MA4605 Lecture 9B

Process problem solving and improvement

1) **Pareto Analysis**
2) **Cause and Effect Analysis**

Pareto analysis
In many things we do in life we find that most of our problems arise from a few of the sources. The Italian economist Vilfredo Pareto used this concept when he approached the distribution of wealth in his country at the turn of the century. He observed that 80–90 per cent of Italy's wealth lay in the hands of 10–20 per cent of the population. A similar distribution has been found empirically to be true in many other fields. For example, 80 per cent of the defects will arise from 20 per cent of the causes; 80 per cent of the complaints originate from 20 per cent of the customers. These observations have become known as part of Pareto's Law or the 80/20 rule.

The technique of arranging data according to priority or importance and tying it to a problem-solving framework is called Pareto analysis. This is a formal procedure which is readily teachable, easily understood and very effective. Pareto diagrams or charts are used extensively by improvement teams all over the world; indeed the technique has become fundamental to their operation for identifying the really important problems and establishing priorities for action.

Pareto analysis procedures
There are always many aspects of business operations that require improvement: the number of errors, process capability, rework, sales, etc.

Each problem comprises many smaller problems and it is often difficult to know which ones to tackle to be most effective.
A definite procedure is needed to transform this data to form a basis for action.

There are two types of Pareto analysis are possible here to identify the areas which should receive priority attention. One is based on the ***frequency*** of each cause of scrap/rework and the other is based on ***cost***.

It is reasonable to assume that both types of analysis will be required. The identification of the most frequently occurring reason should enable the total number of batches scrapped or requiring rework to be reduced. This may be necessary to improve plant operator morale which may be adversely affected by a high proportion of output being rejected. Analysis using cost as the basis will be necessary to derive the greatest financial benefit from the effort exerted. We shall use a generalizable stepwise procedure to perform both of these analyses.

Step 1. List all the elements

This list should be exhaustive to preclude the inadvertent drawing of inappropriate conclusions. In this case the reasons may be listed as they occur , for example moisture content high, excess insoluble matter, dyestuff contamination, low melting point, conversion process failure, high iron content, phenol content >1 per cent, unacceptable application, unacceptable absorption spectrum, unacceptable chromatogram.

Step 2. Measure the elements

It is essential to use the same unit of measure for each element. It may be in cash value, time, frequency, number or amount, depending on the element. In the scrap and rework case, the elements – reasons – may be measured in terms of frequency, labour cost, material cost, plant cost and total cost. We shall use the first and the last – frequency and total cost. The tally chart, frequency distribution and cost calculations are shown in the table below.

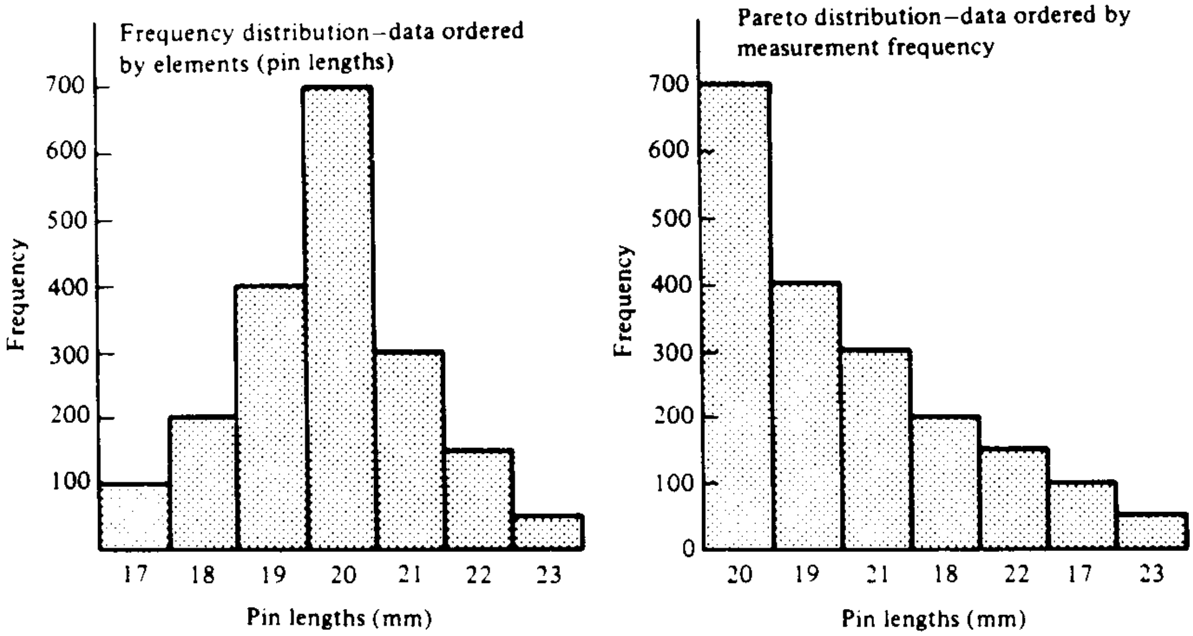
Reason for scrap/rework	*Tally*	*Frequency*	*Cost per batch (£)*	*Total cost (£)*
Moisture content high	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ III	23	650	14 950
Excess insoluble matter	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ II	32	625	20 000
Dyestuff contamination	IIII	4	40 000	160 000
Low melting point	~~IIII~~ ~~IIII~~ I	11	5 000	55 000
Conversion process failure	III	3	40 000	120 000
High iron content	II	2	2 500	5 000
Phenol content > 1%	II	2	4 800	9 600
Unacceptable application	I	1	10 000	10 000
Unacceptable absorption spectrum	I	1	950	950
Unacceptable chromatogram	I	1	4 500	4 500

