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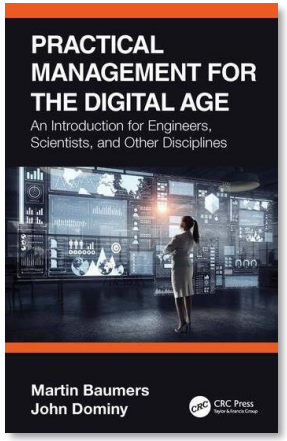
Department of Mechanical, Materials and Manufacturing Engineering

Project Scheduling and Planning

What we will talk about today:

Project Scheduling and Planning

- *Introduction: planning projects*
- *Parallelity and precedence*
- *Logic network and critical path*
- *Work breakdown structure and Gantt chart*
- *Starting a network analysis*
- *The events network*
- *Forward pass and backward pass*
- *Activity-on-node Network*



Lecture builds on Chapter 16 in Baumers and Dominy (2021) – Please read!

Planning the project

- In this lecture we look at how we plan a project
- Modern project planning and scheduling techniques have their origin in the 1950s to manage large commercial and military projects

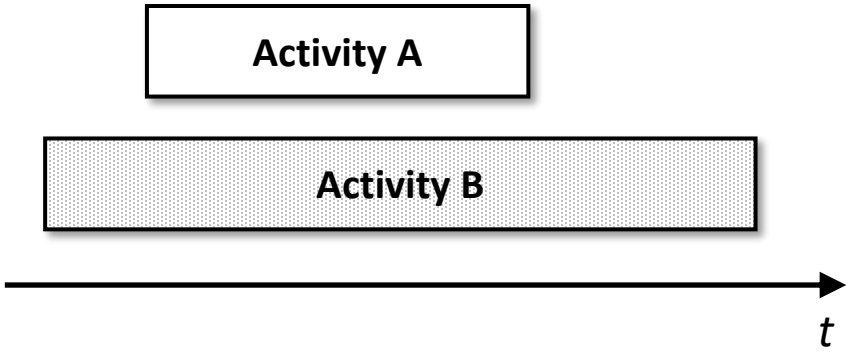
- With the emergence of digital planning techniques these approaches are now implemented as software products

The underlying problem

- The structure of projects is usually determined by two aspects that shape the planning and scheduling task:

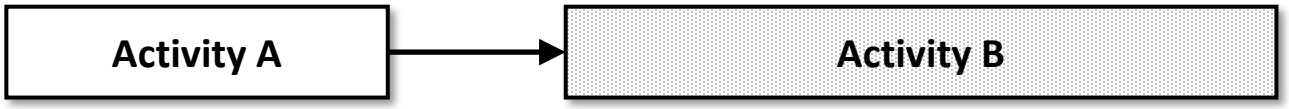
1. Parallelity of activities

Meaning the some activities can take place simultaneously



2. Precedence of activities

Meaning that some activities must precede others



The simple example we will be using in the lecture

How do we make a cup of tea?

- fill kettle
- boil kettle
- warm pot
- put tea in pot
- pour water into pot
- pour tea into cup
- pour milk into cup
- deliver to customer

- We could complete each task in the sequence above, or…….

…….where possible carry out tasks in parallel;

- fill kettle
- boil kettle

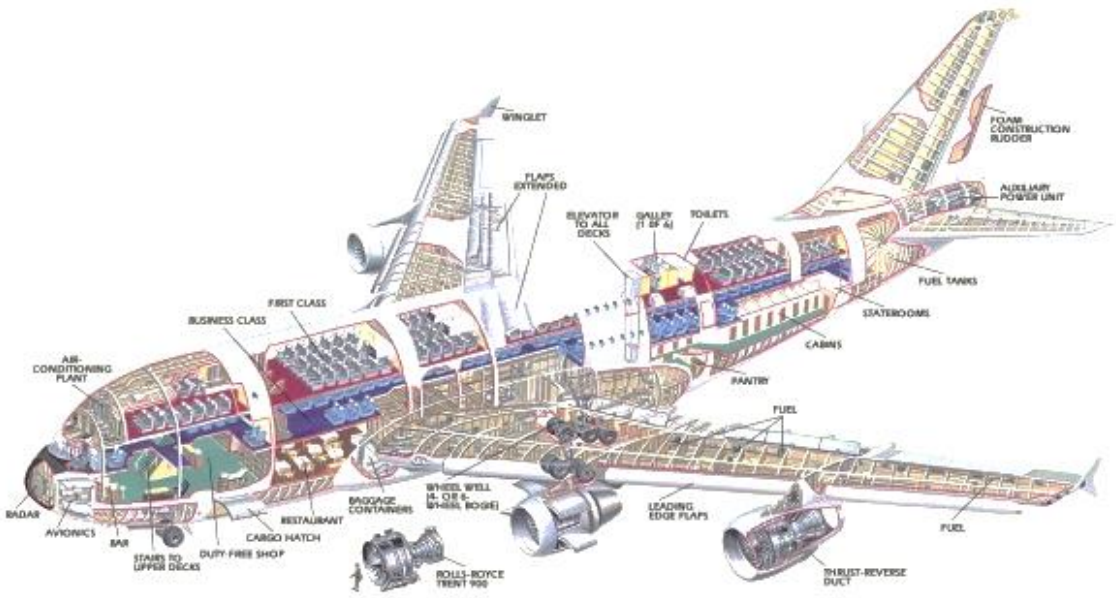
-warm pot
-put tea in pot
-put milk in cup

} While kettle is boiling

- pour water into pot
- pour tea into cup
- deliver to customer

Note that the tasks defining the length of the project (the Critical Path) are reduced from eight to five

Often the number of parallel tasks will grow significantly as the project develops



As we've seen, the individual elements necessary to complete the work were:

- fill kettle
- boil kettle
- warm pot
- put tea in pot
- pour water into pot
- pour tea into cup
- pour milk into cup
- deliver to customer

→ **but there are constraints that limit us to certain sequences of tasks**

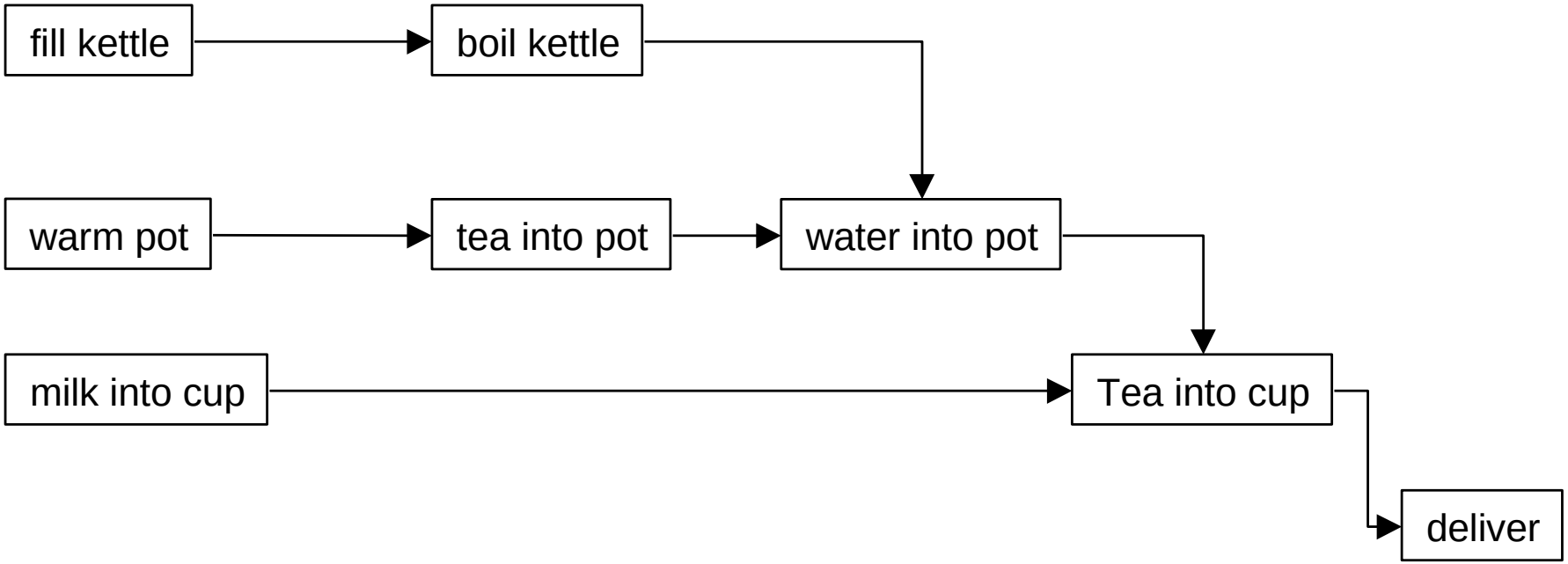
Precedence constraints in a project

We can list the constraints or rules to make a cup of tea:

