

## Networks, Gantt charts and Critical Paths

Robin Beaumont Date: 18/12/2001 14:00

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## 1. Learning outcomes check list for the session

Each of the sessions aims to provide you with both skills (the 'be able to's' below) and useful information (the 'understand what's' below) listed below. After you have completed this session you should come back to these points ticking off those you feel happy with.

Learning outcome	Tick box
Be able to describe a Gantt chart	<input type="checkbox"/>
Be able to describe the purpose of a Gantt chart	<input type="checkbox"/>
Be able to describe a Network diagram	<input type="checkbox"/>
Be able to describe the purpose of a Network diagram	<input type="checkbox"/>
Be aware of the 4 overall aims of Project management as espoused by the PRINCE method	<input type="checkbox"/>
Be able to provide examples of events	<input type="checkbox"/>
Be able to provide examples of activities	<input type="checkbox"/>
List the difference between event and activity centred network diagrams	<input type="checkbox"/>
Be able to develop a Network diagram from a list of activities	<input type="checkbox"/>
Describe the purpose of event numbering in Network diagrams	<input type="checkbox"/>
Be aware of the PERT method of activity duration estimation	<input type="checkbox"/>
Describe the traditional method of activity duration estimation along with its dangers	<input type="checkbox"/>
Be aware of the importance of considering external constraints	<input type="checkbox"/>
Be able to modify Network diagrams to show the activity duration's.	<input type="checkbox"/>
Describe, and be able to carry out the process of Forward Pass	<input type="checkbox"/>
Describe what Earliest time (E) is along with its relationship to Project duration	<input type="checkbox"/>
Describe what Latest time (L) is	<input type="checkbox"/>
Describe, and be able to carry out the process of Backward Pass	<input type="checkbox"/>
Describe what a Critical Path (CP) is	<input type="checkbox"/>
Describe what Critical Path Analysis (CPA) is	<input type="checkbox"/>
Describe the various types of "periods of inactivity"	<input type="checkbox"/>
Describe how periods of inactivity can be manipulated	<input type="checkbox"/>
Be aware of resource issues	<input type="checkbox"/>

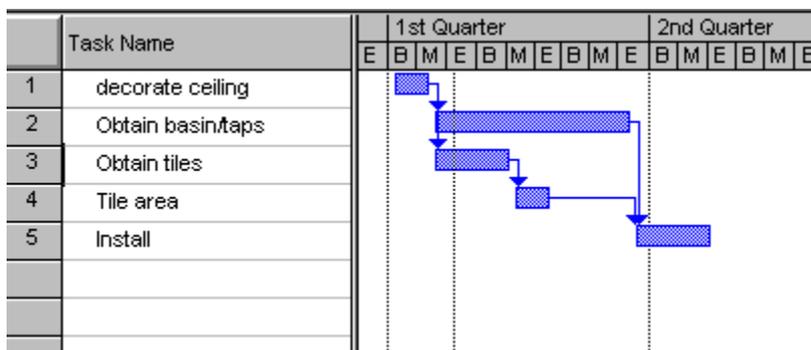
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## 2. Introduction

This short introduction describes a quantitative method of specifying projects which has gained almost universal acceptance.

Although there are numerous software packages available to support this process, this introduction expects you to use the old pencil and rubber technique. Admittedly I have used several software packages to produce the various graphical examples in this introduction including Microsoft Project98 for the Gantt charts along with the drawing tools provided as part of Word98 for the Network diagrams. However, there is no reason why, for a small project such as one that involves only one or two people, a pencil and rubber should not be used, and it is probably more time efficient than learning yet another new piece of software. In contrast for large projects a significant proportion of a manager's time can be taken up with managing the documentation even if they know the computer package.

Most people equate project management with the production of a chart, called a Gantt chart, similar to the one below which in this instance was produced by Microsoft Project98. Although this is the most popular way to specify a project it is not necessarily the most helpful for all participants where the alternative Network diagram is easier to follow. While the network diagram is the focus of this document a brief description of a standard Gantt chart is given below.



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## 3. The Gantt chart

A Gantt chart shows the project activities as a series of rectangles. Each rectangle represents an activity and the activities themselves are listed down the side of the chart. In the above Gantt chart there are five activities listed. Along the top of the chart is the time scale. In this instance it is in thirds of months (marked **B**eginning, **M**iddle, **E**nd). In Microsoft Project98 you can easily adjust the time units to be anything from minutes to years. Microsoft Project98 also allows you to define various activity types and explode high level activities into a number of lower level ones (e.g. the high level activity 'Literature review' might be divided into: developing search strategy, doing, and reporting).

