Leaving Certificate

Technology

Project Management

Teacher Notes

1 Project Management

This is the first of three key topics that form *Project and Quality Management* in the Technology Syllabus *core*. These are,

- *Project Management*
- *Quality Management*
- *Reliability Management*

Many of the concepts involved form a foundation for the related option in *Manufacturing Systems* where they are treated in greater depth.

1.1 Introduction:

This document is intended to be used as a resource by the Teacher and is written with this in mind. Accordingly, each of the topics is covered in enough depth to facilitate the subsequent delivery of them in the school. The accompanying set of student notes and workbook has a different emphasis and should complement the material given here.

As there will inevitably be a variation in the level and type of projects encountered in the classroom, it is important to establish the general principles involved in project management before applying them to specific examples. By having an understanding of the underlying principles of project management and planning and where they came from, the teacher will be better equipped to deal with the application of them on a day to day basis.

The approach taken here is as follows:

First the concept of project management is outlined and some key ideas are described
Then two key techniques for the planning of projects are described.
Next, these techniques are applied to a typical school design & make project.
Finally, having worked some problems by hand, the process is automated by a software package.

1.2 Overview of Project Management

Project management techniques originated in industry to address the need for managing increasingly complex activities such as civil and mechanical engineering projects. The techniques involved are something quite different in scope and purpose from the 'Design Process' that is familiar to the teacher. Project management concentrates on the management of resources and time over the lifetime of a project in a systematic manner. While the approaches outlined were originally developed to aid in the management of large scale projects, they can also be effectively applied in the classroom.

In order to understand the techniques it is helpful to look at what constitutes a project and what makes a project different from the 'routine' activities of an organisation.

1.2.1 What is a Project?

A project is any task within an organisation that does not fit neatly into 'business-as-usual'. The Luas system and the Dublin port tunnel are two examples of large scale projects. On smaller scale, an individual might self-build a new house, a car manufacturer may want to develop a new engine or a company may want to set up a quality system. In the school context, pupils are given a design and make project which needs to be managed – albeit on a smaller scale – using many of the same principles as the larger projects.

All projects have a number of characteristics in common. These are:

- Each task is *specific* and *unique*
- Each task has a specific *deliverable* item when complete
- This deliverable is aimed at meeting a *specific need* or *purpose*.
- There is usually a *specific due date for completion* of the project.

Note that design is not necessarily a central part of the project activity. A project may involve carrying out a tried and trusted procedure that has been used many times before in similar situations.

One definition of what defines a project is given as:

A temporary endeavour undertaken to create a unique product or service
(Project Management Institute)

1.2.2 Who is involved?

In industry, many projects are complex and may involve input from people with different kinds of knowledge and expertise. Projects usually involve a *team* who are managed by a *project manager* or *project leader* who may be appointed for the duration of the project. It is worth noting that project management is adopted as a career specialism by many engineers and is considered to be a mainstream engineering discipline. There is an abundance of published material such as textbooks available on the various project management techniques.
The design and make project that occurs in the school context is a particular type of project and can be managed using the same techniques as used in industry. These techniques should be used to complement the existing methods of managing the project rather than replace them.

1.2.3 What is Managed?

Project management refers to the administration of the project, its supervision and organisation. It means analysing the objectives of the project, defining the tasks needed to achieve these objectives and controlling the execution.

Projects have three interrelated objectives, these are to:

- Finish on time
- Meet the specifications that satisfy the brief
- Meet the budget

As work progresses on a project, unexpected problems will usually arise that will threaten to throw the project off schedule or specifications. Project management involves applying a systematic approach to achieving the objectives of the project, and when project management is done properly, the probability of a successful outcome to the project is increased.
A project can be broken down into a number of subsidiary tasks. A number of project management tools exist to allow the scheduling and resourcing of each of these tasks. Problems such as bottlenecks or conflict between resources can be identified and dealt with. One activity that is central to all of this is *Project planning.* Project Planning techniques will be the focus of the remainder of this section.

1.3 Project Planning.

A project plan can be as simple as a list of tasks that need to be carried out or it can be a complex document involving a number of charts, tables, costings etc. depending on the needs of the project itself.
In describing the project planning methods, we will first look at some of the techniques and how they fit together. Once this is done we will apply them to a typical Leaving Cert. Technology project.

The first stage of planning a project is to define the objectives and goals of the project. This means understanding the needs of the project and defining clear, measurable objectives. In the school context, this would happen during the ’analysis of the brief’ stage of the design process.

Once the objectives have been defined, the tasks are identified that are necessary to achieve the objectives. Where the project is a new or novel one, this can be a difficult task. But where a similar project has been carried out before, it is common to adopt many of the tasks carried out by the earlier team.

The end result of this analysis is a *Work Breakdown Structure* (WBS). The WBS can be depicted as a chart that shows the primary tasks associated with the project and then the sub tasks that comprise them. A typical WBS is shown in Figure 1.