- kettle must be filled before it can boil
- water must boil before it can be added to tea
- milk can not be added to tea before water
- milk can only be put into cup - not directly into tea pot

The Logic Network of a project

These constraints can be captured and summarised in a type of flow chart known as the Logic Network

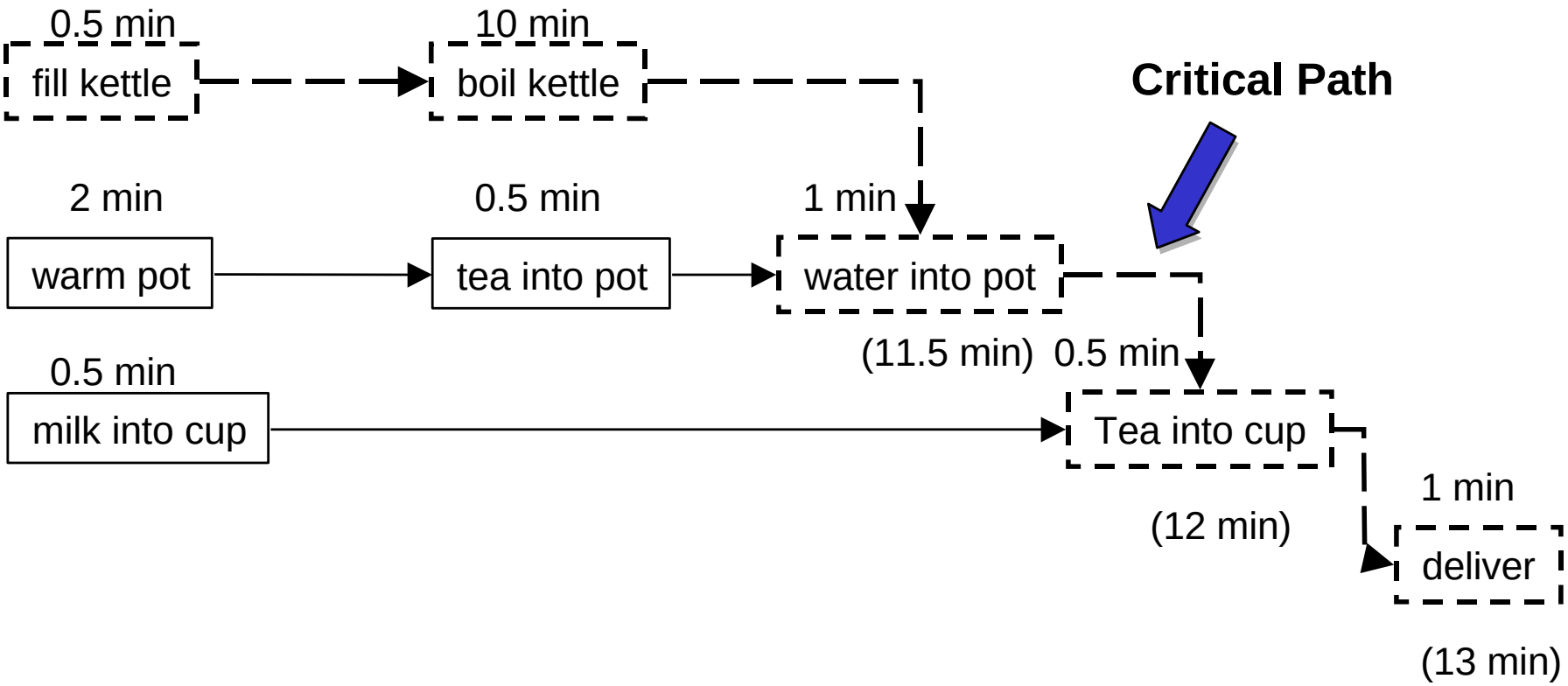


Adding time to the Logic Network

The next step is to consider the time necessary to complete the project

- 0.5 min fill kettle
- 10 min boil kettle
- 2 min warm pot
- 0.5 min put tea in pot
- 1 min pour water into pot
- 0.5 min pour tea into cup
- 0.5 min pour milk into cup
- 1 min deliver to customer

The times can be added to the Logic Network



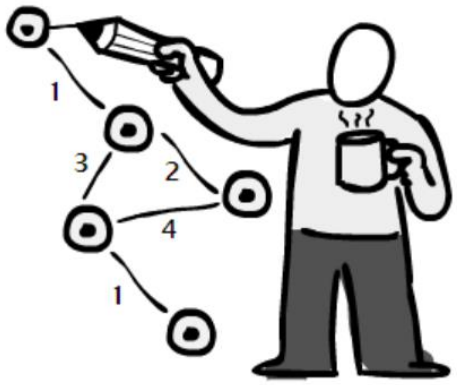
Note that the numbers above boxes indicate the duration of a task, and the numbers below in brackets represent elapsed time to the completion of the step.

Identification of the Critical Path

The next step is to consider the minimum time required to complete the project subject to the precedence constraints.

The path that satisfies this criterion is known as the **“Critical Path”.**

- The Critical Path therefore defines the minimum duration in which a project can be completed
- It will driven by the tasks with the (relatively) longest duration in the project
- It is critical in the sense that any delay in the individual tasks will inevitably delay the completion of the project

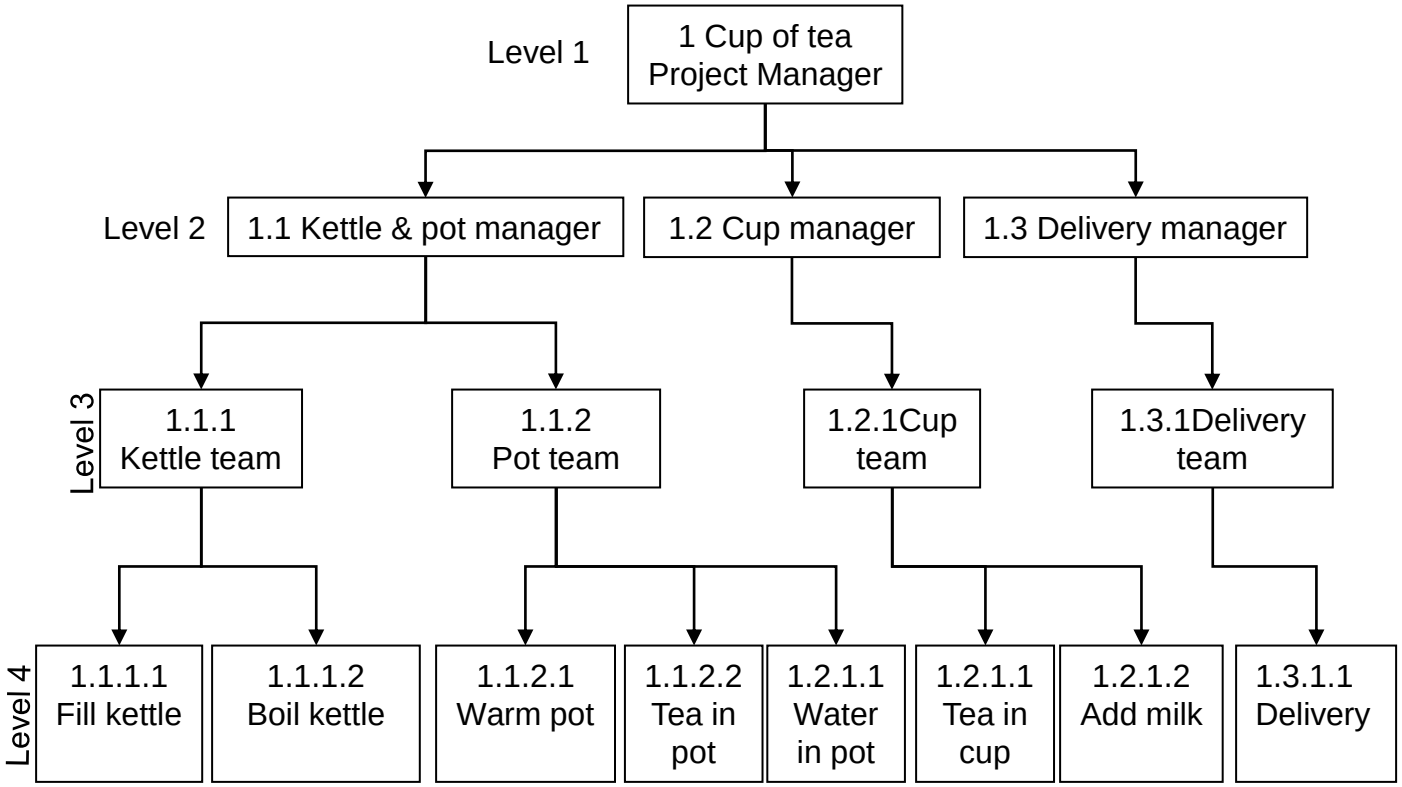


The Work Breakdown Structure

The Work Breakdown Structure (WBS) is a means of providing a logical subdivision of work for various purposes.