Port folio exercise

Considering the units of time in the above Gantt chart. Create a table with two columns. The first column should specify the unit of time and the second give an example of a project where it is an appropriate time measure. Save this in your Portfolio.

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## 4. Main project phases

There are hundreds of project management techniques around supporting a host of 'consultants', and while each technique purports to offer some additional benefit over rivals little empirical research has taken place. The lack of empirical findings has not prevented the development of various standards such as ISO 9001 (International Standards Organisation) and BS5750 (British Standard). Within these standards specific project management methods have developed such as that of PRINCE (Projects in Controlled Environments). Such methods have been designed for large projects and are often too unwieldy to be downsized. However, some of PRINCE's principles are worth bearing in mind:

The overall aim of project management, according to the PRINCE method, is to:

- Deliver required products
- Deliver specified quality
- Deliver on time
- Deliver within budget (resource constraint)

PRINCE expects you to be able to define the products ('deliverables') at the start of the project in a document known as the PID (Project Initiation Document). Although this is often very difficult in the research environment where investigation is the prime activity one should not forget the poor researcher of a TV programme who is given a defined deliverable in a specified time. Possibly the variable quality of the outcome in this situation demonstrates the dangers of such an approach! In the research setting it is possible to define deliverables but these are frequently re-defined or developed during the project. Creativity and project management often make uncomfortable bed fellows.

PRINCE has three main aspects:

- **Organisation** - A project board and Project site office (PSO) consisting of people with set responsibilities.
- **Plans** - Various plans specifying technical, resourcing, quality and exception issues.
- **Controls** - These are of two types; Managerial controls assess progress throughout the project with various defined assessment and checkpoint (actual versus planned achievements) meetings. The other type of control concerns the product ('deliverables').

### **Port folio Exercise:**

Considering the organisation, plans and controls issues of PRINCE how might they be relevant when planning a research project investigating the quality of nursing care patients receive in three local hospitals? This should be no longer than one page of A4.

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## 5. Activities and events

At the most basic level a project consists of a series of activities and events.

Different management methods place more emphasis on one of these aspects. An example should help. Consider the project of installing a new bathroom sink (referred to as the 'sink' project from now on) which can be viewed either as a series of activities or events:

Activity (task)\perspective	Event perspective
Decorate ceiling	Finish decorating ceiling
Tile area	Area tiled
Install basin / taps	Basin / taps installed
Obtain basin/taps	Basin/taps obtained
Obtain tiles	Tiles obtained

From the above it can be seen that an activity usually results in at least one event so the two perspectives are in reality related. One perspective emphasises the process while the other concentrations more on the outcome. In reality a good project manager controls both aspects. It is usual at the start of a project to decide which perspective will be used. Microsoft project98 software expects a series of activities ('tasks') and I feel that the activity perspective is the most intuitive, at least for the people actually undertaking the project.

### Key point:

Create a list of activities (or events) when starting to define a project.

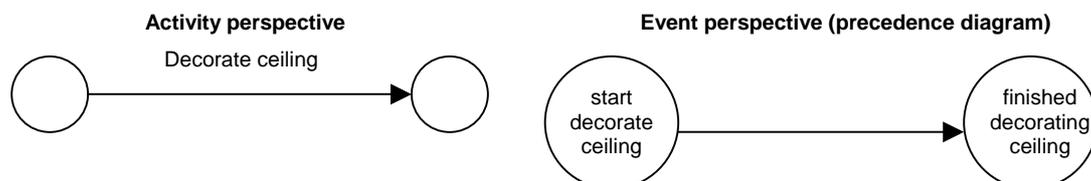
### Port folio Exercise:

Think of a small project (i.e. less than 15 activities) and list the activities you would need to undertake. Such a project might be moving wards, establishing a new service, producing a article or book chapter for publication or planning a local community health event.

This should be no longer then one page of A4.

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Once you have the list of activities in tabular format (i.e. as above) you can begin to sort them into a logical order of some type. You can also depict them graphically such as in a network diagram:



The next section will look in more detail at the type of network diagram that uses the activity perspective.

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## 6. Network Diagrams

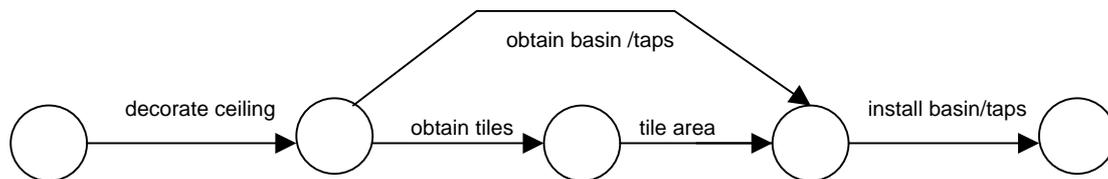
When drawing a network diagram it is sensible to ask the five following questions for each activity:

1. Is it a start activity?
2. Is it a finish activity?
3. What activity, if any, immediately precedes this activity?
4. What activity, if any, immediately follows this activity?
5. What activity, if any, is concurrent with this activity?

