Rewarding Learning

AS LEVEL Section D

# FACT FILES

# Technology & Design

For first teaching from September 2011
For first award in Summer 2012

## Designing Part 3

FACT FILE

technology and design

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## 1.27 Designing Part 3

technology and design

### Learning Outcomes

**Students should be able to:**

Students should be able to:

- Demonstrate knowledge and understanding of the Design Process including:
  - planning for manufacture using Flow Process charts, Gantt charts and Critical path analysis;
  - selection of processes and techniques used in manufacture to produce products for different production levels;
  - formative and summative evaluation techniques used for evaluation and testing;
  - product review and testing.

### Course Content

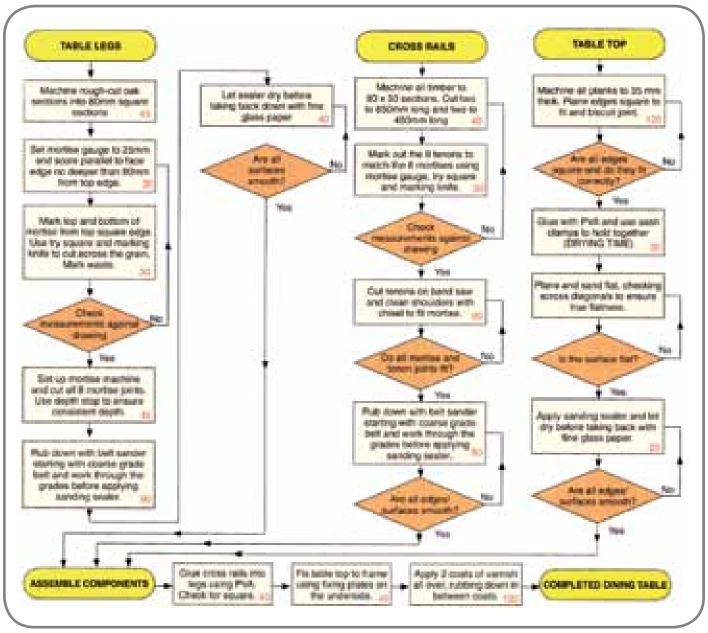
## Planning For Manufacture

Once a design has been finalised the company producing it starts to plan for its manufacture. To ensure that the company is equipped to produce what is intended the production engineers will come to the fore.

A considerable amount of detailed planning will have been carried out so that manufacturing can be carried out smoothly. A detailed production plan explains the sequence of operations to be carried out during the manufacture of a product. Production managers will schedule every process within a master plan, using devices such as flow process charts, Gantt charts or critical path analysis. Contracts will have been drawn up and agreed with suppliers and supply chains will have been organised that feed into the manufacturing plant. Sales departments will be ready to deal with the flow of new products and marketing strategies will be implemented.

## Flow Process Charts

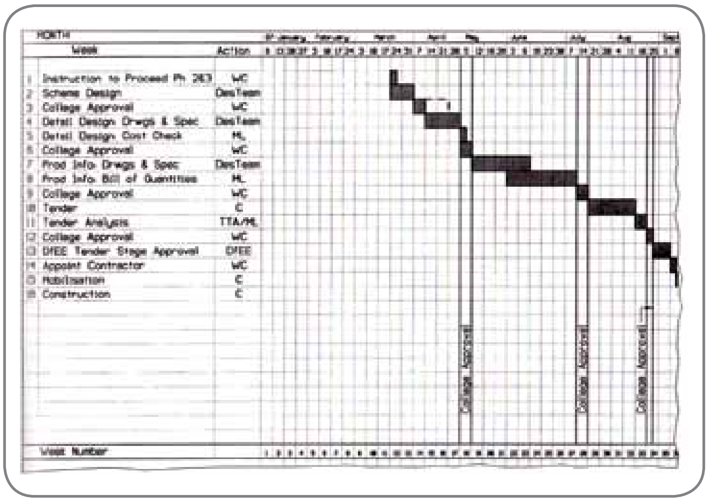
A production plan should include a work order or schedule, which can be presented in the form of a flow chart. The work order should include the order of assembly of parts/ components, as well as the tools, equipment and processes to be utilised during manufacture. Quality control points, with the quality check specified, should also be identified throughout the production plan so that high-quality products are produced.