- It is an additional means of tracking who does what and when.
- The WBS defines individuals who have responsibilities for each task
- in a complex programme involving many subcontractors (e.g. a large building), the WBS may become a legal document

Example WBS for tea making

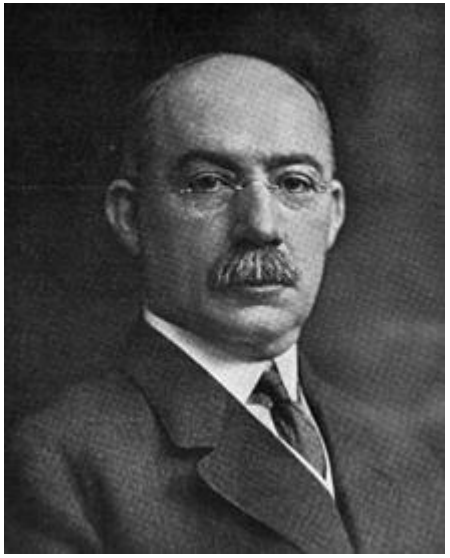


The Gantt chart

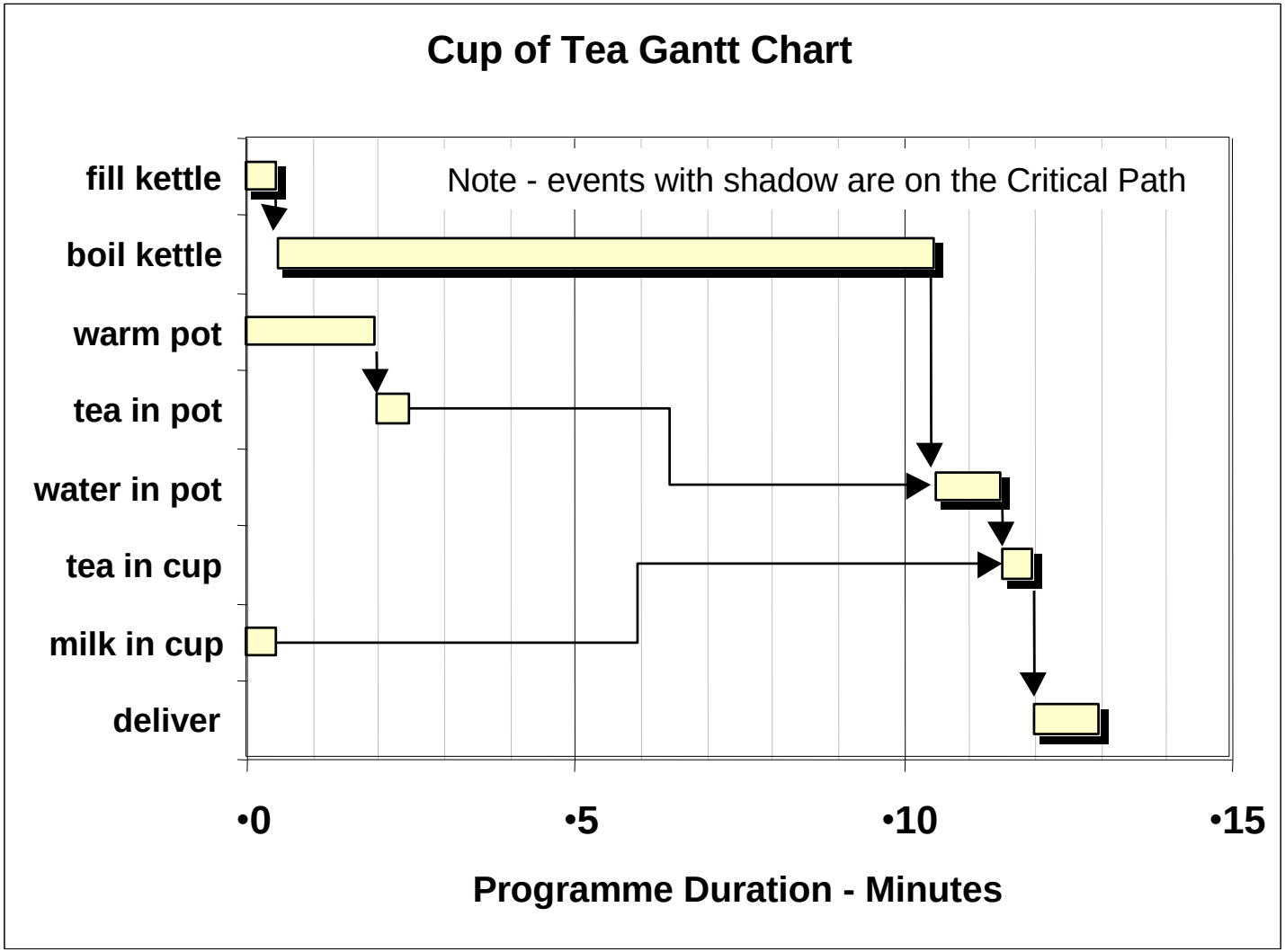
One the basis of the logic network and the WBS it is possible to construct a Gantt chart.

- The Gantt chart cannot be completed without the Logic Network (except for very simple projects)

- A Gantt chart will define:
  - the sequence of the tasks
  - their timing
  - the relationships between them (dependencies)



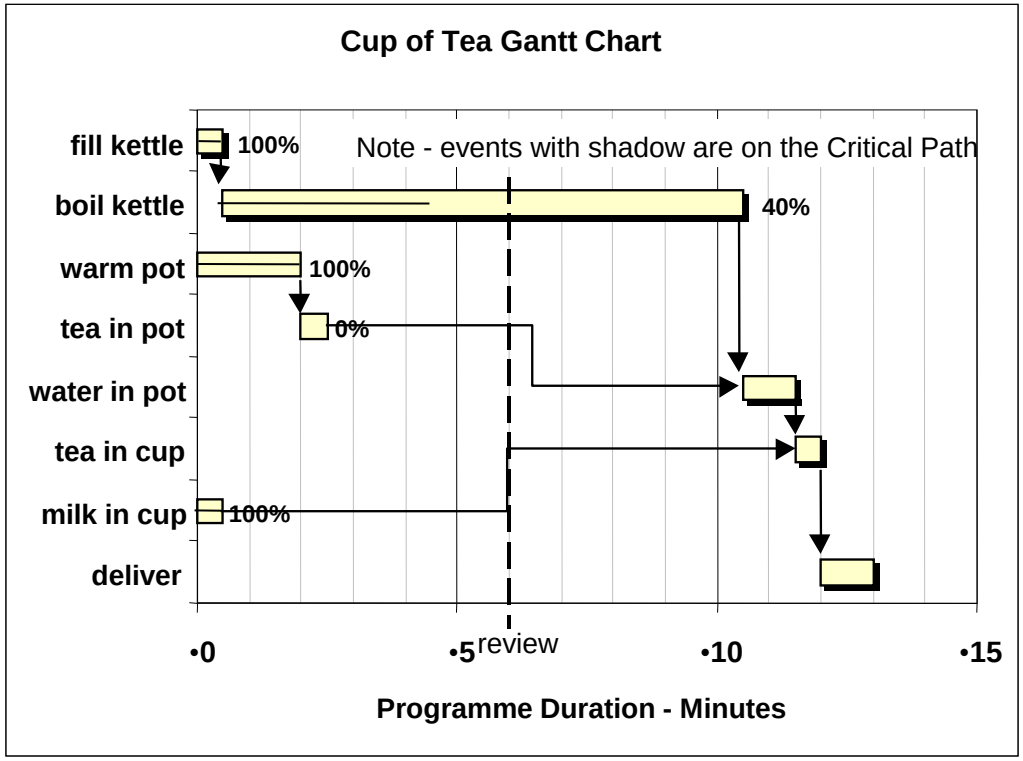
Henry Gantt (1861-1919)


Cup of Tea Gantt Chart
Note - events with shadow are on the Critical Path
fill kettle
boil kettle
warm pot
tea in pot
water in pot
tea in cup
milk in cup
deliver
•0
•5
•10
•15
Programme Duration - Minutes

Project status

Even the best managed programmes rarely run to schedule. We can show progress by using “bars within bars”