Considering the example of the installation of a basin given earlier (the 'basin' project). We can say that 'decorate ceiling' is the first activity and 'install basin / taps' is the finish activity, after all you do not want to take the basin out to tile behind it. If you do not see the logic in this do not worry to much as I'm assuming that your the type of person who likes to do as much decorating as possible at the earliest opportunity and worry about messy tiling! We therefore have graphically:

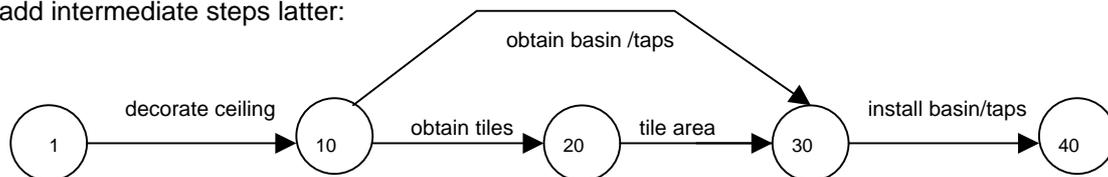


Clearly the other activities fit somewhere in between the start and finish activities. The activity 'tile area' must be preceded by the activity 'obtain tiles'. In contrast the activity 'obtain basin /taps' at first appears to have no proceeding activity, however I decide that I can only choose the colour / style of them after having decorated the ceiling, a similar thing applies to choosing the tiles. I also decide that I can look for the basin / taps at the same time as the tiles as both need to co-ordinate with the ceiling colour. The network diagram now looks like:



### 6.1 Event numbering

To ease the management process each event is given a unique number. These usually start with the lowest value for the first event and have a equal gap in the sequence so that you can add intermediate steps latter:



#### Port folio Exercise:

For the small project you chose draw a network diagram with event numbers.

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## 6.2 Additional exercises

1. Draw a Network diagram for 'sending a letter' including the following activities:

- Write letter
- Put in envelope
- Address letter
- Place stamp on letter
- Post letter

2. Draw a Network diagram for ' Writing a research paper', including the following activities:

- Agree subject area with supervisor
- Review literature
- Prepare section headings
- Prepare first draft
- Initial discussion of first draft with supervisor
- E-mail first draft for internal peer review
- Collate e-mailed comments
- Prepare final draft
- Discuss final draft with supervisor
- Prepare final version
- Disseminate
- Review comments on final version
- Present findings

3. Draw a Network diagram for 'putting on a half day seminar'.

4. Draw a Network diagram for your career development in the next five years

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## 7. Time considerations

The network diagram above says nothing about the actual time the project will take, only the sequence of activities and events. The first stage in considering the duration of the project is to obtain an estimate for each activity.

### 7.1 Estimating

While it is usual to provide a single estimate for each activity a method called PERT (Program Evaluation and Review Technique) demands you supply three estimates for each activity:

- Quickest reasonable time
- Most likely time
- Worst time

The actual estimate for each activity is then taken to be:

$$=(\text{Worst} + 4(\text{Most likely}) + \text{Quickest})/6$$

This may seem unnecessary overkill (the PERT technique was used to develop the Polaris missile) but it may be particularly pertinent in the academic environment where the duration is often taken to be the quickest rather than the most likely! Because external dependencies are rarely considered the 'worst time' is not even thought of. Microsoft Project98 allows you to enter these three types of estimate as well as the more traditional single one.

#### **Port folio exercise**

Consider four activities you have identified for your exercise and calculate their duration using the PERT method. What problems, if any do you see using it? Keep your work in your portfolio

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### 7.2 External dependencies and Quality issues

Project managers often advise those making time estimates to simply double any initial figure they come up with! This may seem rather radical but if one considers that project activities often have unseen external dependencies which can have dire consequences it is not too far from the truth. For example in the 'basin' project each activity depends upon a supplier being able to provide the required materials. Also the desired level of quality has an affect on activity duration, for example the taps I want (they are manufactured by a company with my surname which engraved on the taps) are only available in Brighton necessitating a visit for closer inspection. Another aphorism goes something like 50% effort for 90% of the quality. You must always ask yourself if the small increase in quality is worth the disproportionate effort?