Unit 1.27 Designing (Part 3)

## Gantt Charts

When complex operations require inputs from many sources, Gantt charts enable processes to be carried out on schedule, or components to be delivered on time. These simple charts can help designers and companies map each task and all aspects of product manufacture against time available and enable them to draw up an order of priority.



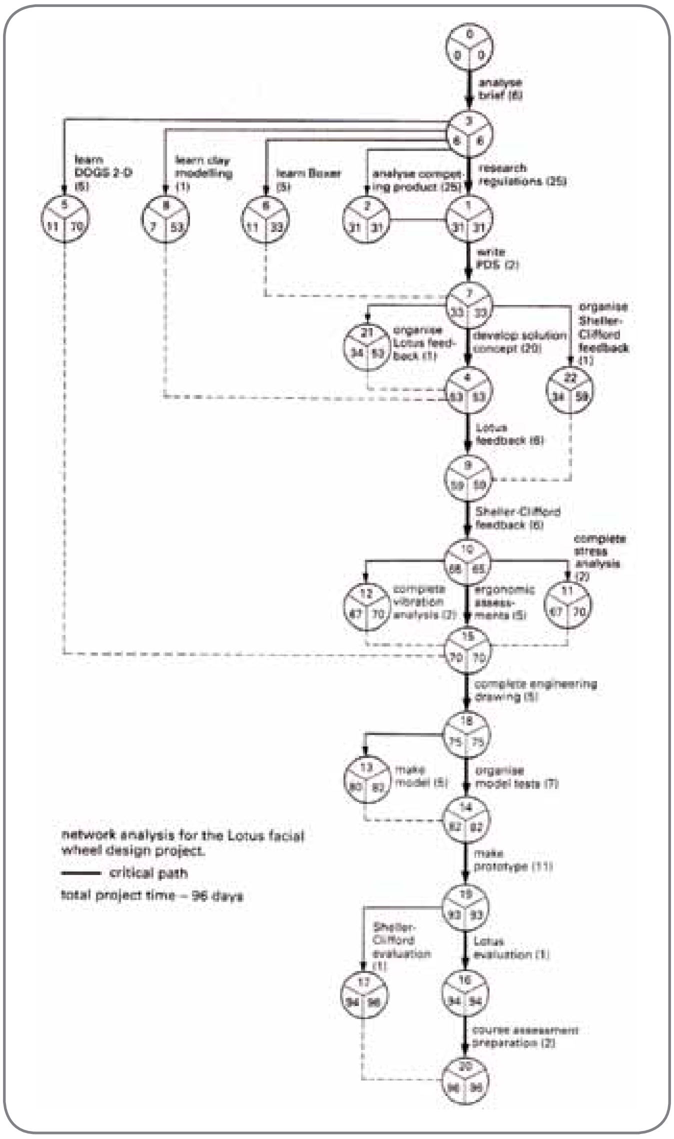

## Critical Path Analysis

In the 1950s the *Programme Evaluation and Review Technique (PERT)* was developed in America. In its most basic form the technique is also known as **critical path analysis**. There are three different stages to a critical path analysis:

1. **List all activities**
   When you have listed all the activities you must estimate the time taken to carry out the various design and manufacturing tasks. A useful exercise is to ask teachers, experienced designers and manufacturers for their advice.

2. **Draw a network**
   The order in which the activities can be carried out must be determined before a decision concerning the total project time can be taken. Some activities can be carried out simultaneously or in parallel to one another. However, some activities can only be carried out when another finishes. A circular symbol represents each activity in the network, as shown in the figure above and to the right.