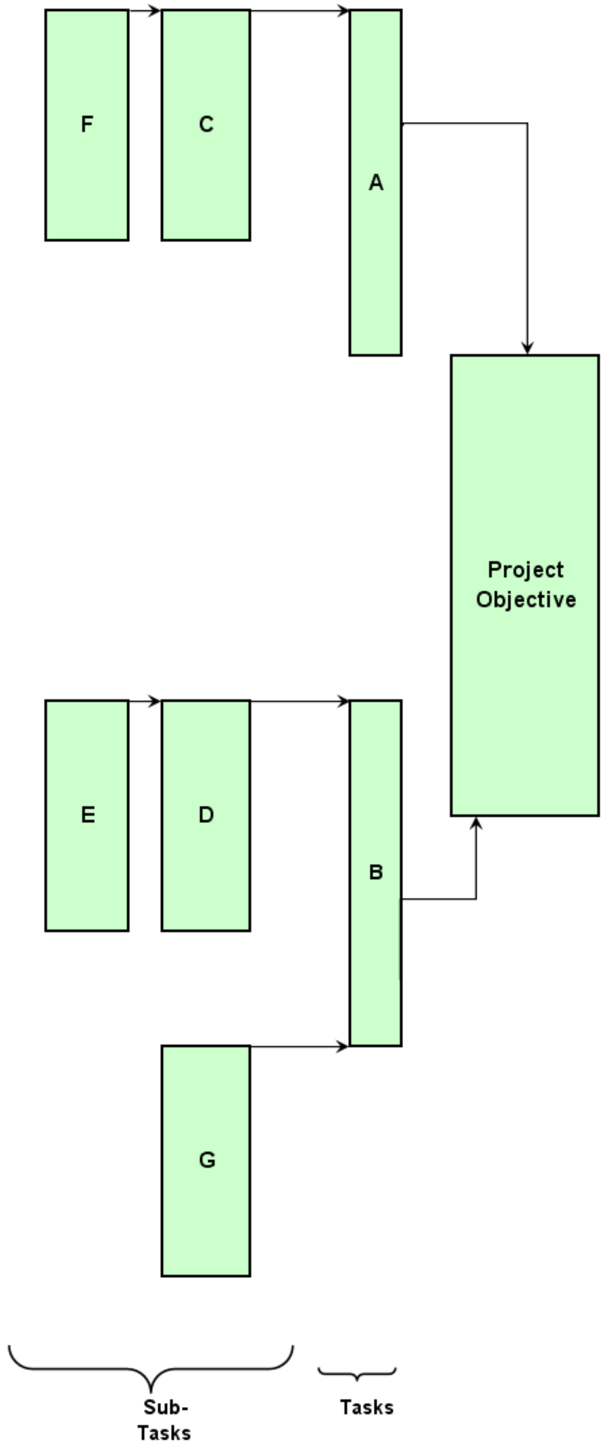
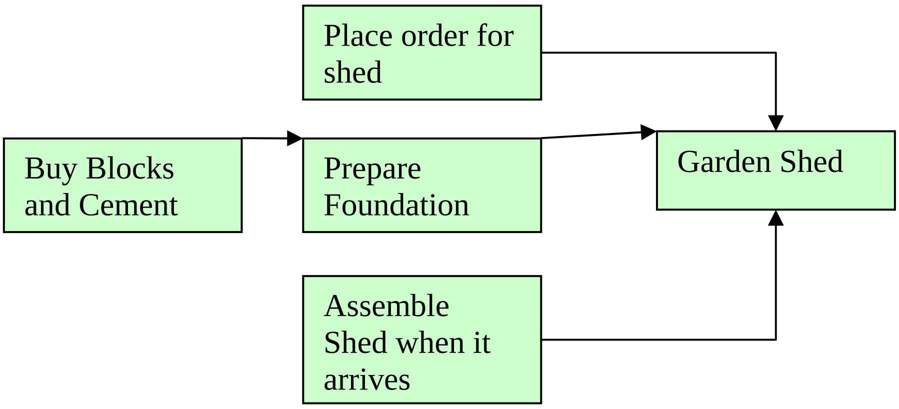


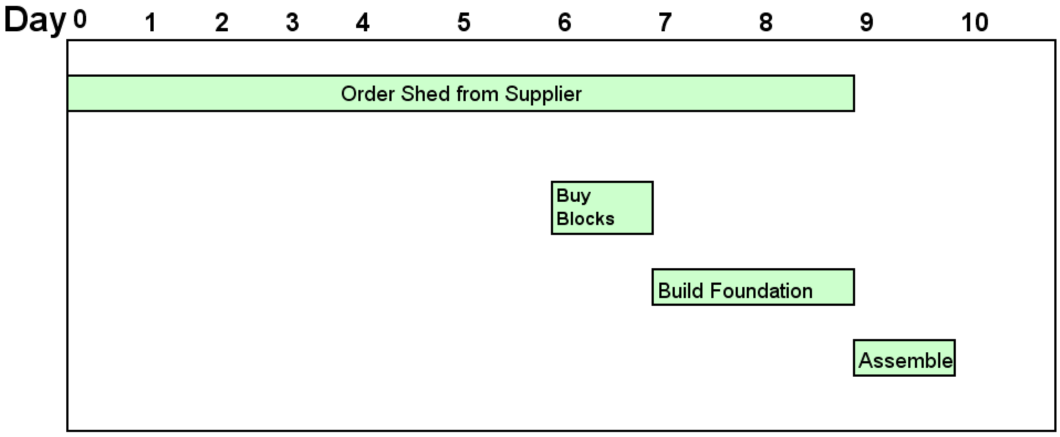
Figure 1 Work Breakdown Structure for a project

A simple example:

Draw up a Work Breakdown Structure for the erection of a garden shed. The shed will come prefabricated but will need to be assembled. A foundation will need to be prepared for it beforehand.



Gantt Charts
For simple projects like this one, the activities can be arranged along a timeline using a *Gantt chart* to show the timing for each of the tasks. A Gantt chart is simply a horizontal bar chart showing the start and finish time of the tasks. It is a useful aid when planning the activities in a project.



Notice that the delivery time for the shed is nine days. The times estimated for the other tasks are: one day for buying the blocks and cement needed for the foundation, two days to make the foundation and one day to assemble the shed once it arrives. Using the Gantt chart, the start times for each of these activities can be chosen so that the foundation is ready just in time as the shed arrives. Of course, the foundation could have been started at an earlier time and allowed to age while waiting for the shed to arrive if desired.

Exercise: Redraw the chart so that the maximum amount of time is allowed for the ageing of the foundation.

Exercise: Draw up a WBS and a Gantt chart for planning a family holiday abroad

1.3.1 Network Diagrams

For more complex projects, the number of tasks and the relations between them make it difficult (or undesirable) to go directly from the WBS to the Gantt chart. It is usual to create an intermediate step that involves making a *network diagram.* A network diagram is useful in that it identifies the relationships between the tasks, the sequence in which each task is performed and the interdependencies between the tasks.

Terms used for network diagrams:

- **Activity** – A task or set of tasks required by the project.
- **Network** – Diagram of nodes representing activities connected by directional arrows that defines the project and shows the relations between all of the activities. Networks are usually drawn with a 'Start' node on the left and a 'Finish' node on the right.
- **Path** – A series of connected activities in the network
- **Critical Path** – the set of activities on a path from the project's start event to its finish event that if delayed, will delay the completion date of the project.
- **Critical Time** – The time required to complete all activities on the critical path.