#### **Port Folio Exercise:**

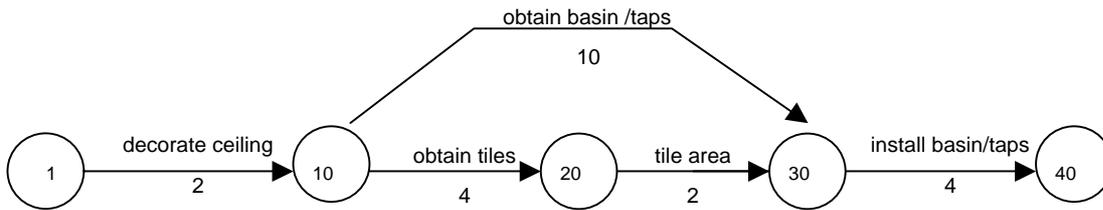
For the small project you chose in the previous exercise list the external dependencies for each activity. Rate the degree of risk (none, low medium, high) these might have on the duration of each activity.

Despite the difficulty in obtaining realistic duration estimates they are essential as the overall project duration is dependent upon them.

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### 7.3 Annotating Network diagrams

The duration for each activity is shown along the arrow in network diagrams. The estimates (in weeks) given below are for me doing the work in my spare time:



**Port folio Exercise:**

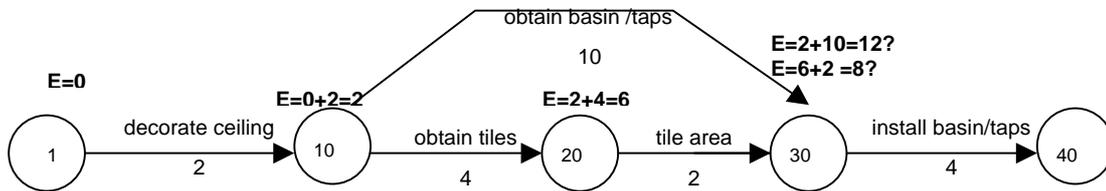
For the small project you chose in the previous exercise add times to each of the activities you specified.

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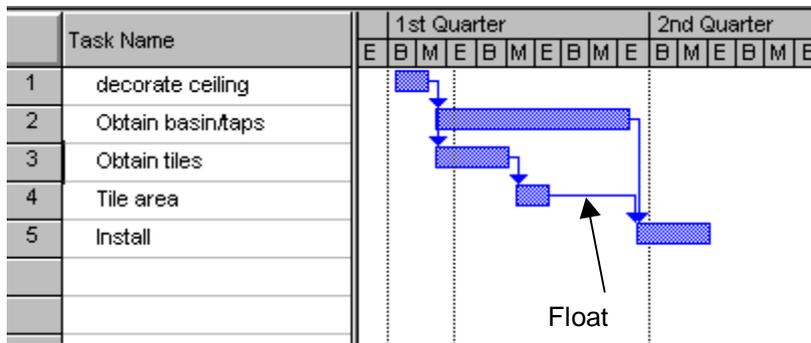
### 7.4 Earliest time (E) /Forward pass and Project duration

We will now look at obtaining the overall project duration along with the critical path of the project.

The overall project duration is calculated by taking the 'earliest time' each event can occur. This is the 'earliest time' for the preceding event plus the duration of the corresponding activity. The project is assumed to start at time zero and therefore the earliest event time is also zero. The earliest time for each event on the network diagram is shown beside the letter 'E'. At event 30 we appear to have two estimates for the 'earliest time' depending upon which path we take.



The reason for this is made clear by looking at a Gantt chart view of the information. The concurrent activities [Obtain basin/tiles + tile area] and obtain basin/taps do not add up to the same duration the former activities being finished before the latter. The spare time is called **float** and will be discussed in more detail latter.

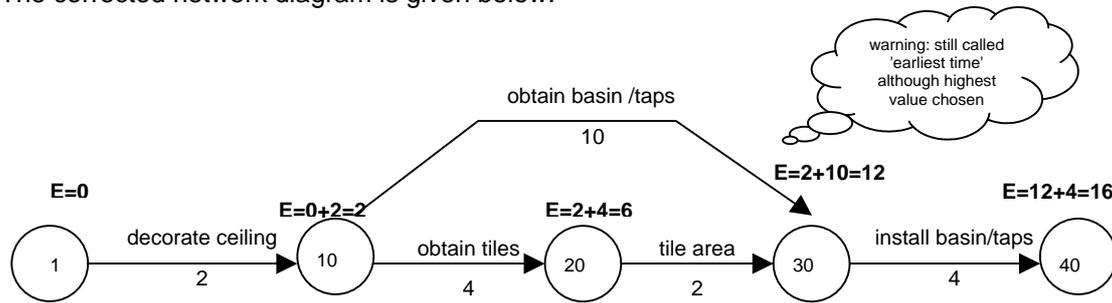


As we can't do anything about the 'obtain basin / taps' activity and we are dependent upon it being completed before commencing the basin installation we take the highest value for 'E' to be the acceptable value.