- Length of inner bar represents the percentage of the task that is compete

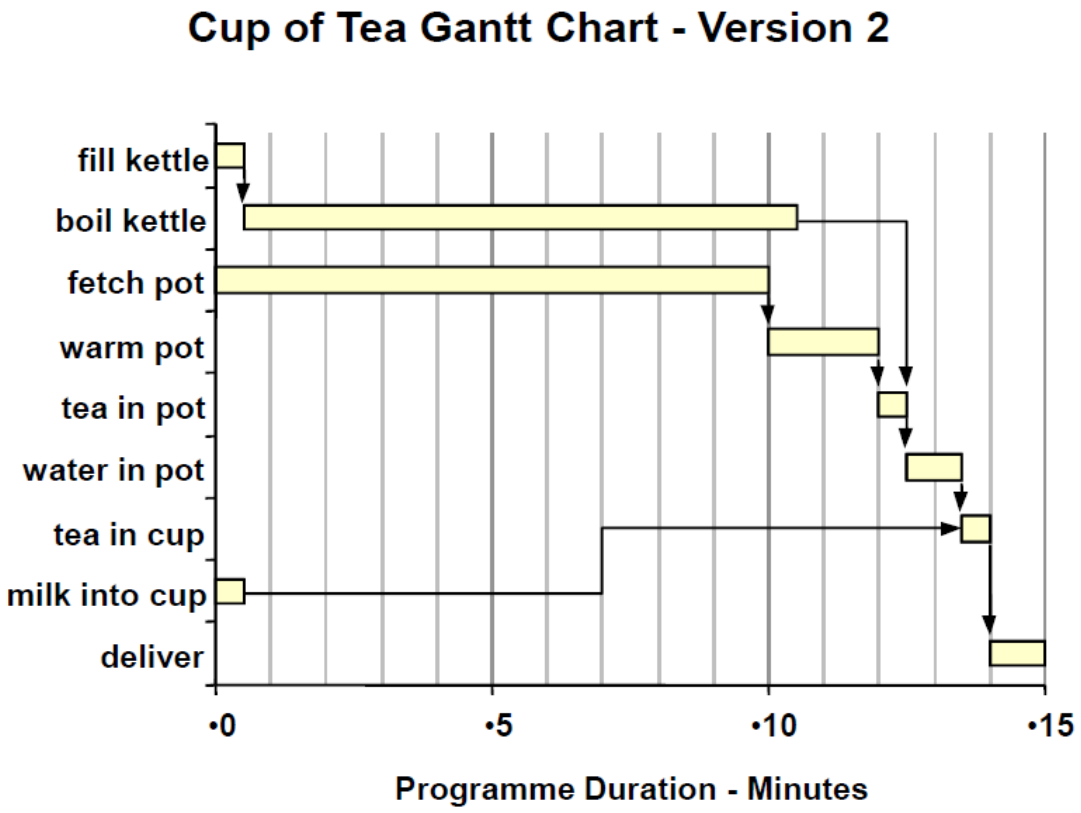


- More on this in the lecture on project monitoring

Adding and removing activities

Occasionally, it will be necessary to add or remove activities from a project.

- The following shows the example after a 10 minute activity “fetch pot” has been added

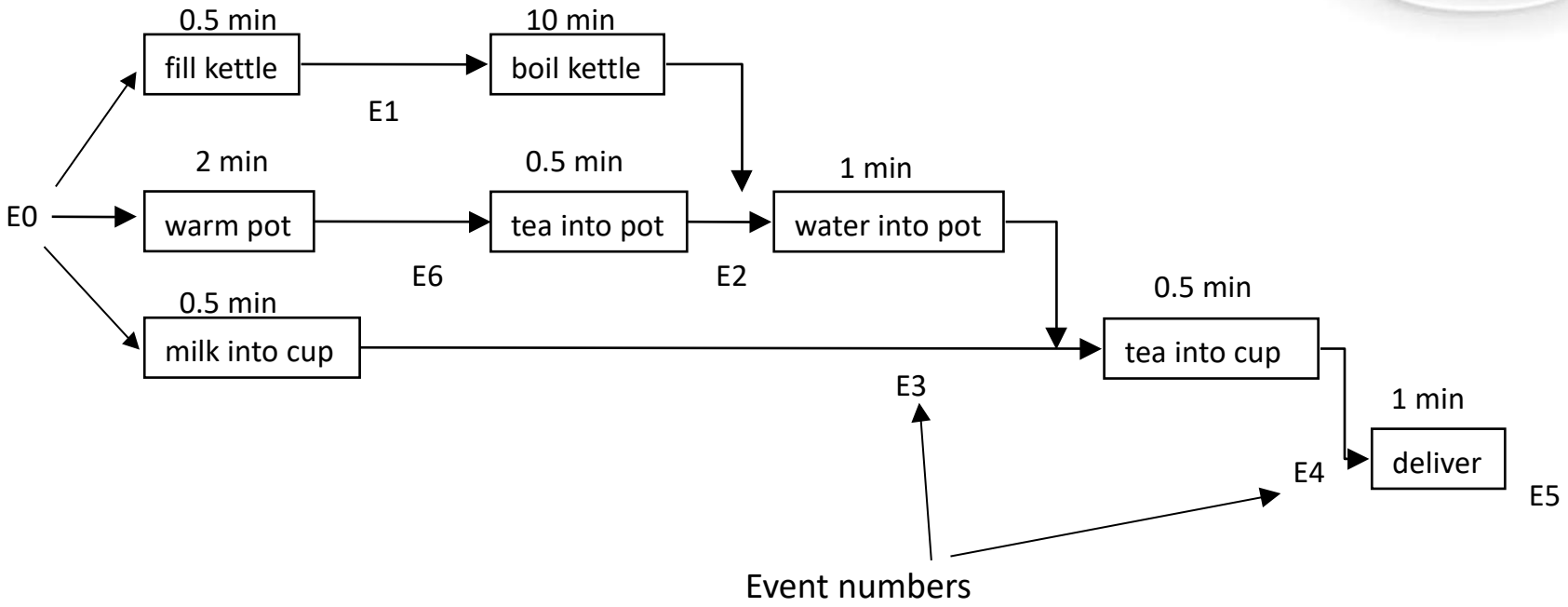


Starting a network analysis

The first step towards a network analysis is to introduce the concept of events.

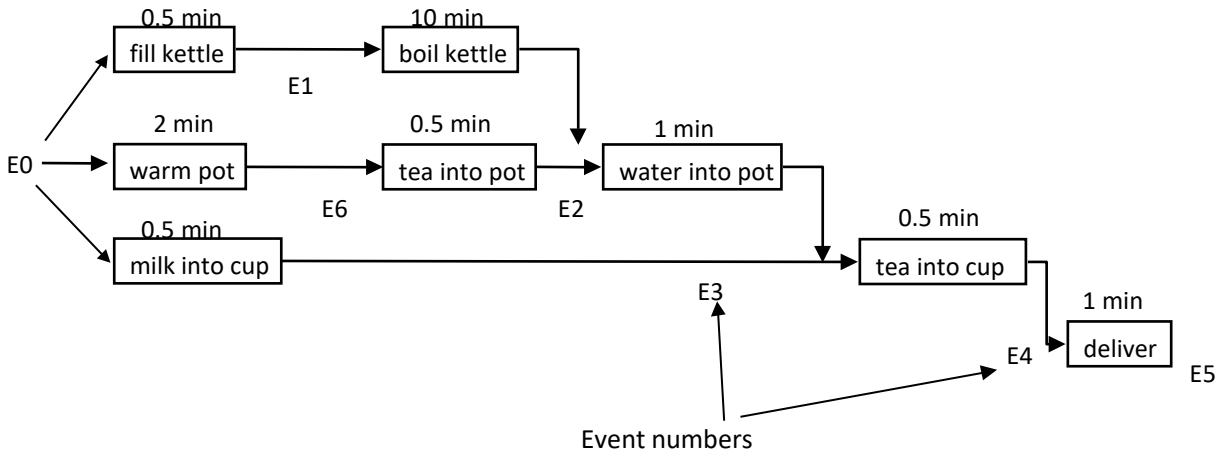
- An event occupies the space between activities. They are assigned numbers for identification (e.g. E1)
- Events have no duration, they occur instantaneously
- Events are important because they are the points where networks can branch
- Note that the project start and project termination are both events (project start is normally assigned normally E0)

Events in the logic network



Note that we can now define activities very precisely by stating the adjacent events. For example, the activity “boil the kettle” can be defined as (E1,2).