Step 3. Rank the elements

This ordering takes place according to the measures and not the classification. This is the crucial difference between a Pareto distribution and the usual frequency distribution and is particularly important for numerically classified elements.

For example, the two histograms shows the comparison between the frequency and Pareto distributions from the same data on pin lengths. The two distributions are ordered in contrasting fashion with the frequency distribution structured by element value and the Pareto arranged by the measurement values on the element.

To return to the scrap and rework case, the first histogram shows the reasons ranked according to frequency of occurrence, whilst the second histogram has them in order of decreasing cost.



Step 4. Create cumulative distributions

The measures are cumulated from the highest ranked to the lowest, and each cumulative frequency shown as a percentage of the total.

The elements are also cumulated and shown as a percentage of the total. The Tables below show these calculations for the scrap and rework data – for frequency of occurrence and total cost respectively. The important thing to remember about the cumulative element distribution is that the gaps between each element should be equal.

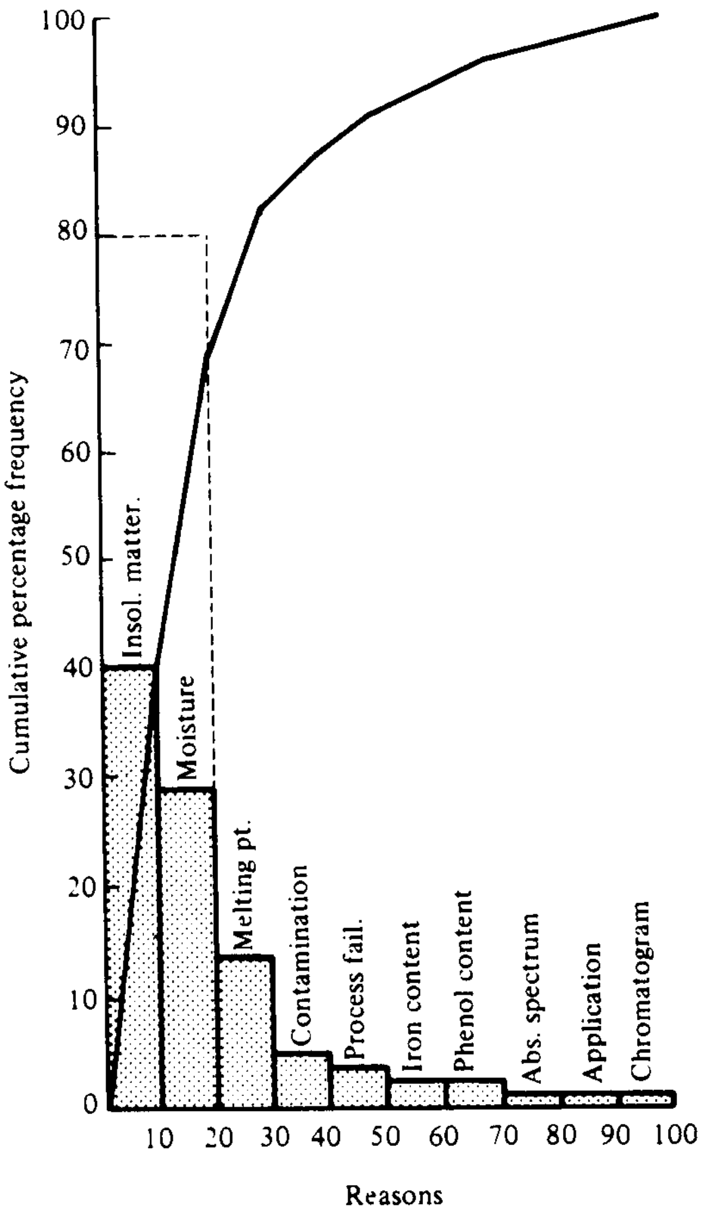
If they are not, then an error has been made in the calculations or reasoning. The most common mistake is to confuse the frequency of measure with elements.