This is also the general rule:

If you obtain more than one 'Earliest time' value for an event choose the highest.

The corrected network diagram is given below.



The project duration is therefore 16 weeks! Not 6 days as I had originally thought.

**Port folio Exercise:**  
 For the small project you chose annotate the network diagram to work out the project duration.

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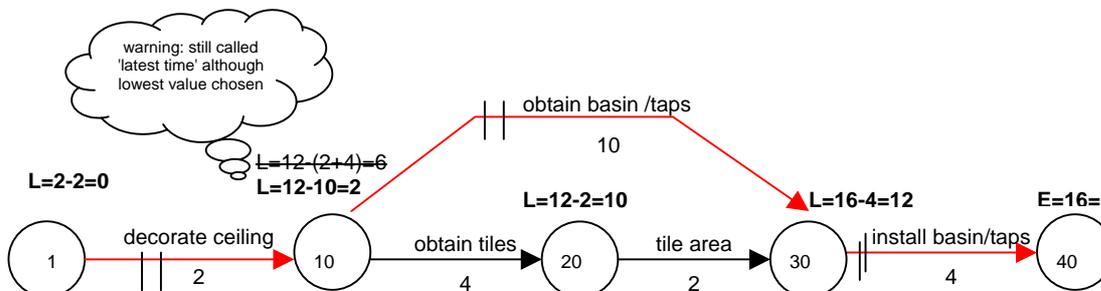
### 7.5 Latest time (L) /Backward pass and the Critical Path

In the previous section the project duration was calculated, and in doing so took into account points where some activities were idle ('Floating') in other words waiting for another activity to complete before being able to move on. By moving backward over the various activities from the project finish event (i.e. Backward pass) we are able to determine a path of activities/events that contain no idle periods (Float/Slack). Such a path is called the **Critical path**. As none of the activities have any leeway on the critical path it is said to be 'critical' in terms of project management because it is important that each activity starts and ends as scheduled along it.

Backward pass involves calculating the Latest time (L) for each event. This is done in much the same way as calculating the Earliest time in the previous section:

- Working backward from the finish event make the 'latest event time equal the project duration.
- The 'latest time (L)' for an event is the 'latest time' of the succeeding event minus the corresponding duration.
- If there appear to be two or more 'latest times', choose the lowest.
- Mark the critical path in some way (e.g. in red as Microsoft project does or double line through each arrow (==)) as below

The above process is shown in the network diagram below:



**Port folio Exercise:**  
 For the small project you chose annotate the network diagram to show the critical path.

The events that occur along the critical path are referred to as **milestones**, and much management effort is put into ensuring project milestones are achieved on time. Note that in Microsoft Project the term milestone has a different meaning. A quick way of checking to see if you have identified the critical path correctly is to verify that all the Earliest and Latest times on the critical path are identical (no slack).

The process of obtaining a Critical Path is called Critical Path Analysis (CPA). Not to be confused with other meanings for CPA such as the Care Programme Approach in Psychiatry.

## 7.6 Obtaining a critical path in Microsoft Project98

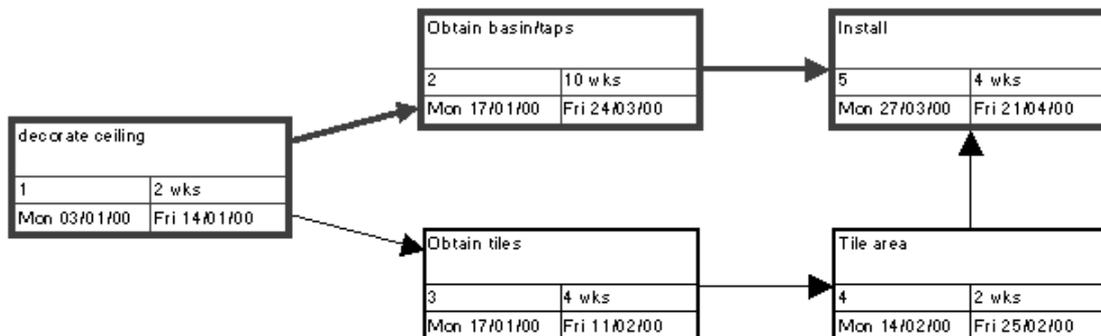
Microsoft project provides a number of very easy ways of obtaining a critical path for a project. Once you have drawn a Gantt chart in Microsoft project, click on the Ganttchartwizard icon and at step two when you are asked 'what type of information do you want' click the 'critical path' option. Alternatively you can click on the menu option ->view -> 'tracking Gantt' option. This is set-up to show the critical path in red. If all you want to see is the critical path you can choose the menu option -> Project -> filter for -> Critical.