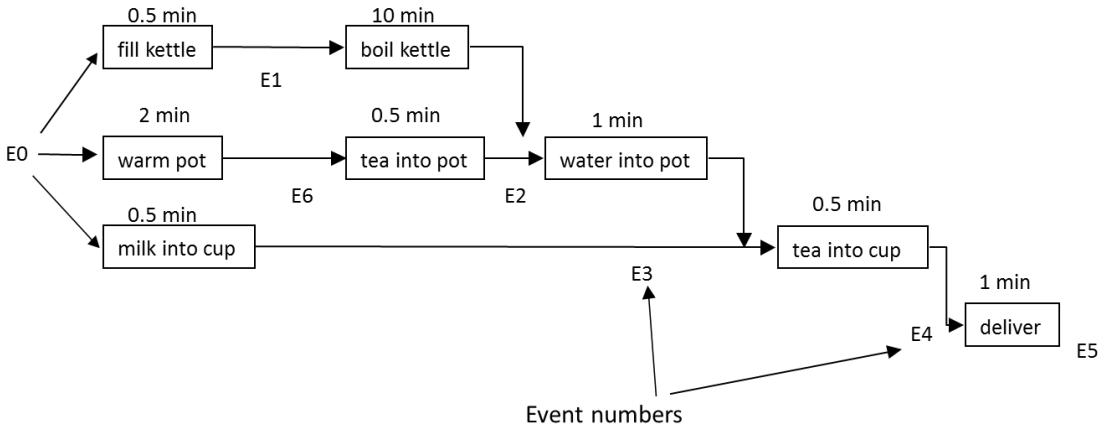
Constructing a table of events

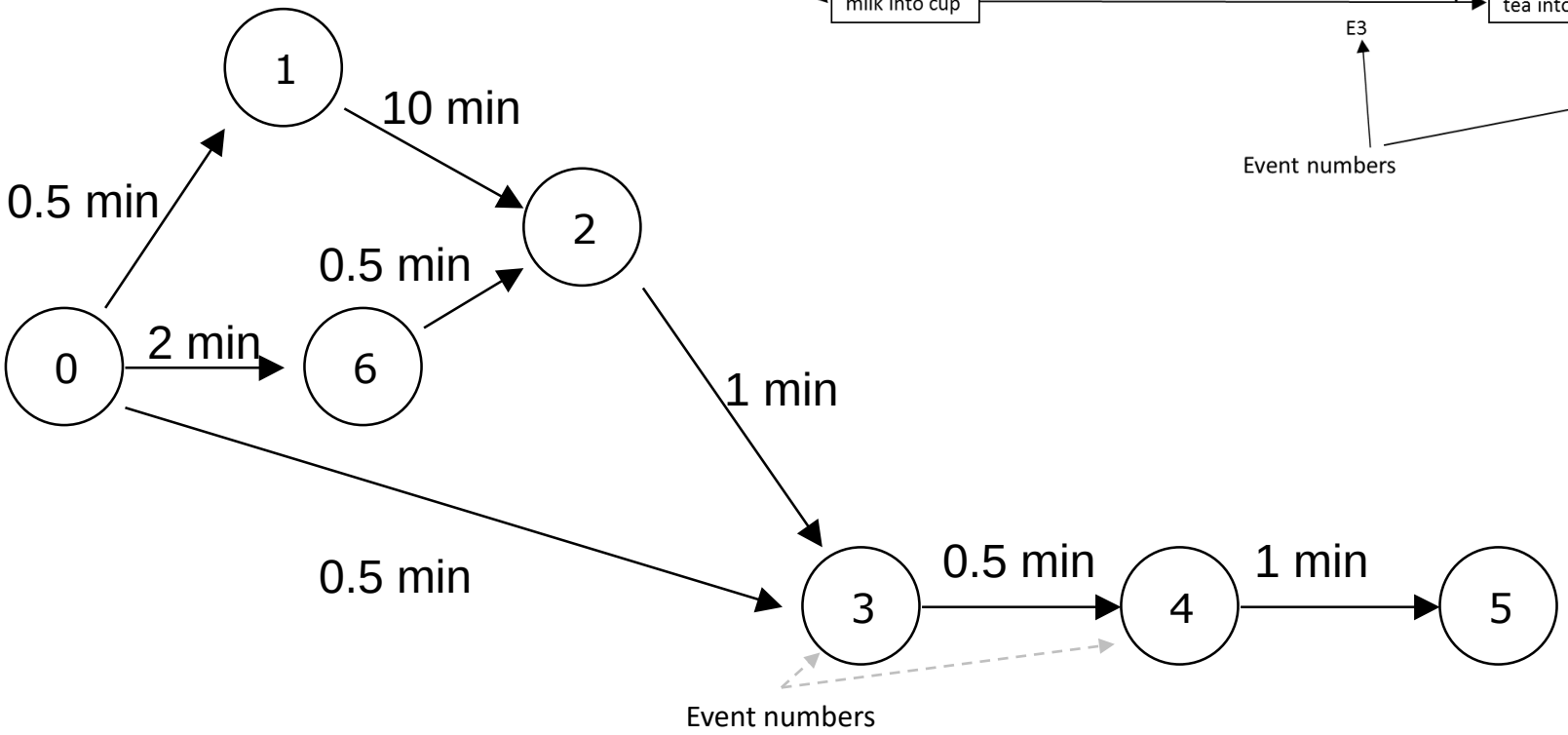


Events	Activity	Activity duration
(E0,1)	Fill kettle	0.5
(E1,2)	Boil kettle	10
(E0,6)	Warm pot	2
(E6,2)	Tea into pot	0.5
(E2,3)	Water into pot	1
(E0,3)	Milk into cup	0.5
(E3,4)	Tea into cup	0.5
(E4,5)	Deliver tea	1

This allows us to build the Events Network of the project

Switching from a focus on activities to a focus on events:





The Forward Pass

To further analyse the project we must identify the Earliest Activity Start (EAS) for each activity and the duration of the critical path.

- This is done with a technique called the Forward Pass.

- The Forward Pass is a calculation of how long it takes to work through our programme.

This is done by obtaining the duration of each possible path through our programme:

  - Path 1: E0 - E1 - E2 - E3 - E4 - E5
  - Path 2: E0 - E6 - E2 - E3 - E4 - E5
  - Path 3: E0 - E3 - E4 - E5

Earliest Activity Start

The next step is to simply add up the durations of the activities on each path:

- Path 1: E0 - E1 - E2 - E3 - E4 - E5
  = 0.5+10+1+0.5+1 = 13 minutes

- Path 2: E0 - E6 - E2 - E3 - E4 - E5
  = 2+0.5+1+0.5+1 = 5 minutes

- Path 3: E0 - E3 - E4 - E5
  = 0.5+0.5+1 = 2 minutes

Earliest Activity Start

Now we add these up and use a table to show when we get to each event for each path:

Path 1		Path 2		Path 3	
Event	Time of occurrence	Event	Time of occurrence	Event	Time of occurrence
0	**0**	0	**0**	0	**0**
1	**0.5**	6	**2**		
2	**10.5**	2	2.5		
3	**11.5**	3	3.5	3	0.5
4	**12**	4	4	4	1
5	**13**	5	5	5	2

- If there are multiple paths to an event, as is the case with (E2) and (E3) in our programme, the EAS is the latest of the possible times (shown in **blue**).

- For each activity, the EAS is the latest occurrence of the event preceding this activity.

The Backward Pass

We repeat this logic, but from the end of the project (E5 in our example):

- This is done with a technique called the Backward Pass
- The Backward Pass is a calculation of how long it takes to work backwards through our programme

  → This starts with the minimum completion time of the project which is the duration of the critical path.

- This allows us to identify the Latest Activity Finish (LAF) for each activity

Latest Activity Finish

This time we subtract durations (in the opposite direction!) and use a table to show when we get to each event for each path:

Path 1		Path 2		Path 3	
Event	Time of occurrence	Event	Time of occurrence	Event	Time of occurrence
5	**13**	5	**13**	5	**13**
4	**12**	4	**12**	4	**12**
3	**11.5**	3	**11.5**	3	**11.5**
2	**10.5**	2	**10.5**		
1	**0.5**	6	**10**		
0	**0**	0	8	0	11