## Critical Path Analysis



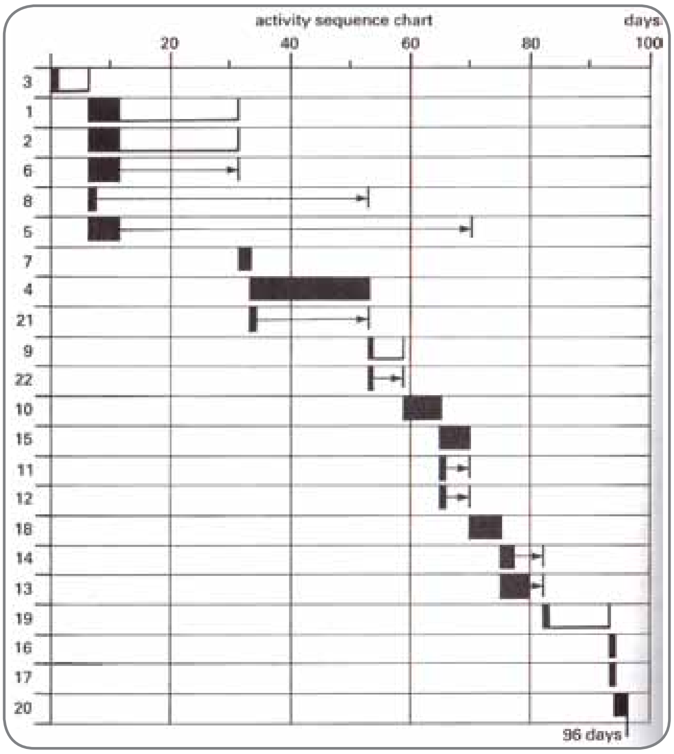

The number in the top sector identifies the activity, the left sector contains the earliest time the activity may be completed and the right sector, the latest time.

Solid lines join activities with arrows in the order in which they must be completed. When one or more parallel activities must be completed before another can begin then they are joined by a dotted line, sometimes known as a *dummy activity*.

The figure above right shows a network drawing. The critical path is shown by a thickened line and this path represents the shortest time in which the project can be completed. The earliest and latest completion times are the same. There is no slack time and any delays in a particular activity will delay the whole project.

3. **Draw an activity sequence chart** - The figure below shows an activity sequence chart which has been constructed from the network analysis diagram above. This consists of blocks of time – the shaded part of each block represents the time the student actually spends on the various activities. If an activity could take place in parallel, the block of time will appear together with an arrow which indicates the latest possible finishing time.

The first set of parallel activities, 2, 6, 8 and 5, can be carried out in the slack time for activity 1. Activities 22 and 13 can also be slotted in, in parallel. Extra personnel could be brought in at these times, so that it would still be possible to finish the project in 96 days if required. However, if you're working on your own 5 more days would be needed – the total time necessary to complete activities 21, 11 and 12.




Therefore, the identification of the 'critical path' is the path that takes the shortest time. This needs to be balanced against the best use of resources. You may find that the shortest time means using a lot of personnel during some weeks and very few during others. This could be seen as poor resource management.

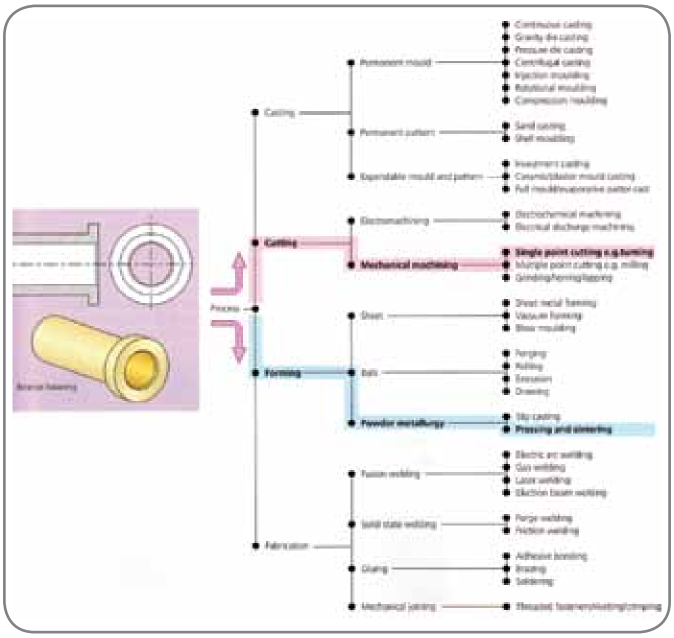
## Selection of Processes and Techniques Used in Manufacture

Making cost-effective decisions about the manufacturing route depends on a knowledge of the materials and processes to be employed. A detailed design must reflect the materials selected and the manufacturing method, therefore it is important for these to be chosen as early as possible in the design process. A detailed design must also make effective use of standard components.