### Optional port folio exercise

This is an optional exercise for those of you who have a copy of a piece of project management software:  
 For the small project you chose use the software you have to show the critical path.  
 Keep your work in your portfolio.

## 8. Network diagrams in Microsoft Project98

While Microsoft Project demands that you use the Gantt chart to enter the initial project specification it does provide a number of other charting options. The nearest to the Network diagram provided is the PERT chart which unfortunately is event rather than activity orientated. The 'PERT chart' output for the 'basin' project is given below.



### Optional port folio exercise

This is an optional exercise for those of you who have a copy of a piece of project management software:  
 For the small project you chose use the software you have to create a PERT or Network diagram.  
 Keep your work in your portfolio

## 9. Slack and float

Different authors use the above terms interchangeably and 'Microsoft Project98 Help' considers them to be synonyms. I will try not to confuse? Float tends to refer to activities (e.g. an activity can expand to fill the float) while slack refers to the periods of inactivity ( e.g. sleep - a period of slack enables an activity to start later). A useful Mnemonic?

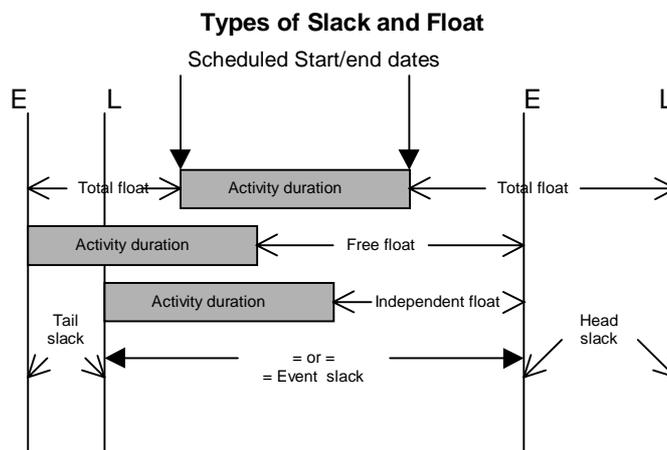
Float fills the time with activity

Slack makes one go to sleep

Before we can consider either we need to look at the total time available for each activity.

Consider the activity 'tile area' in the basin example. The earliest time (E) it could start is on week 6 of the project. Notice this is how it is drawn in the Gantt chart as Microsoft Project98 does this automatically. However there is no reason why it could not be scheduled to start at any time between week 6 (E) and week 10 (L) of the project.

Therefore although you may think of only the start and end dates for each activity there are really up to 6 possible dates for activities not on the critical path. These are the earliest, scheduled, and latest start and end dates. Considering these we have a number of ways at looking at the periods of inactivity (slack/float):



**Total float/slack** is the amount an activity can expand, or be delayed without affecting the overall duration of a project. For example in the 'basin' example the activity 'tile area' could expand up to a total of 6 weeks before affecting the project although it would force the next activity to start at the latest possible time. Utilising total float may force the following activity to start at the latest time. It can be calculated by:

$$\text{Total time available for the activity} - \text{activity duration}$$

**Free float(slack)** Is the amount an activity can expand, or be delayed, without affecting the succeeding activities start date options in other words it does not encroach on the succeeding activities Earliest time. It can be calculated by:

$$\text{Total float} - \text{head slack}$$

**Head slack** is the difference between the Earliest and Latest time (L-E) for the event following the activity.

**Tail slack** is the difference between the Earliest and Latest time (L-E) for the event prior to the activity.

**Independent float/slack** is the amount an activity can expand without affecting the preceding or succeeding activity.

Microsoft Project98 allows the user to provide all the dates discussed above. It also automatically calculates the free and total slack(float). Here are the entries for the 'tile area' activity:

Free slack(float)	Early start	Start (scheduled)	Late start	Early finish	Finish (scheduled)	Late finish
4 wks	14/02/00 Mon	14/02/00 Mon	13/03/00 Fri	25/02/00 Fri	25/02/00 Fri	24/03/00

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In Microsoft Project98 when you enter the start and end dates for an activity (called the scheduled dates) the same values are also set for the 'Early start' and 'Early finish' dates respectively. Microsoft Project98 assumes you want everything to happen as soon as possible!

