysis

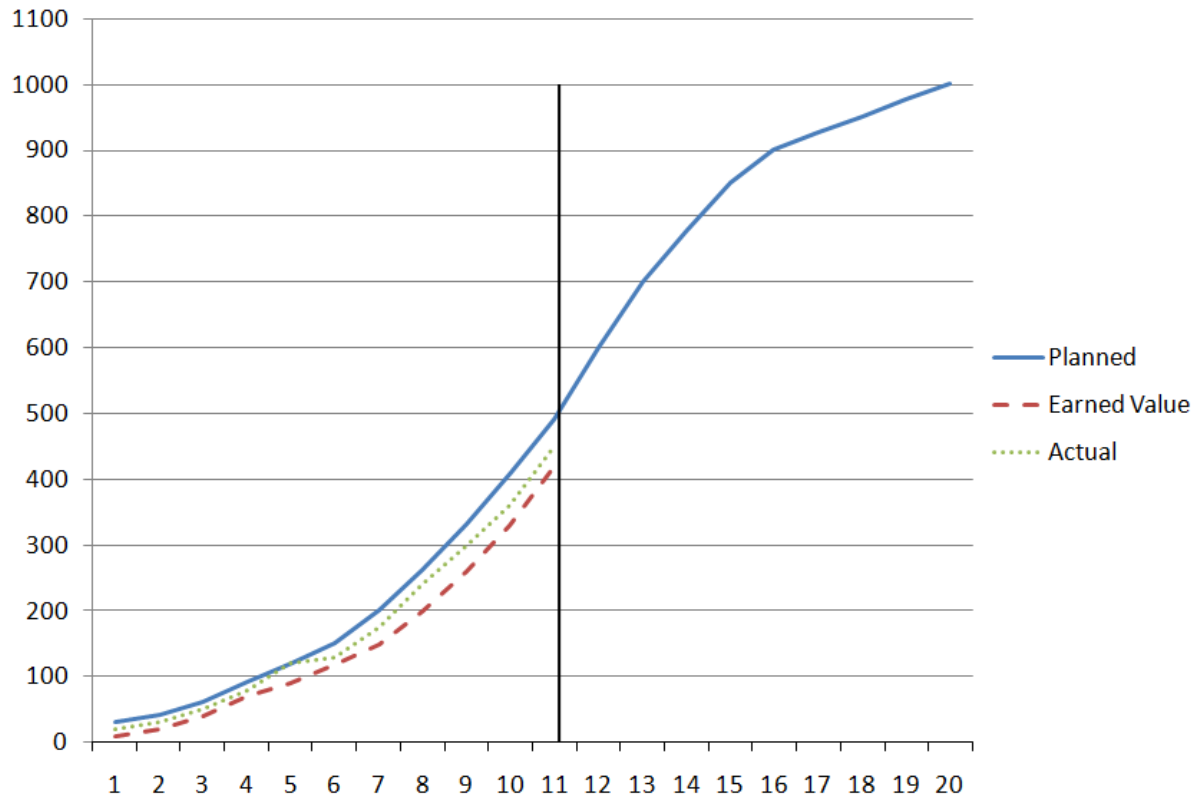
- ❑ Measures work done against expenditure
- ❑ Control is achieved by calculating variances
- ❑ Positive: good, negative: Bad
- ❑ Indices give a summary of project health
- ❑ >1.0 : good, < 1.0 : bad
- ❑ Generates forecast to completion based on current trends
- ❑ SPI and CPI can be used as a measure of efficiency

Good News or Bad News



Ahead of Schedule / Under Budget

Good News or Bad News



Behind Schedule / Over Budget

Exercise 5

- ❑ Earned Value Analysis is being used to monitor and control a 12 month £200,000 capital project. The following values have been extracted for four months of the project

Month	1	2	3	4
Planned Value	16,000	32,000	48,000	64,000
Earned Value	14,000	28,000	40,000	54,000
Actual Cost	11,000	22,000	32,000	43,200

- ❑ Calculate cost & schedule variances and the SPI and CPI for each Period
- ❑ At the end of month 4 what is the: Forecast completion and Estimated cost at completion
- ❑ How would you describe the projects performance and what corrective action (if any) would you advise

Exercise 5 Answer

Months	BCWS	BCWP	ACWP	SV	CV	SPI	CPI	Forecast	EAC
1	16,000	14,000	11,000	-2,000	3,000	0.88	1.27	13.6	157,480
2	32,000	28,000	22,000	-4,000	6,000	0.88	1.27	13.6	157,480
3	48,000	40,000	32,000	-8,000	8,000	0.83	1.25	14.5	160,000
4	64,000	54,000	43,200	-10,000	10,800	0.84	1.25	14.2	160,000

Exercise 5 - Answer cont.

How would you describe the projects performance and what corrective action (if any) would you advise

- The project is behind schedule and under spending. This can be an indication of lack of resources, i.e. the resource you have are performing very efficiently and costing less than expected, however they are behind schedule.
- Corrective action would be to employ more resources to get back on schedule, this will increase the SPI and reduce the CPI, as more resource normally work less efficiently, i.e. 10 men do not produce twice the output of 5 men.

Certification / Exams



http://www.apmg-international.com/en/qualifications/ProjectPlanningControl/Project_Planning_Control.aspx

<http://www.apmg-international.com/earned-value.aspx>

[http://www.aacei.org/cert/PSP/What is a PSP.pdf](http://www.aacei.org/cert/PSP/What_is_a_PSP.pdf)

[http://www.aacei.org/cert/EVP/What is a EVP.pdf](http://www.aacei.org/cert/EVP/What_is_a_EVP.pdf)

Get Involved

- EVA21 on 16/6/16
- Events see www.apm.org
- Join an APM SIG, it's free.
- Podcast / newsletters / discussion
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Thank you for Listening