A major set of constraints concern suitability for manufacture, some of which might apply in any circumstance (e.g. every material has inherit limitations) and some of which are specific to the particular design under consideration (e.g. whether or not a machining process would be cost-effective for a particular product).

Some manufacturing processes impose constraints on the designer, an example being vacuum forming. Moulds for these products must taper slightly and avoid sharp corners, whether or not this is desirable for other reasons, otherwise consistent quality of product is impossible.

As well as imposing constraints, there are times when a production process is an opportunity, or a stimulus for new ideas. For example, if a part has been fabricated previously from metal and casting becomes available as an alternative, new flowing forms to suit the casting process are then required, which will allow the designer to explore forms that were not feasible using a fabricated approach.



## Manufacturing Systems

The system of production chosen will be the one that best suits the type of product and volume of production required.

***One-off production*** - refers to the specialised processes involved in the manufacture of single items such as power stations, bridges, spacecraft and craft-based products like jewellery. One-off production has a high unit cost and often requires highly skilled personnel.

***Batch production*** – A batch can be any specified quantity from a few to a few thousand. Batches, or production runs, can be repeated any number of times as required. The important feature of batch production is that the process, machines, tools and workforce are flexible. They must be able to change quickly from the production of a batch of one component to the production of another. Batch production processes benefit from the flexibility of CNC machines, a skilled workforce and the adoption of modern manufacturing practices.


***Mass production*** – High volume 'mass' production is necessary for consumer products such as personal computers and televisions, in order to supply demand at low cost. This is also true of standard components and sub-assemblies. These and many other products need items such as nuts and bolts, springs, electrical components, batteries and paint. Mass production processes, particularly assembly areas, consist of short, easy to learn operations that are designed to gain maximum flexibility from a largely unskilled workforce.

***Continuous production*** - is the name applied to those manufacturing processes that are continuous and are only economic if they are kept running. Aluminium, steel and many plastic materials are manufactured on a continuous process. All forms of process production require large investment in capital equipment.

## Process Engineering

Selecting the most appropriate manufacturing process at any stage within the manufacture or assembly of a product or component part, is a very important task. Decisions must be based upon a sound knowledge of the available manufacturing technology, particularly if investment is to be made in new plant or equipment.


Process engineers are the people who specialise in making these decisions, and it is essential that they keep up-to-date with new manufacturing processes and techniques. Another key aspect of process selection is the ability to refine the design of a product to best suit any potential manufacturing process that is being proposed. The dialogue that takes place between the designer and the process engineer, where each can begin to understand the problems of the other, results from the adoption of Concurrent Engineering practices (CE).

## Process Selection

There are a number of considerations that will influence the process engineer's decisions. The key factors in making process selection decisions are:

**Quantity** – this is possibly the most significant reason and one that will influence the selection of any manufacturing process. Large quantities, with extended production runs, are more likely to justify large investment than small batches.

**Resource cost** – the need to invest in equipment and tools and the level of such investment is measured against the potential return.


**Workforce, training & supervision** – labour costs at all levels are a major contribution to the costs of any manufacturing process. With 'on-costs' such as heating, lighting and various aspects of employer liability, these costs can quickly outweigh other investment costs.

**Material cost & availability** – there are a number of factors to consider here. Materials and components may be expensive, difficult to transport, difficult to store, or in short supply. Failure to keep a process supplied with material resources can be very costly.

**Energy consumption** – this can be a major consideration with primary processing such as refining and material production, and also when considering casting and heat treatment processes.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***Tolerance & finish*** – products and component parts that need to be manufactured to a high specification of dimensional accuracy and finish require high-cost processing and often a high-cost workforce.

***Waste & recycling*** – recycling is good for business. Responsible manufacturing requires a responsible attitude to the production of waste, energy consumption and the ability to use and to recycle materials.