**Port folio Exercise:**

For the small project you chose annotate the network diagram to show the total slack, free slack, and head slack for each activity.

While most of the above information is provided chiefly for reference purposes a basic understanding of slack/float is useful allowing you to be more flexible and creative with project plans. The periods of inactivity can be manipulated by:

Lengthening the activity period thereby reducing the resource intensity.

Moving, to possibly make more appropriate use of a resource shared between several activities.

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## 10. Resource analysis

For industrial projects resource management is of key importance. Put simply the greater the resource input the quicker the job gets done provided the input is of a comparable quality. Because it is often easy to obtain casual labour at low rates in this situation and reduction in time (e.g as in building a new store) is essential to optimise profits projects are devised to take the least time with the greatest resources available.

Unfortunately in academia and other specialist areas there is not a large one, if one exists at all, pool of casual expertise that can be utilised and in reality there is frequently only one source of each type of expertise. In such a situation resourcing is not considered as the pragmatics of the situation mean that 'the individual' just works harder and longer hours within the allotted time to get the work done. A very unsatisfactory situation.

Because resource analysis is a separate issue with a distinct set of techniques it is not possible to discuss it in the time we have to complete this module. In this handout I have assumed that the project that have been presented would be undertaken by a single individual.

## 11. Now check what you have learnt

Now read through the 'Learning outcomes check list' again. How many can you tick? If you are not sure about any particular item get the person beside you to explain or ask / e-mail me.

## 12. Additional optional exercises

1. Set up a discussion board thread about Project management to discover:
  - What people found difficult to understand in this section
  - What was missing
  - If anyone has used these techniques in the real world discover what they thought of them
2. Ask various administrators at your place of work if you may have a look at some past or present project plans. See how they conform to the techniques described in this section.

## 13. References

Argyle M 1989 (2nd ed.) The social psychology of work Penguin

Field M Keller L 1998 Project management. Thomson learning & the Open University see [www.thomsonlearning.co.uk](http://www.thomsonlearning.co.uk)

Gilb T 1988 Principles of software engineering management. Addison-Wesley

Karasek R Theorell T 1990 Healthy Work: Stress, productivity and the reconstruction of working life. Basic Books

Lang D W 1977 (2nd ed.) Critical path analysis. Teach yourself books - Hodder & Stoughton

## 14. MCQs

The following Multiple choice questions have been designed to see if you have read through the material carefully.

1. Which of the following software packages provides support for project management?
  - a. Powerpoint
  - b. Access
  - c. Paradox
  - d. Microsoft project98
2. In a Gantt chart which of the following statements are true (there may be more than one)?
  - a. The top of the chart displays who's responsible for each task
  - b. The activities within the project are shown as a series of rectangles
  - c. You can explode activities to define sub-activities
  - d. You can choose from a wide range of time periods to specify the project
  - e. Tasks are listed vertically
  - f. Tasks also have a unique number attached to them automatically by Project98
3. PRINCE stands for:
  - a. Projects in Clinical Environments
  - b. Projections, Requirements in Clinical Environments
  - c. Projects in Controlled Environments
  - d. People Responding in a Controlled Environment

4. Which of the following four specify the overall aims of PRINCE:
  - a. Deliver required products
  - b. Deliver products that are required by the organisation
  - c. Deliver highest possible quality
  - d. Deliver specified quality
  - e. Deliver as soon as possible
  - f. Deliver when required
  - g. Deliver on time
  - h. Deliver within budget
  - i. Deliver as cheaply as possible
  
5. Which of the following presentments the main aspects of PRINCE:
  - a. Organisation, planning, managerial Controls
  - b. Organisation, budgetary planning, Controls
  - c. Managerial controls, product controls, project board, plans
  - d. Controls, organisation, planning
  
6. Which is the most common criticism of PRINCE within the research environment:
  - a. Managerially too complex
  - b. Unable to define product
  - c. Controls too rigid
  
7. A project can be said to consist of two main aspects (hint to answer this question you will need to look at several pages in this section. Particularly the 'critical path' page and also other pages which provide synonymns for 'events' and 'activities'):
  - a. Activities and Milestones
  - b. Milestones and Events
  - c. Events and Activities
  - d. Activities and processes
  - e. Processes and Milestones
  
8. A precedence diagram depicts a project from which perspective:
  - a. Activity
  - b. Event
  - c. Resource
  - d. Cost
  