Reason for scrap/rework	*Frequency*	*Cum. freq.*	*% of total*
Excess insoluble matter	32	32	40.00
Moisture content high	23	55	68.75
Low melting point	11	66	82.50
Dyestuff contamination	4	70	87.50
Conversion process failure	3	73	91.25
High iron content	2	75	93.75
Phenol content >1%	2	77	96.25
Unacceptable:			
Absorption spectrum	1	78	97.50
Application	1	79	98.75
Chromatogram	1	80	100.00

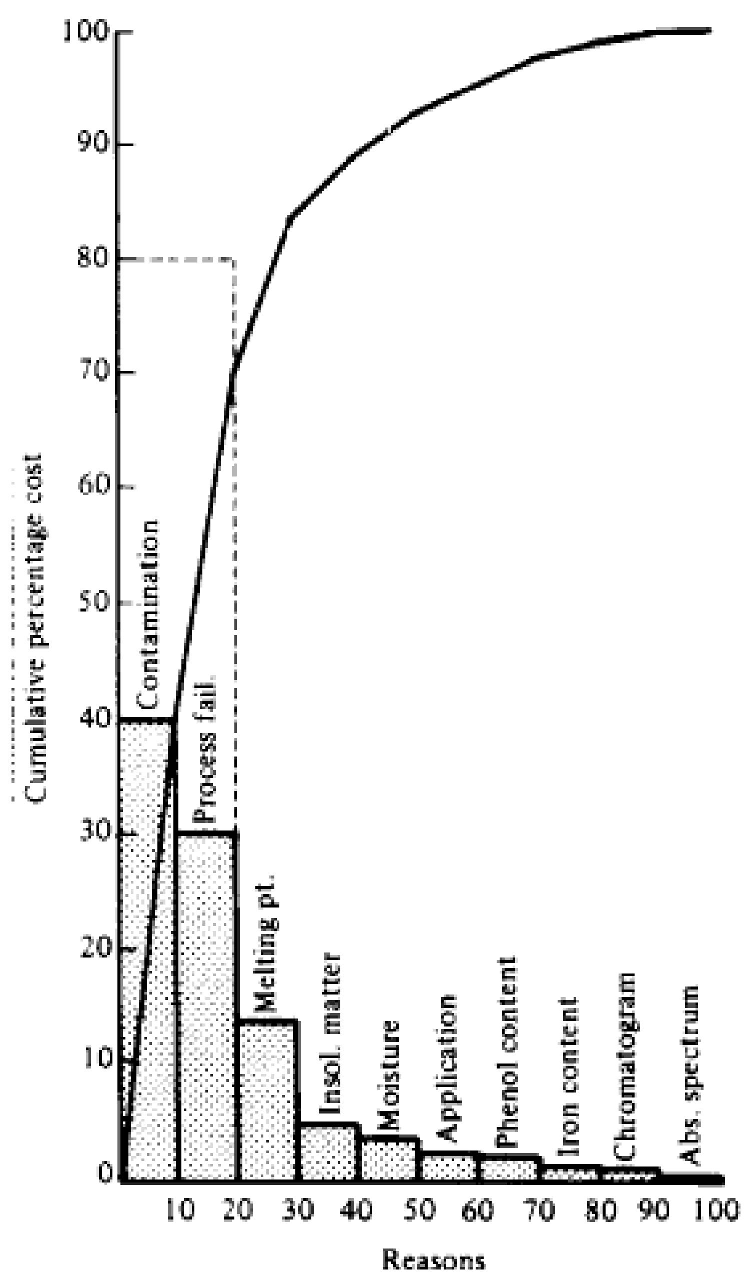
Reason for scrap/rework	*Total cost*	*Cum. cost*	*Cum. % of grand total*
Dyestuff contamination	160 000	160 000	40.0
Conversion process failure	120 000	280 000	70.0
Low melting point	55 000	335 000	83.75
Excess insoluble matter	20 000	355 000	88.75
Moisture content high	14 950	369 950	92.5
Unacceptable application	10 000	379 950	95.0
Phenol content >1%	9 600	389 550	97.4
High iron content	5 000	395 550	98.65
Unacceptable chromatogram	4 500	399 050	99.75
Unacceptable abs. spectrum	950	400 000	100.0

Step 5. Draw the Pareto curve

The cumulative percentage distributions are plotted on linear graph paper. The cumulative percentage measure is plotted on the vertical axis against the cumulative percentage element along the horizontal axis. The two subsequent charts are the respective Pareto curves for frequency and total cost of reasons for the scrapped/reworked batches of dyestuff product.