Drawing a network diagram is a relatively easy task, and can be accomplished by listing each task on a piece of paper and pinning them onto a white board to represent the sequence in which the tasks take place. Lines and arrows are drawn between the pieces of paper to show which tasks follow on from others. The diagram aims to portray how the tasks relate to one another i.e. which tasks have to be completed before others begin and which tasks can be performed simultaneously. Creating the network is an iterative process and may involve a number of revisions before an optimum solution is found.

Each task is listed along with any tasks (predecessors) that need to be completed before it can start. Returning to the example shown in figure 1, the tasks might be listed as follows:

Table 1 Tasks and predecessors for a sample project

Task	Predecessor
A	-
B	-
C	A
D	B
E	B
F	C,D
G	E

The partly completed network diagram would look like Figure 2 below

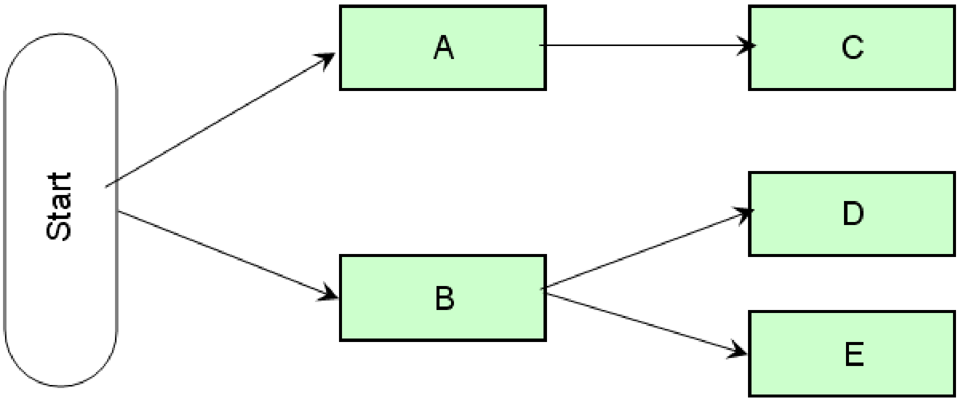


Figure 2 Partly complete network diagram

Note that task C has A as a predecessor and that D and E have B as predecessors. Because A and B have no predecessors they are connected to the starting node.

The network is easily completed using the remaining information in the table.

Task F has both C and D as predecessors while G follows E.
Because there are no more tasks, all the loose ends are tied to the finish node. The complete diagram is shown below in Figure 3.

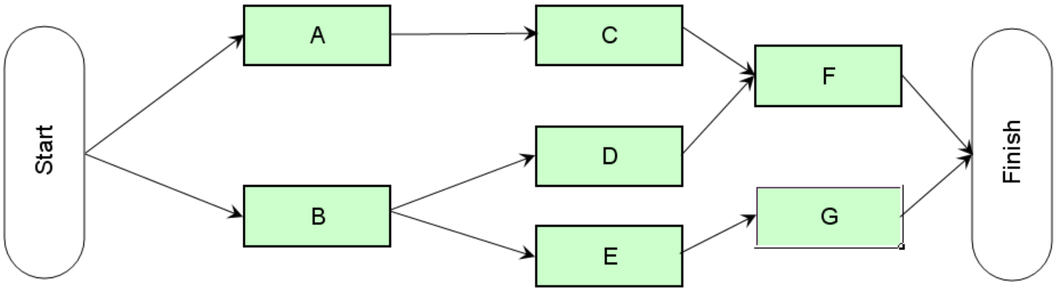
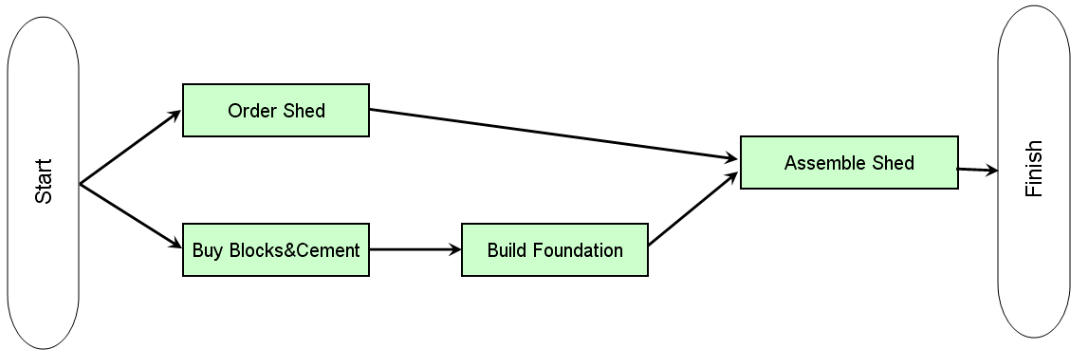


Figure 3 Complete network diagram

Example:
Draw up a network diagram for the garden shed project described previously.



1.3.2 Finding the Critical Path and the Critical Time.

While the network shown above is useful in depicting the relationships between the tasks, to effectively schedule and plan for them, the amount of time required for each needs to be taken into account. If the amount of time taken for each task is known, it is possible to assign start and finish dates to them as shown in the next example. Note that the unit of time used here is the *Day* in order to aid readability. In the context of a school project another unit e.g. *class period* or *week* might be used instead.

Table 2 A sample problem for finding the Critical Path and Critical Time

Task	Predecessor	Duration
A	-	5 days
B	-	4
C	A	3
D	A	4
E	A	6
F	B,C	4
G	D	5
H	D,E	6
I	F	6
J	G,H	4

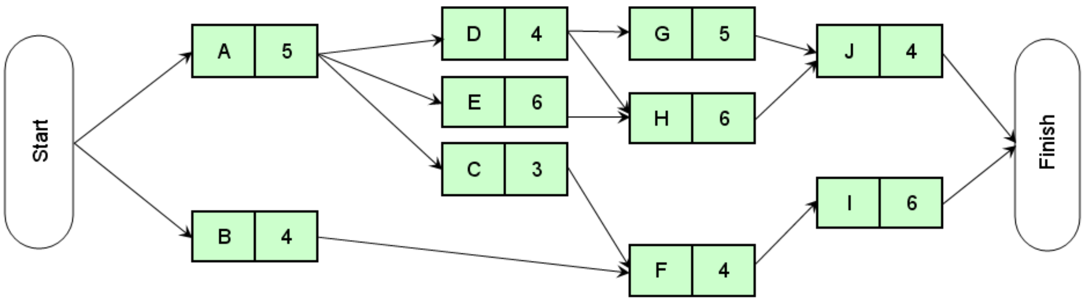


Figure 4 Network showing activities and times

Looking the data in Table 2 we can draw the associated network as in Figure 6. The activity names and the duration of each are shown in each of the nodes.