## Formative and Summative evaluation techniques used for evaluation and testing

**Formative evaluation** takes place during and has a strong influence on the development of the product.
**Summative evaluation** is a review that takes place following the completion of the product.

The benefits of a clearly written product design specification (PDS) can be clearly seen during the evaluation of a design as it progresses, and against the final product. This allows each aspect of the design to be considered carefully and an assessment made of how closely that particular design objective has been met. The PDS can also be subject to review, due to changes in either the market or the available technology that often occurs while the project is in progress. Tests that simulate the expected use of the product provides the most reliable form of feedback to the designer and is a key stage before a final decision to manufacture the product can be made.


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The design must be constantly reviewed as it progresses and carefully evaluated when completed. The process of constantly reviewing a design while it is in progress, particularly in industry, is known as value engineering. If the same kind of review is held on existing products it is known as **value analysis**.

## Value Engineering and Analysis

Value engineering and value analysis are concerned with finding ways in which a particular function or objective can be achieved at a reduced cost. This is not the same as always looking for cost reductions for particular components or assemblies. The fundamental questions for either value engineering and value analysis are:

- What is it?
- What does it do?
- What does it cost?
- What else will do the job?
- What does that cost?

The processes are generally carried out by teams and in a number of stages as described below. They can also be carried out in schools with teams of student reviewing each other's designs.


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**Team formation** – A typical industrial team would consist of a multidisciplinary team as in thought showers.

**Selection of a product to study** – With value analysis a suitable product may be indicated by high production costs, a competitor with a cheaper line, a difficult manufacturing method, high rejection rates or the excessive production of scrap.

**Speculation** – Questions that will be asked are:

- Can something else be used?
- Can dimensions be reduced?
- Can waste in manufacture be reduced?
- Can standard components be used instead of manufactured parts?
- Can cheaper components be substituted?

It is important to establish that all ideas are welcomed as in brainstorming sessions and judgement on them is temporarily suspended.

**Investigation** – All ideas will be looked at and the best of these need to be investigated. The benefits and the costs of any new proposal will be analysed in detail.

**Recommendation** – The team must present its findings to the management of the organisation for approval. An assessment by an independent group is vital to ensure that some key aspect has not been overlooked.

**Implementation** – If, following the independent assessment, the proposal is still considered a likely success it can be implemented and the organisation can, it will be hoped, reap the benefits.

It might be thought that **value engineering** would always be preferred to **value analysis**, but what is not the case. Against **value engineering** is the fact that it introduces another delay to the start of production with the increased risks from competitors, changes in the market and new technology.

## Product Review and Testing

The finished product should be tested under realistic conditions to decide on its success using the Product Design Specification to check the product's performance and quality. Tests should be objective and many should be carried out by the client/user group. Other potential users could be involved in the testing process and this would be a reliable way of gathering unbiased and reliable third-party feedback. This information can be used to make suggestions for possible modifications and future improvements to products.


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Testing procedures for products and prototypes are among the most common subjects covered by British Standards. If a product has been manufactured under a safety system drawn up by BSI and agreed with the manufacturer or supplier, then it can carry either the Kitemark or the Safety Mark.

Testing is more often concerned with the functional aspects of a product: Does it work as it should? Will it continue to work over a period of time? Will it work in different environments? Sometimes the testing that has to be done is damaging or destructive, and only a limited number of products would be tested in this way because of the expense. Testing methods are constantly being developed to provide similar results without the need to damage or destroy. This is referred to as 'non-destructive testing' (NDT).

## Revision questions

1. (a) When planning the production of work in a school workshop it is important that resources are used efficiently. Identify and discuss the factors that must be considered in connection with each of the following: (i) time (ii) facilities (iii) materials.

   (b) Compare the factors identified in (a) with the equivalent planning operated in industry.
2. Why are the selection of materials and manufacturing processes important design considerations? Use **three** different examples of products found in the kitchen to illustrate you answer.
3. Carry out a value analysis of a small product such as a stapler or hole punch. Make sketch drawings of all the component parts and say what materials they are made from. State the processes that have been used in their manufacture and the order in which the product has been assembled. How would you improve the design of the product?