Cumulative percentage frequency
100
90
80
70
60
50
40
30
20
10
0
Insol. matter.
Moisture
Melting pt.
Contamination
Process fail.
Iron content
Phenol content
Abs. spectrum
Application
Chromatogram
10
20
30
40
50
60
70
80
90
100
Reasons



100
90
80
70
60
50
40
30
20
10
0
Cumulative percentage cost
Contamination
Process fail.
Melting pt.
Insol. matter
Moisture
Application
Phenol content
Iron content
Chromatogram
Abs. spectrum
10
20
30
40
50
60
70
80
90
100
Reasons

Step 6. Interpret the Pareto curves

The aim of Pareto analysis in problem solving is to highlight the elements which should be examined first. A useful first step is to draw a vertical line from the 20–30 per cent area of the horizontal axis. This has been done in both charts and shows that:

1) 30 per cent of the reasons are responsible for 82.5 per cent of all the batches being scrapped or requiring rework.
   The reasons are:
   - excess insoluble matter (40 per cent)
   - moisture content high (28.75 per cent), and
   - low melting point (13.75 per cent).
2) 30 per cent of the reasons for scrapped or reworked batches cause 83.75 per cent of the total cost.
   The reasons are:
   - dyestuff contamination (40 per cent)
   - conversion process failure (30 per cent), and
   - low melting point (13.75 per cent).

These are often called the 'A' items or the 'vital few' which have been highlighted for special attention. It is quite clear that, if the objective is to reduce costs, then contamination must be tackled as a priority. Even though this has occurred only four times in 80 batches, the costs of scrapping the whole batch are relatively very large.

Similarly, concentration on the problem of excess insoluble matter will have the biggest effect on reducing the number of batches which require to be reworked.

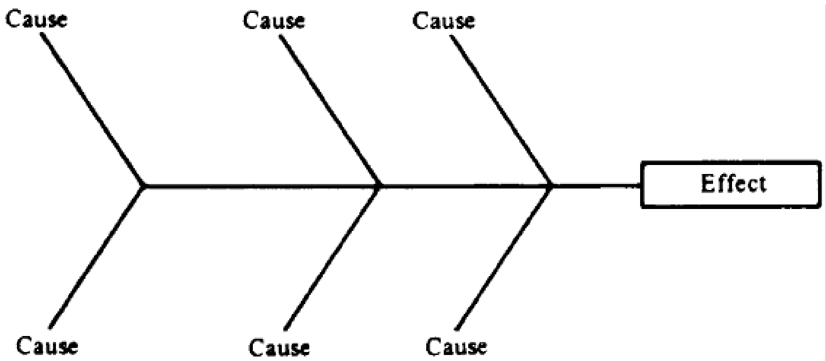
It is conventional to further arbitrarily divide the remaining 70–80 per cent of elements into two classifications – the B elements and the C elements, the so-called 'trivial many'. This may be done by drawing a vertical line from the 50–60 per cent mark on the horizontal axis. In this case only 5 per cent of the costs come from the 50 per cent of the 'C' reasons. This type of classification of elements gives rise to the alternative name for this technique – ABC analysis.

2. Cause and effect analysis

In any study of a problem, the *effect* – such as a particular defect or a certain process failure – is usually known. Cause and effect analysis may be used to elicit all possible contributing factors, or *causes* of the effect. This technique comprises usage of cause and effect diagrams and brainstorming. The cause and effect diagram is often mentioned in passing as, 'one of the techniques used by quality circles'.

Whilst this statement is true, it is also needlessly limiting in its scope of the application of this most useful and versatile tool. The cause and effect diagram, also known as the ***Ishikawa diagram*** (after its inventor), or the fishbone diagram (after its appearance), shows the effect at the head of a central 'spine' with the causes at the ends of the 'ribs' which branch from it. The basic form is shown below.

The principal factors or causes are listed first and then reduced to their sub-causes, and sub-sub-causes if necessary. This process is continued until all the conceivable causes have been included.



The factors are then critically analysed in light of their probable contribution to the effect. The factors selected as most likely causes of the effect are then subjected to experimentation to determine the validity of their selection. This analytical process is repeated until the true causes are identified.