Note that activity F follows both B and C. If the diagram is drawn so that C is placed directly below the D and E nodes, it will avoid having several arrows crossing one another. This kind of arrangement is quite common when drawing networks and avoids the confusion of arrows crossing one another.

More information can be added to the nodes on the network. Just above each node it is common to show what is called the *earliest start time* (EST) and the *earliest finish time* (EFT). Just below each node is shown the *latest start time* (LST) and the *latest finish time* (LFT) for the activity. The node would appear as in Figure 5

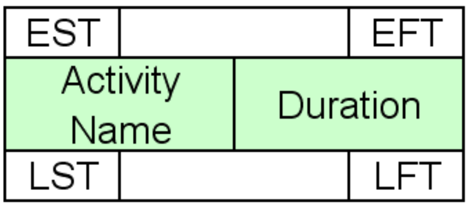


Figure 5 Node with all information included

The network shown in Figure 4 can now be drawn with the extra information included as shown in Figure 6. The derivation of the figure is now described in detail below. While the method might look a bit daunting at first it is in fact quite simple and easily done.

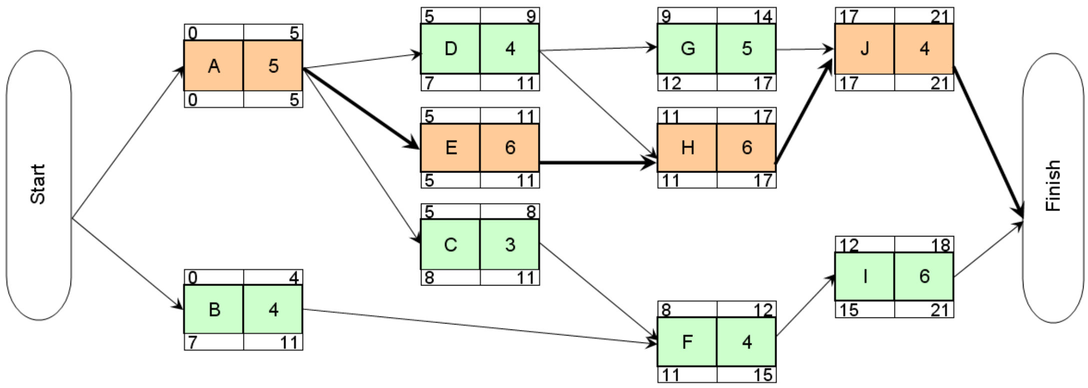


Figure 6 Complete Network Diagram

Looking at the diagram, activities A and B can start at Day 0, their ESTs. Their EFTs will be equal to their durations, five and four days, respectively.

Tasks C,D and E cannot start before A is completed on Day 5 – this becomes their EST.

Adding their respective durations to their ESTs gives us their EFTs, with C finishing on Day 8, D finishing on day 9 and E on Day 11.

Task F cannot start before both B and C are finished on Day 8, resulting in the EFT for F on Day 12.

Similarly, we find EFTs for tasks G (9+5=14) and H (11+6=17).

Remembering that a successor cannot be started until all the predecessors are complete, task H cannot start until Day 11 when both D and E are finished.

The same situation is true for task J which cannot commence until G and H are finished on Day 17.

This gives an EFT for J on 17+4=Day 21.

Task I following task F has an EFT of 12+6=Day 18. No tasks follow I and J and when both are finished, the project is finished. This event occurs on Day 21.

All activities and thus all paths must be completed to finish the project. The shortest time to completion is equal to the longest path through the network, in this case **A-E-H-J**.

If any activity on the **A-E-H-J** path is delayed, then the project will be delayed. **This identifies A-E-H-J as the critical path and 21 Days as the critical time.**

In Figure 6 the critical path is shown by a bold line and the nodes on critical path are coloured pink. In this example, the critical path and critical were found by beginning at the start node and moving from left to right over the network. This is called a *forward pass* and makes it easy to find the critical path and critical time.

1.3.2.1 Completing the Remainder of the Diagram.

In order to find the LST and LFT for the nodes, a *backward pass* is carried out, beginning at the finish node.

Looking at Figure 6, the starting point is the finish node which corresponds to Day 21, i.e. the critical time. Both of the activities, I and J must be complete by this time so both of them have LFTs of 21.

Given a task time of 4 days, task I must be started no later than Day 17 in order to be completed by Day 21. Likewise task J can be started as late as Day 15 and still be finished by Day 21 given the 6 day task time.

Because task J cannot be started later than Day 17, tasks G and H must be completed by Day 17.

In a similar fashion, Task F must be completed by Day 15 so as not to delay task I beyond its LST.

Subtracting the task times, from the LFT for each of the tasks, gives LSTs of 11,11 and 12 for tasks F,H and G respectively.

Looking at task D, it precedes both tasks G (LST=12) and H (LST=11).