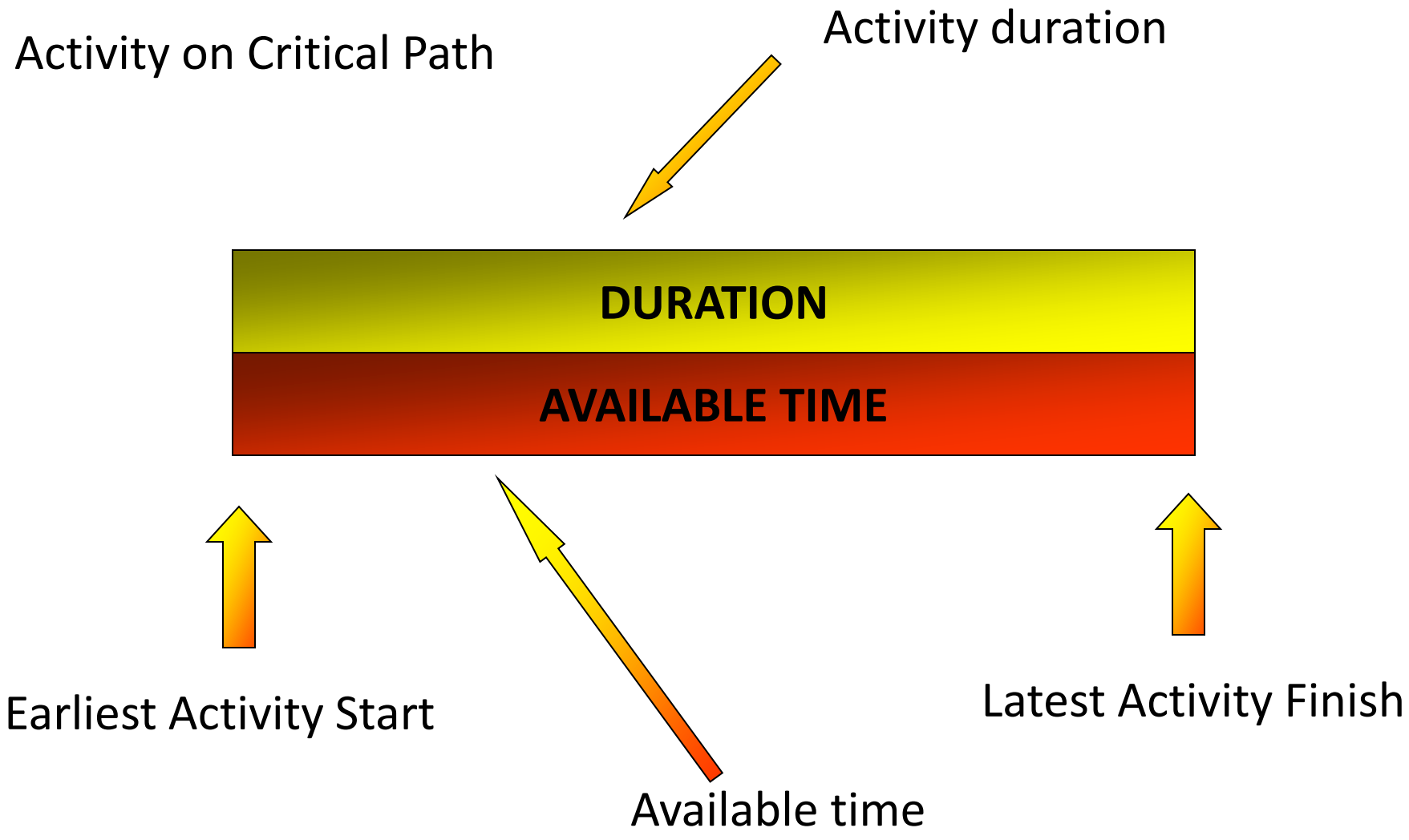
- If there are multiple paths to an event, as is the case with (E0) in our programme, the LAF is the earliest of the possible times (shown in **red**)
- For each activity, the LAF is the earliest occurrence of the event following this activity

Constructing the Activity-on-Node network

The final step in the analysis is to construct the Activity-on-Node network:

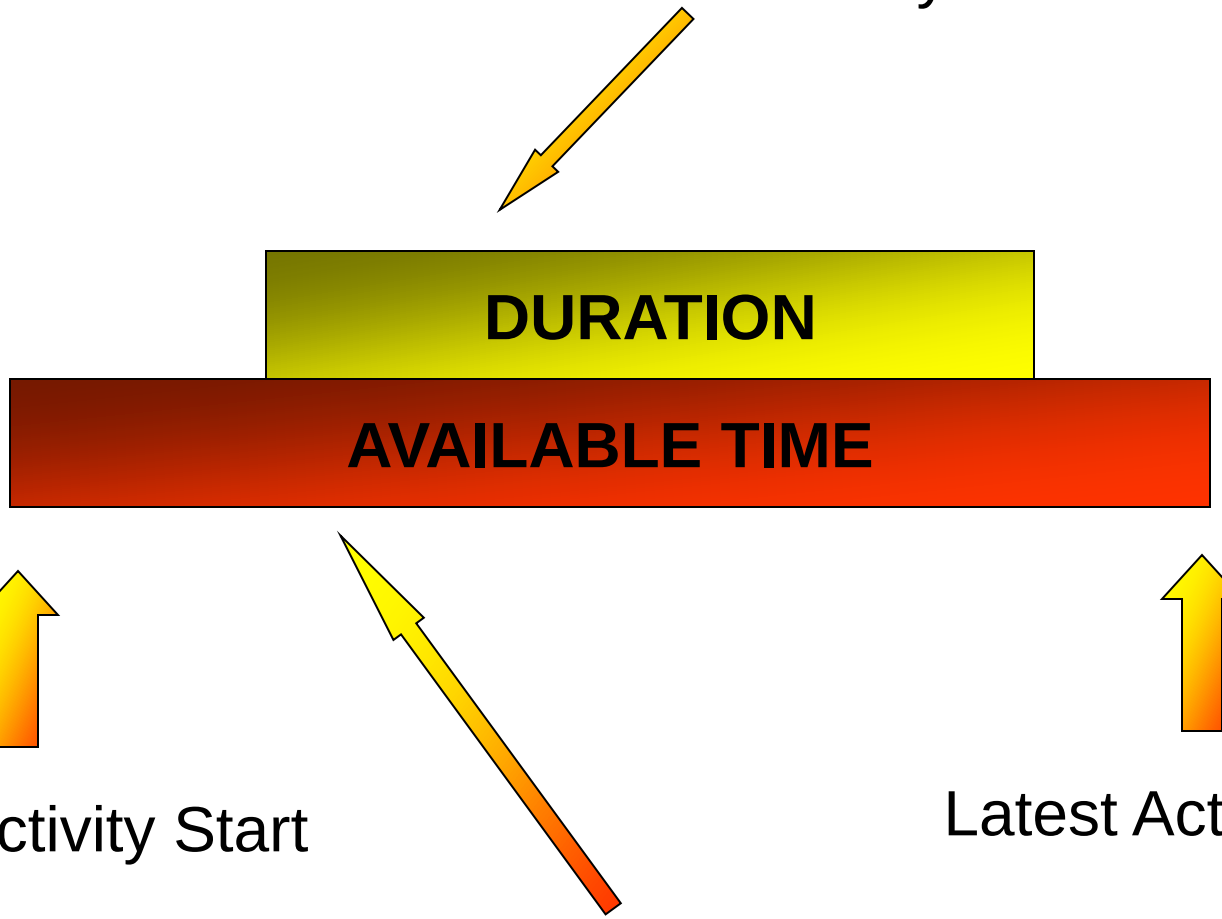
- While this approach seems complicated, this technique is a standard process in project management
- It is captured in norms and standards, i.e. BS6079
- The main aspect project managers want to obtain from the analysis is an aspect known as the “float” of an activity