9. Network diagrams depict a project from which perspective:
  - a. Activity
  - b. Event
  - c. Resource
  - d. Cost
  
10. Event numbering in a Network diagram is:
  - a. Sequential with uneven gaps
  - b. Sequential with even gaps
  - c. Sequential with no gaps
  - d. Any order you want it as long as each activity is uniquely numbered
  
11. In a Network diagram it is possible to have (more than one may be correct):
  - a. Only one arrow entering the activity
  - b. More than one activity entering an activity
  - c. Only one arrow leaving an activity
  - d. More than one arrow leaving an activity
  - e. Arrows separating on route between activities

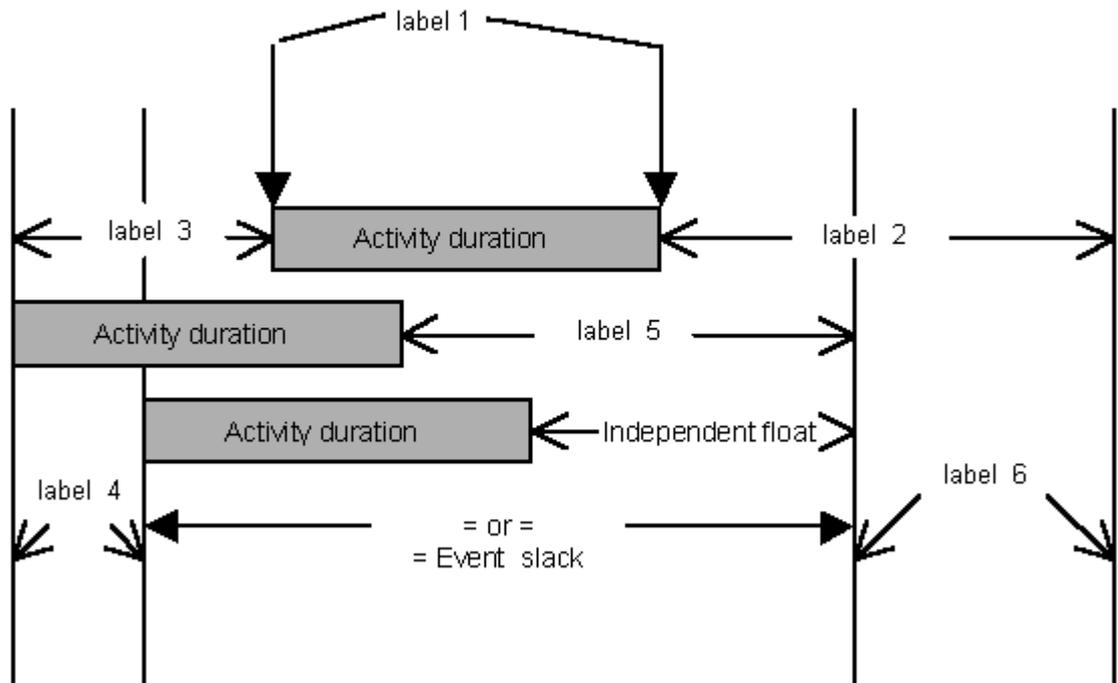
12. Using the PERT method of estimating activity duration involves:
- Finding the quickest reasonable time, most likely time and worst time and adding them together
  - Finding the most likely time and worst time, multiplying this value by 4 and then dividing it by 2
  - Finding the quickest reasonable time, most likely time and multiplying this value by 4. Then adding the worst time and dividing this value by 6
  - Finding the quickest reasonable time, most likely time and multiplying this value by 6. Then adding the worst time and dividing this value by 4
13. Which of the following pairs of factors, according to the notes, have the most affect upon activity duration:
- External dependencies and resourcing issues
  - External dependencies and cost issues
  - External dependencies and quality issues
  - Quality issues and resourcing issues
14. Project duration is calculated by:
- Using the method of backward pass
  - Is the summation of earliest event times
  - Is the summation of earliest event time except when there are two calculated for a particular activity when the smallest Earliest time value is accepted.
  - Is the summation of earliest event time except when there are two calculated for a particular activity when the greatest Earliest time value is accepted.
15. The Critical Path is:
- The chain of activities through the Network diagram which includes the greatest slack
  - The chain of activities through the Network diagram which includes the least slack
  - The chain of activities through the Network diagram which includes as many different activities as possible

16. Please complete the table below indicating which label goes with each MCQ option (note that a MCQ option may be used for more than one diagram label):

- a. Independent float
- b. Free float
- c. Total float
- d. Scheduled start / end dates
- e. Tail slack
- f. Head slack
- g. Head float

Diagram Label	MCQ Option
1	
2	
3	
4	
5	
6	

### Types of Slack and Float



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