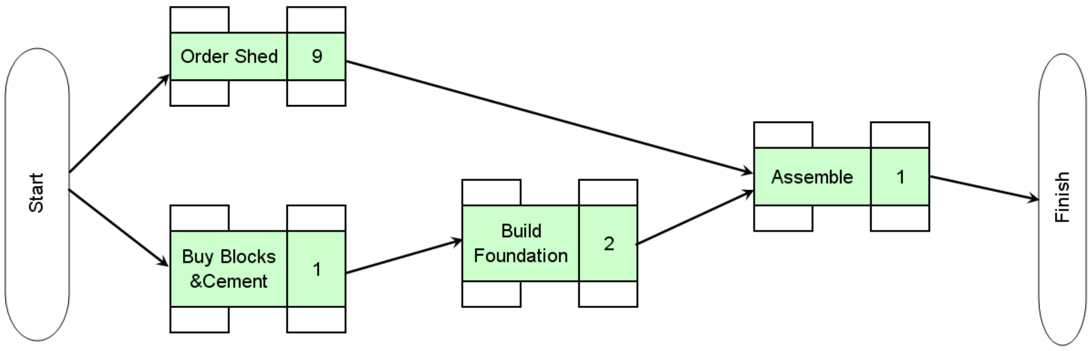
It should be apparent that the LFT for task D is 11, the reason being that if task D were to complete on day 12 then task H could not begin on its LST of 11.

From this example a rule can be derived that where a task precedes more than one other activity, it must have a LFT equal to the earliest of the LSTs that it precedes.

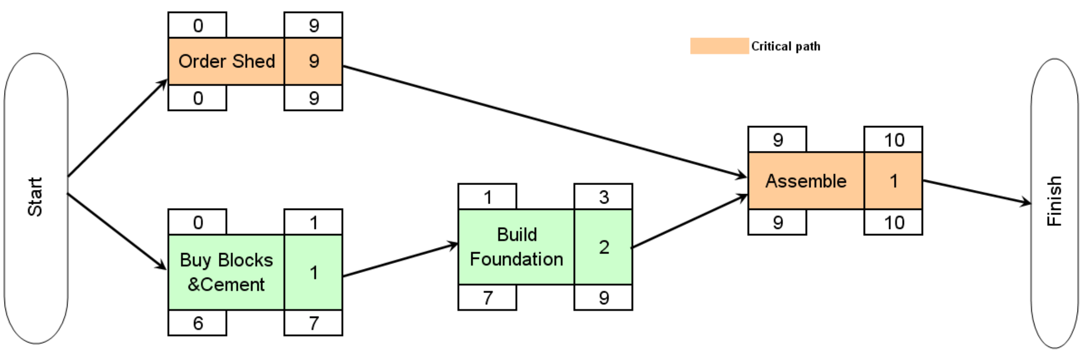
The LST and LFT for the remaining nodes are easily found by subtraction. Note that task E has the lowest EST of five days, the LFT for task A is five days also.

Activity:
The network diagram below shows the garden shed project with the estimated times for each activity.

Complete the EST/EFT and then the LST/LFT dates for them.
Find the critical path and highlight it.



Solution



1.3.3 Calculating Activity Slack.

While activities on the critical path cannot be delayed without causing the entire project to be delayed, the activities that are not on the critical path can be delayed – within limits – without affecting the finish time. The amount of time that a non-critical task can be delayed without affecting the project is called the *slack* or *float* The slack for any activity is easily calculated as *the Latest Start Time* minus the *Earliest Start Time* or the *Latest Finish Time* minus the *Earliest Finish Time* *i.e.*

Float = LST-EST = LFT-EFT

For any activity on the critical path LST=EST and therefore the slack is zero. If any of the activities on the critical path finish later than the EFT the next activity will be delayed and the project will be late.
However, for activities not on the critical path, the LST and EST will differ and this difference is the activity slack.

Taking activity I as an example, it could be begun as early as Day 12 completed as early as Day 18.
However the activity could be delayed by up to three days (LST-EST = 15-12 = 3 Days) without affecting the project completion date.

Taking task G as another example it can easily be seen that this activity has two days of slack (LST-EST = 7-5 = 2 Days)
Slack for the other tasks is determined in the same way.

Activity:
For each of the activities in the garden shed project, Write down the slack time.

Task	Slack Time
Order Shed	
Buy Blocks	
Build Foundation	
Assemble	

1.4 The Gantt Chart

Gantt charts are named after Henry Gantt who was a major figure in the ‘scientific management’ movement of the early twentieth century. He developed the chart around 1917. A Gantt chart is a bar chart that displays the project activities as bars measured along a horizontal time scale. It is a useful tool in displaying activities in the form of a schedule. We have already drawn a simple Gantt chart for the garden shed project. It is common to include some more information relating to which task precedes which and to display the critical path by highlighting certain tasks.
Gantt charts are easy to draw. Because task names are usually descriptive, each task shows its name. An activity with predecessors begins when the when its latest predecessor is completed. Arrows are used to show which tasks precede which. The tasks on the critical path are highlighted in a contrasting colour. A Gantt chart for the network shown in Figure 6 is given in Figure 7.
Float or Slack time can also be shown on the chart. It is usual to depict it as shown in Figure 8