An illustration of float



Activity NOT on Critical Path

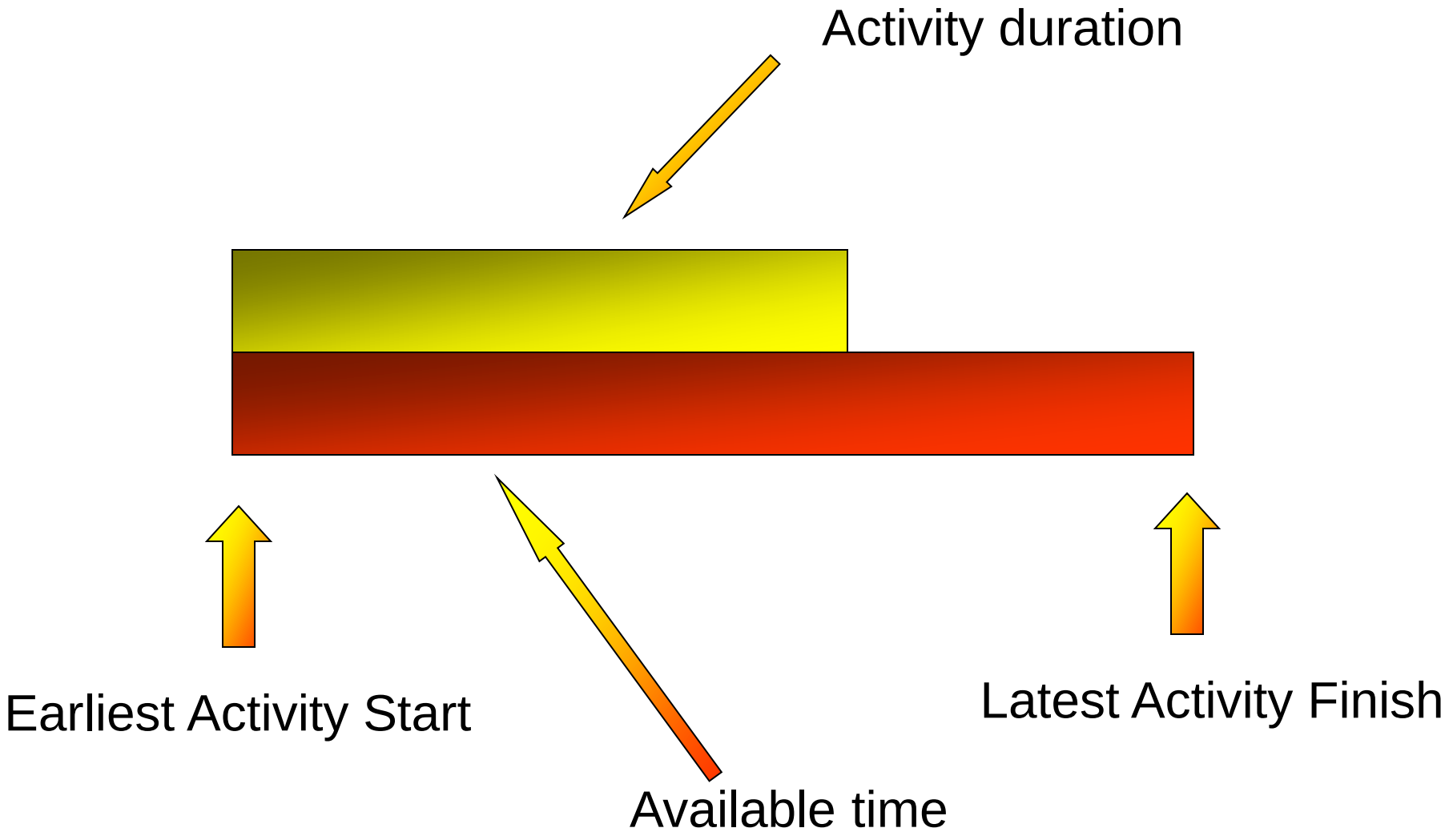
Activity duration

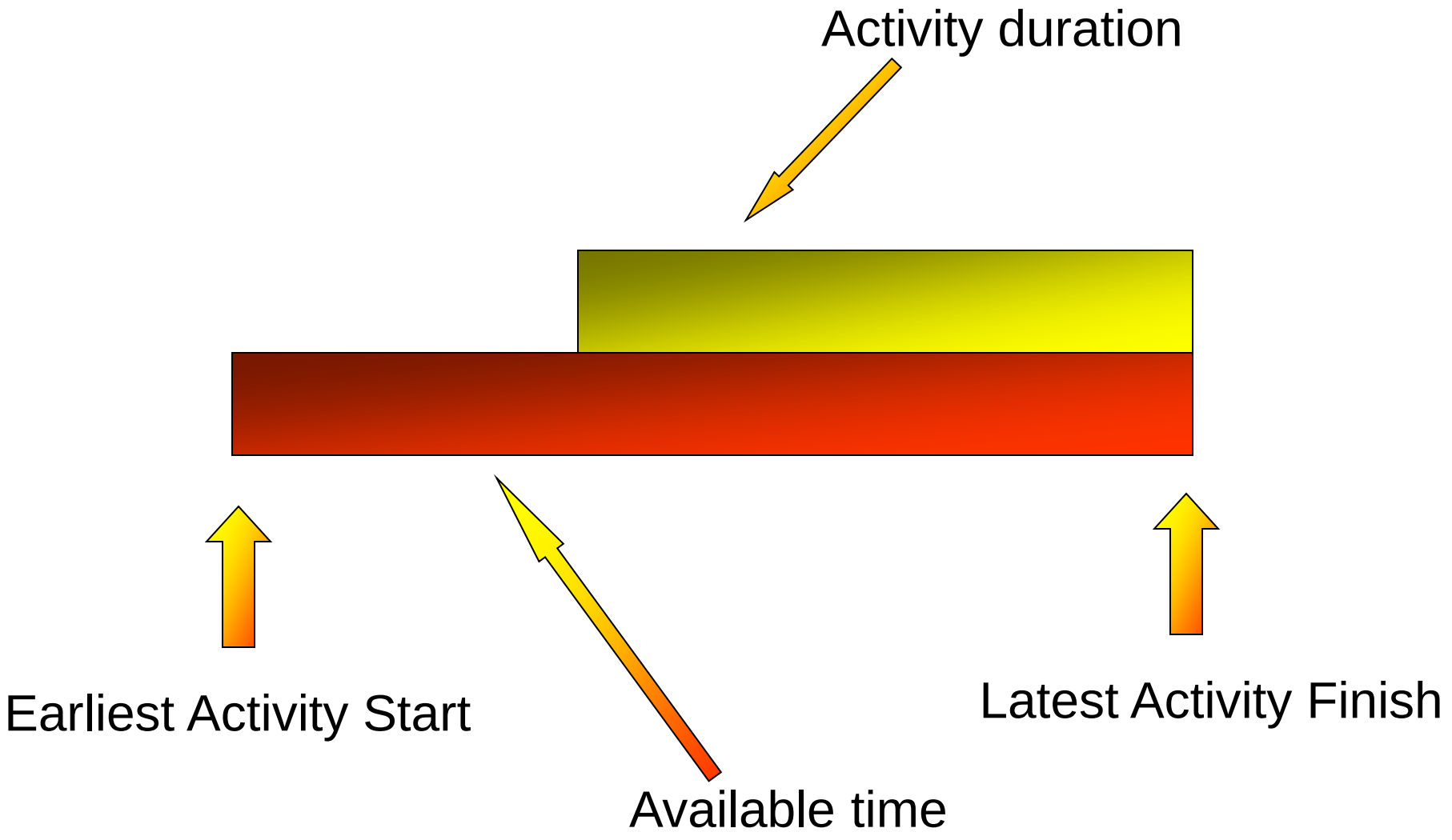


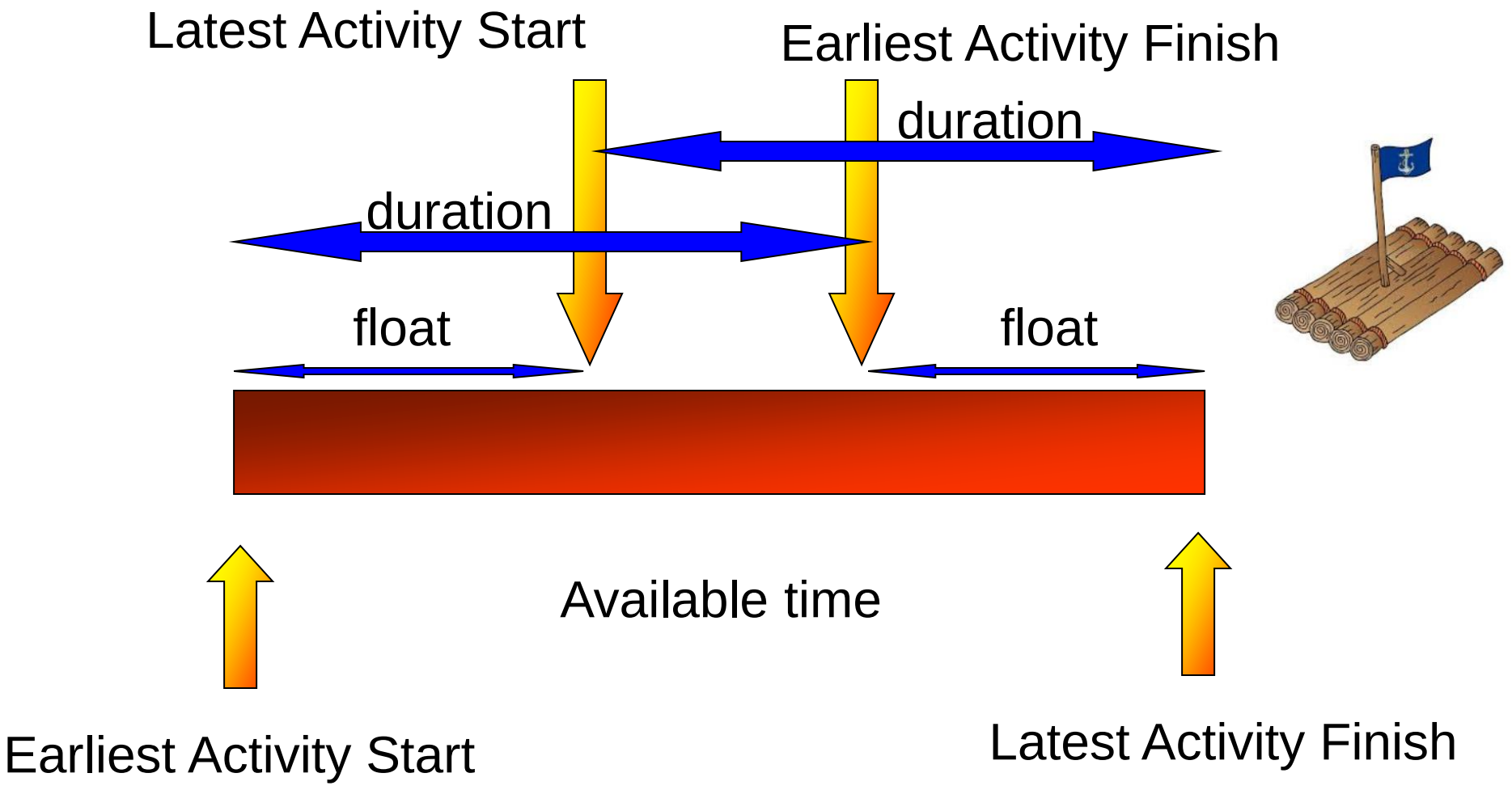
Earliest Activity Start

Available time

Latest Activity Finish


Activity duration
Earliest Activity Start
Available time
Latest Activity Finish

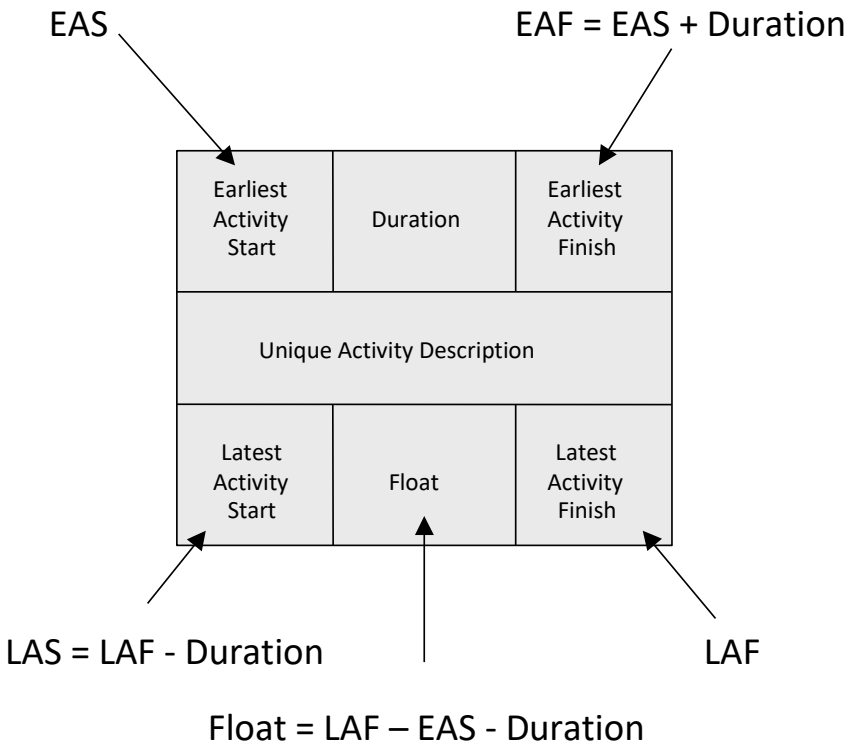

Activity duration
Earliest Activity Start
Available time
Latest Activity Finish


Latest Activity Start
Earliest Activity Finish
duration
duration
float
float
Available time
Earliest Activity Start
Latest Activity Finish

The Activity-on-Node network

The Activity-on-Node network switches the focus of project planning back form the event to the activity. Understanding this is very important.

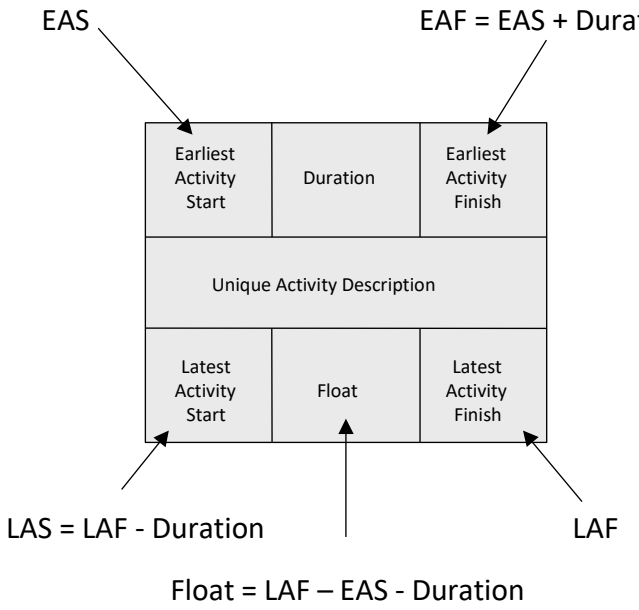
- To do this, a further module is needed to capture what we have learnt so far.
- This is known as the "PERT" module.



Filling the module for each activity

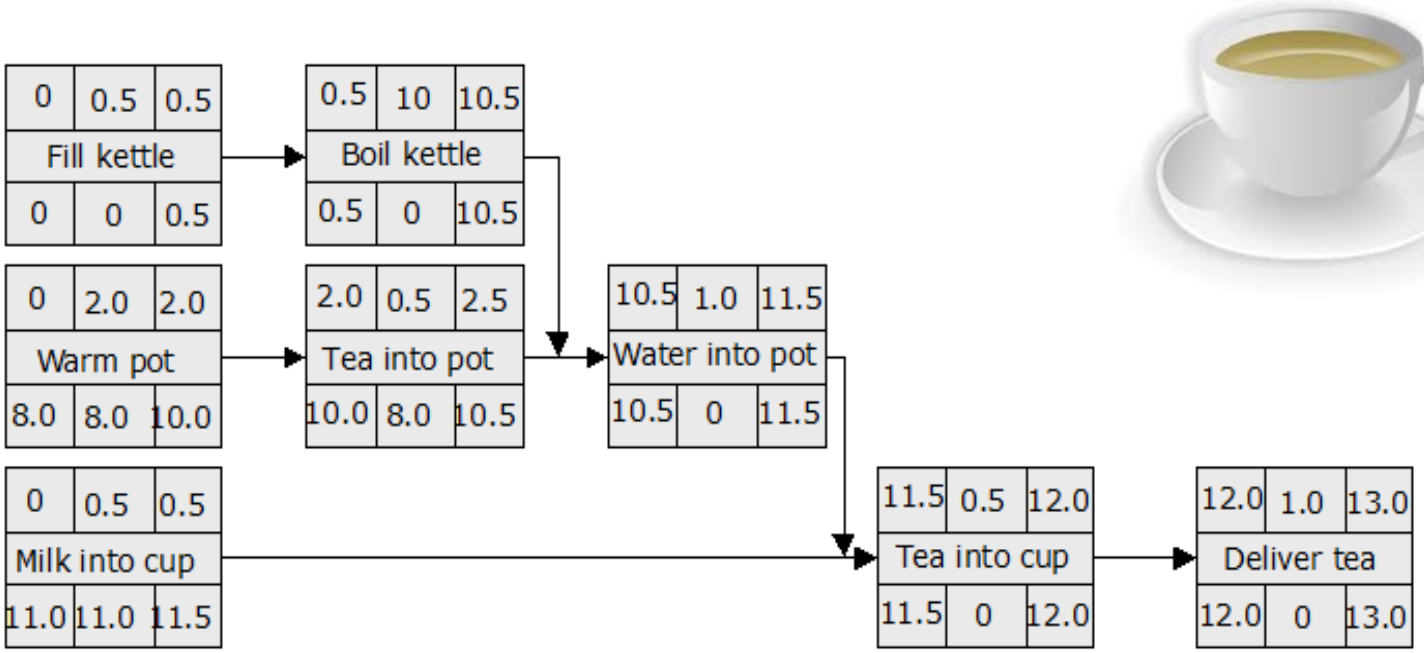
- First enter the duration and the activity descriptor. This is trivial.
- Then insert the EAS in the top left corner (enter zero if this is the first activity).
- Insert the LAF in the bottom right corner (enter the duration of the critical path if it's the last activity).
- Calculate Earliest Activity Finish (EAF) and Latest Activity Start (LAS) as shown.