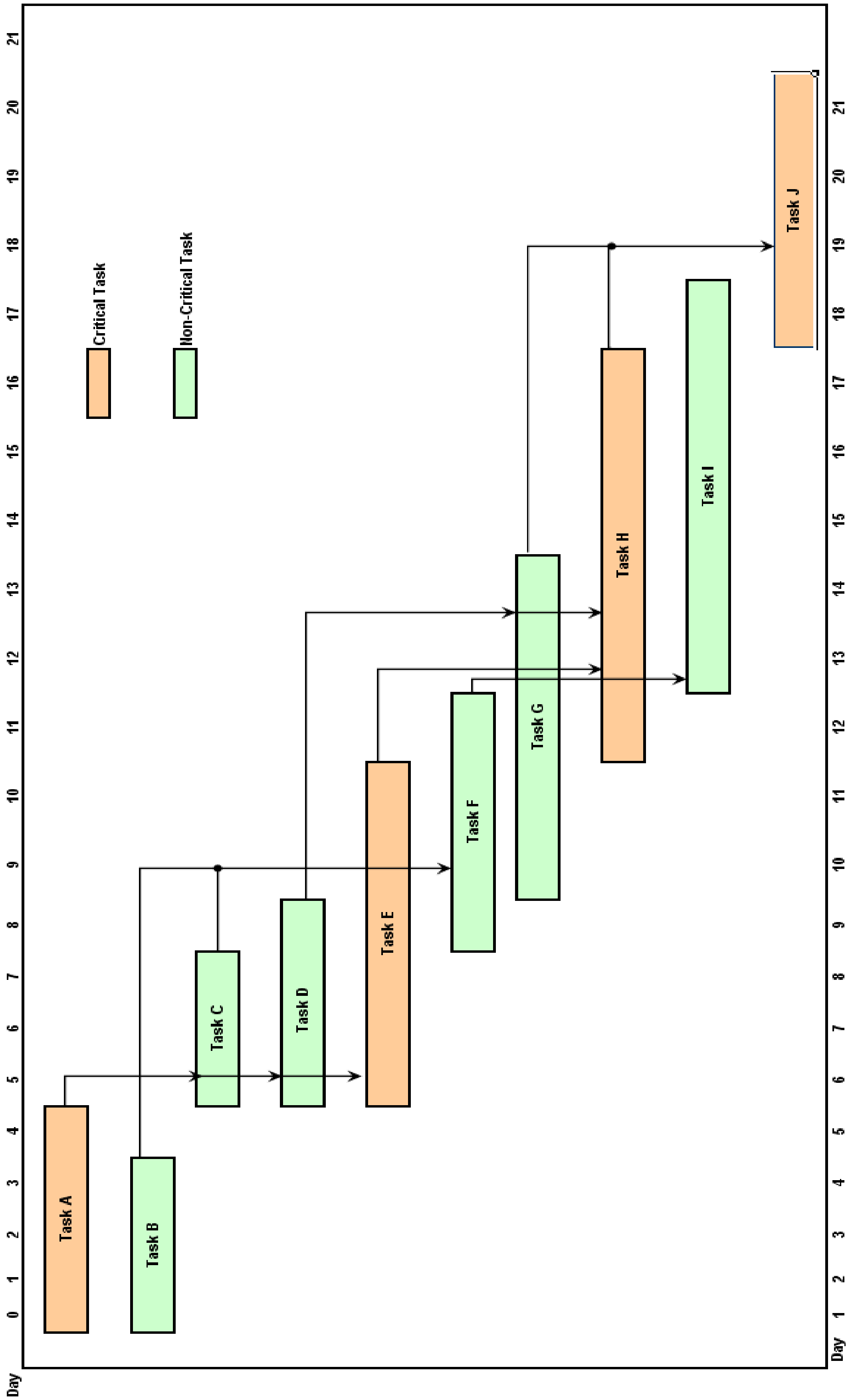


Figure 7 Gantt chart from previous example

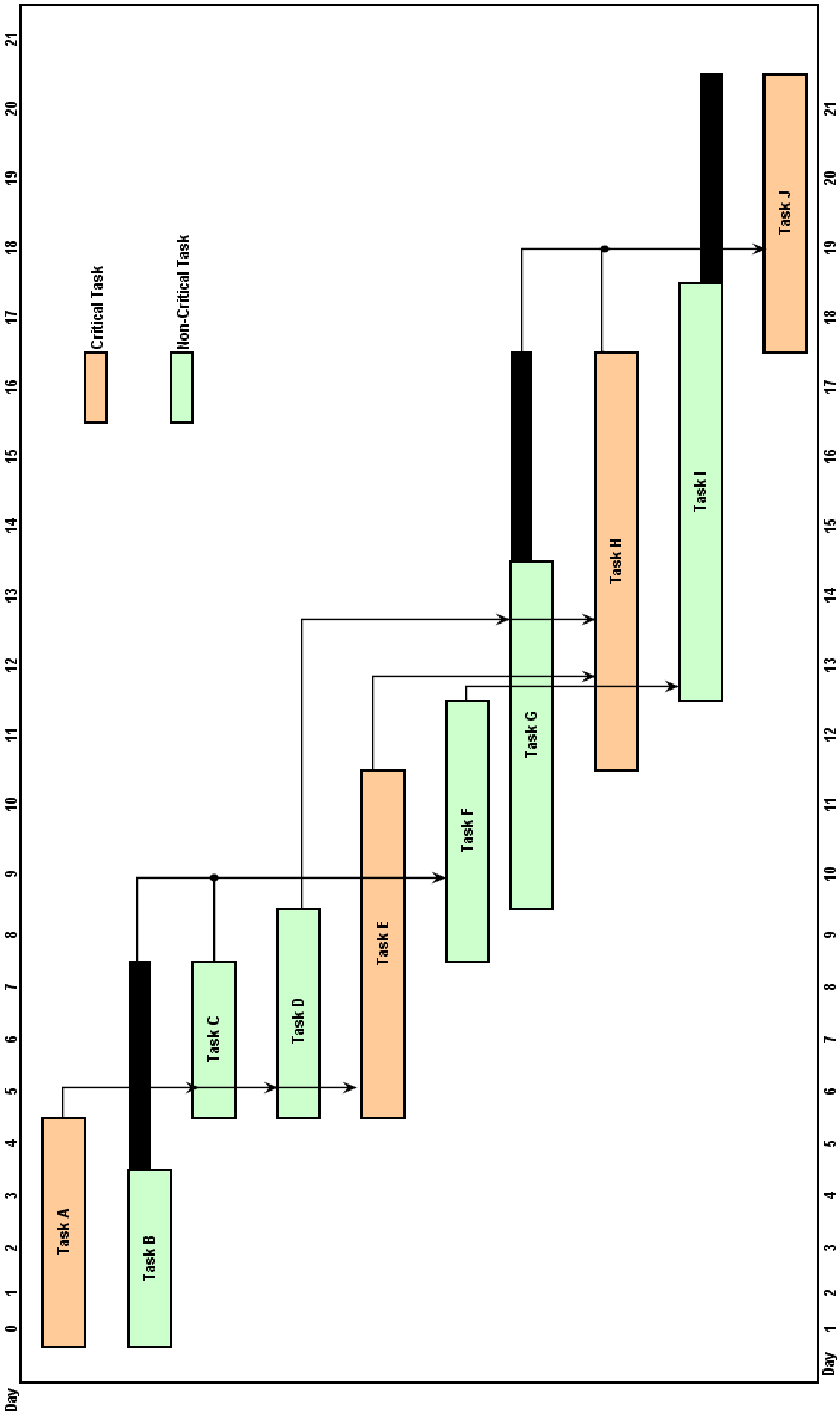


Figure 8 Gantt chart with Slack Time

2 Project Planning for Technology Projects.

In this section, the WBS, Network diagram and Gantt chart will be applied to a typical design & make project in Technology.