- Finally, calculate the float for each activity by applying the formula:

$$Float = LAF - EAS - duration$$



The completed Activity-on-Node network

- As a last step, the filled-in modules are inserted to the logic network



So what insight can we glean from all of this?

It gives the Project Manager a valuable set of data on each activity. This allows us to see:

- The earliest and latest each activity can start
- The earliest and latest that it can finish
- The float in each activity
- The critical path (activities with zero float)

Essentially, the technique allow the project manager to fix the latest time that a task must be started to avoid slip.

→ Float allows a Programme Manager scope to schedule the task within the constraints of other requirements…

Some additional points

- Like with the Gantt chart, the Activity-on-Node diagram is not a “do-and-forget” analysis!

- If the project changes, which is very likely:

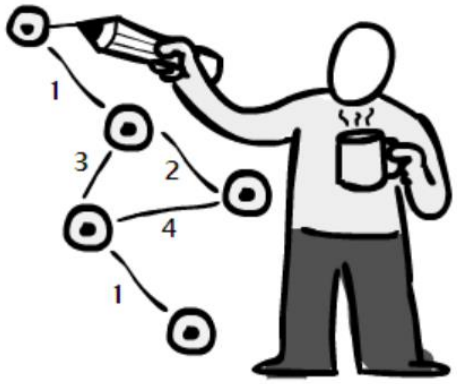
    - Activities will slip or finish early

    - Activities will be introduced or removed

→ The challenge is for the Project Manager to continually monitor and update the programme!

Lecture summary in three points

- Understand how parallelity and precedence shape the structure of a project
- Know now different types of networks…
- Understand the relevance and meaning of float



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Thank you!