Imagine that the project requires the design and manufacture of a personal alarm that will incorporate an electronic circuit as well as the manufacture of a suitable casing

Prior to embarking on the project planning process, the brief will have been analysed and a general plan for the project will have been formulated. The tasks that make up this broad plan will be the basis of the Work Breakdown Schedule

From the analysis of the brief, it is considered desirable to conduct a survey of some sort among potential users to establish what features the device should have before starting any detailed design. However it is clear that an electronic circuit will be needed to produce the alarm sound and some research will be needed in this area before the circuit design can begin.

The first step is to look at the project in terms of the constituent tasks and generate a Work Breakdown Structure that might look like the following:

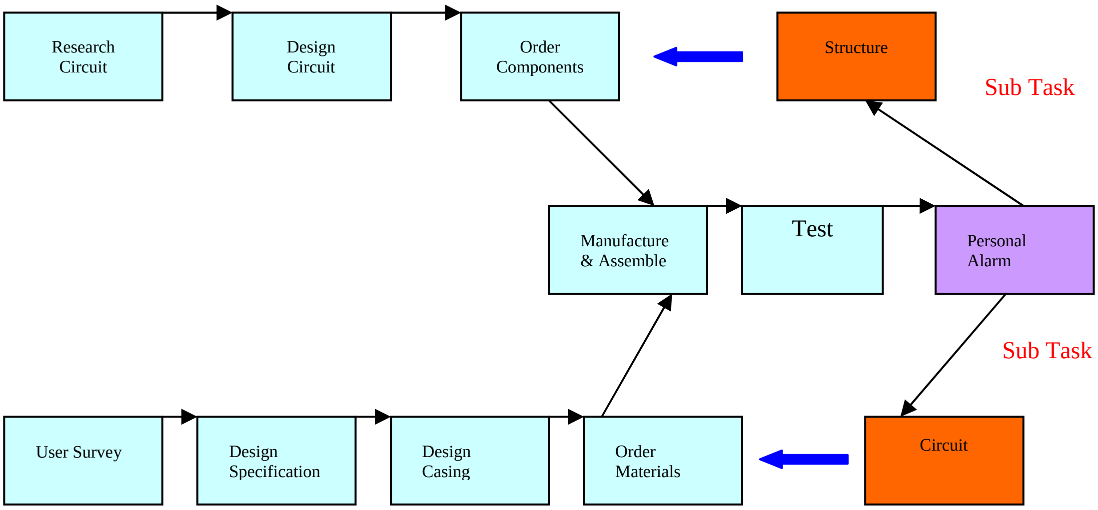


Figure 9 WBS for Alarm Project

The next step is to generate a network diagram for the tasks in the WBS

Table 3 Tasks with predecessors for network diagram

Task	Description	Duration (Single Periods)	Predecessor
1	Research Circuit	14	-
2	User Survey	7	-
3	Device Spec	1	2
4	Circuit Design	3	1
5	Order Components	10	4
6	Design Casing	7	2
7	Order Materials	7	6
8	Manufacture and assembly	7	6,4
9	Test	4	8

Note: In this example, the unit adopted to measure the time is the single class period. However not all activities need class contact time or even student involvement (for example the lead time between ordering the materials and their arrival). For simplicity these type of activities have had their timelines converted into the equivalent number of periods that would elapse during their lifespan.
So, whereas the total number of periods given above totals 60, the amount of input time needed from a student is 60 periods minus (component and material order time) = 60-(10+7) = 43 periods. This equates to approximately 29 hours in total.

Once the precedence of the tasks has been established, drawing up the network diagram is straightforward as shown in Figure 10

The critical path diagram is obtained by completing the times for each activity as shown in Figure 11
The critical path is defined by the nodes shaded in pink. The critical time is 38 class periods which is the shortest time possible for completion of the project.

The final step is to create a Gantt chart from the information given in the critical path diagram. This is shown in Figure 12

2.1 Using the Gantt Chart.

The Gantt chart can be of use when planning a programme of work with a pupil as it enables the setting of clear goals and timescales. It also allows the student to better judge the progress being made as the project is being undertaken.
From the perspective of managing of resources, it is relatively easy to see what resources will be required for the project and when they are likely to be needed. If a number of projects are considered together, bottlenecks with the use of a particular piece of equipment should be more easily apparent. Where a particular activity has slack time, it may be possible to move it either forward or backward to even out the demand for a particular item of equipment.

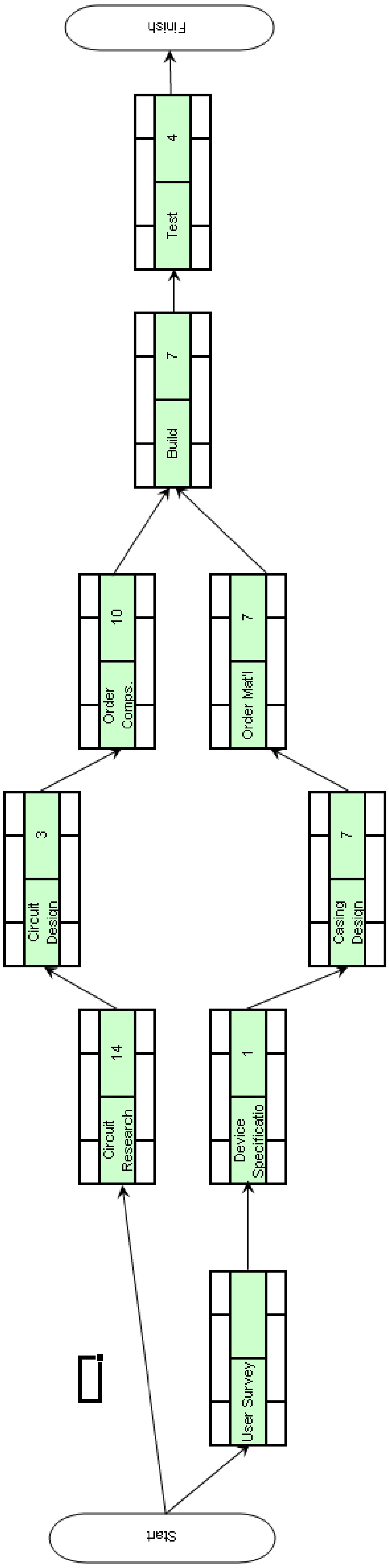


Figure 10 Network Diagram

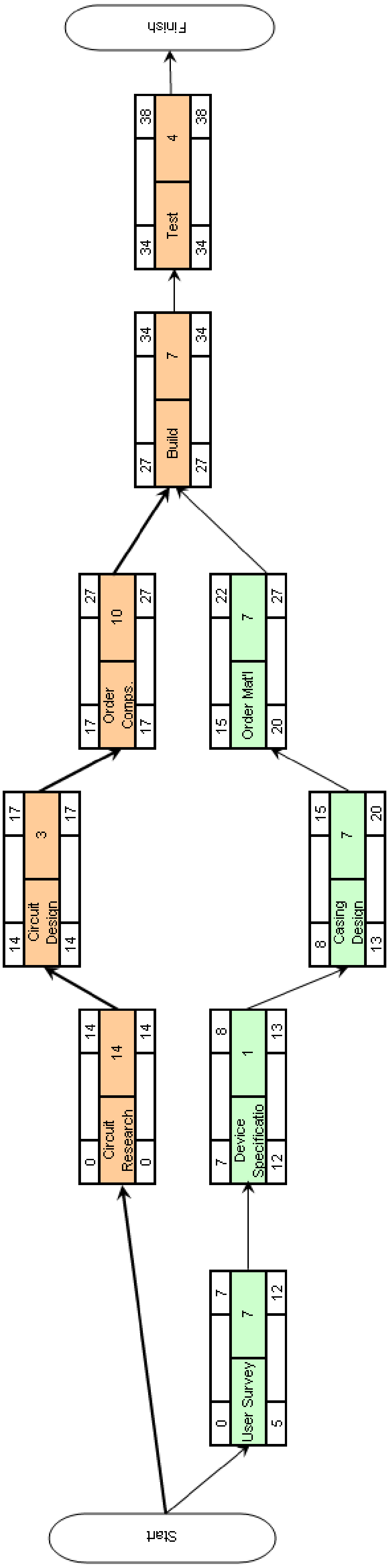


Figure 11 Critical Path Diagram

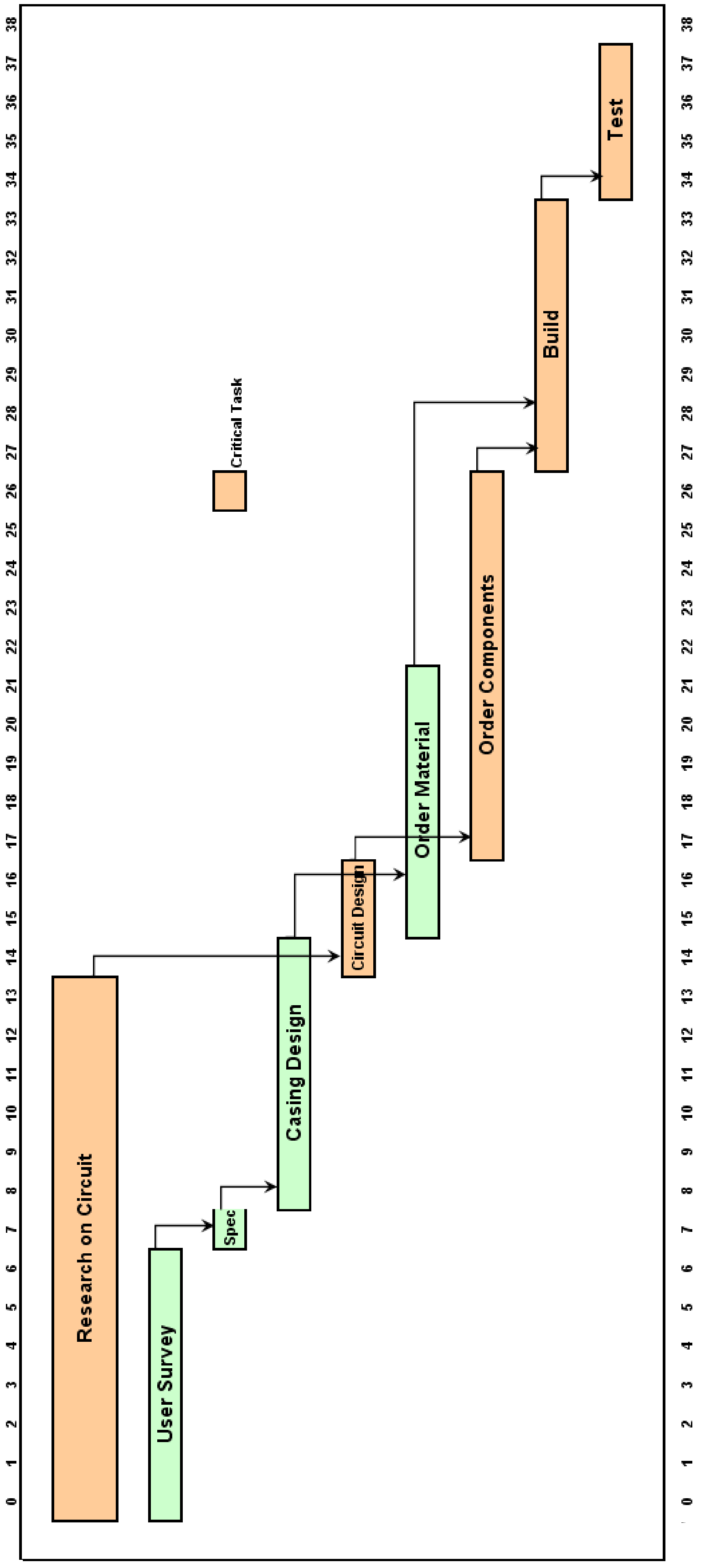


Figure 12 Gantt Chart for project