Constructing the cause and effect diagram

An essential feature of the cause and effect technique is *brainstorming*, which is used to bring ideas on causes out into the open. A group of people freely exchanging ideas bring originality and enthusiasm to problem solving. Wild ideas are welcomed and safe to offer, as criticism or ridicule is not permitted during a brainstorming session. To obtain the greatest results from the session, all members of the group should participate equally and all ideas offered are recorded for subsequent analysis.

The construction of a cause and effect diagram is best illustrated with an example. The production manager in a tea-bag manufacturing firm was extremely concerned about the amount of wastage of tea which was taking place. A study group had been set up to investigate the problem but had made little progress, even after several meetings. The lack of progress was attributed to a combination of too much talk, arm-waving and shouting down – typical symptoms of a non-systematic approach. The problem was handed to a newly appointed management trainee who used the following step-wise approach.

Step 1. Identify the effect

This sounds simple enough but, in fact, is often so poorly done that much time is wasted in the later steps of the process. It is vital that the effect or problem is stated in clear, concise terminology. This will help to avoid the situation where the 'causes' are identified and eliminated, only to find that the 'problem' still exists.

In the tea-bag company, the effect was defined as '*Waste – unrecovered tea wasted during the tea-bag manufacture*'. Effect statements such as this may be arrived at via a number of routes, but the most common are: consensus obtained through brainstorming, one of the 'vital few' on a Pareto diagram, and sources outside the production department.

Step 2. Establish goals

The importance of establishing realistic, meaningful goals at the outset of any problem-solving activity cannot be over-emphasized. Problem solving is not a self-perpetuating endeavour. Most people need to know that their efforts are achieving some good in order for them to continue to participate. A goal should, therefore, be stated in some terms of measurement related to the problem and this must include a time limit.

In the tea-bag firm, the goal was 'a 50 per cent reduction in waste in nine months'. This requires, of course, a good understanding of the situation prior to setting the goal. It is necessary to establish the baseline in order to know, for example, when a 50 per cent reduction has been achieved. The tea waste was running at 2 per cent of tea usage at the commencement of the project.

Step 3. Construct the diagram framework

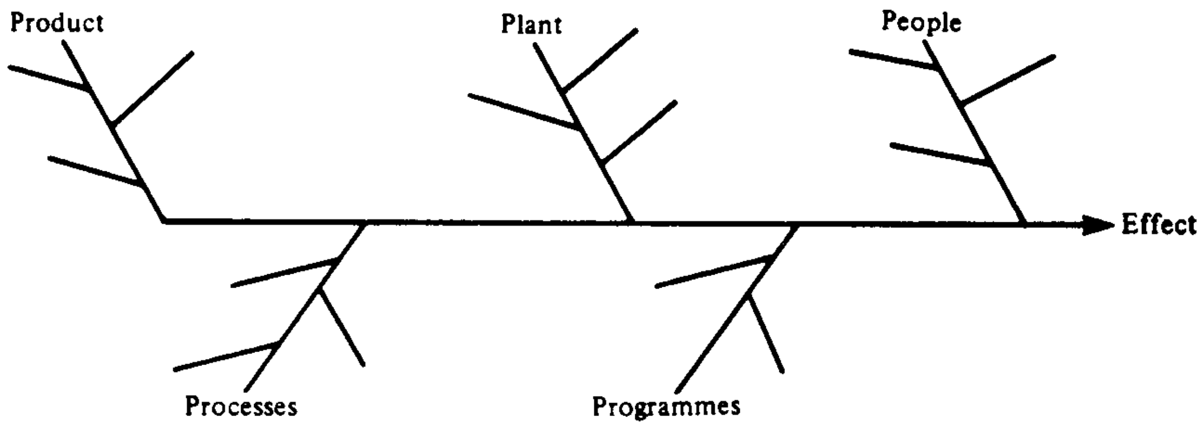
The framework on which the causes are to be listed can be very helpful to the creative thinking process. The author has found the use of the five 'Ps' of production management* very useful in the construction of cause and effect diagrams.

The five components of any operational task are the:

- Product, including services, materials and any intermediates.
- Processes or methods of transformation.
- Plant, i.e. the building and equipment.
- Programmes or timetables for operations.
- People, operators, staff and managers.

These are placed on the main ribs of the diagram with the effect at the end of the spine of the diagram.

The grouping of the sub-causes under the five 'P' headings can be valuable in subsequent analysis of the diagram.



Step 4. Record the causes

It is often difficult to know just where to begin listing causes. In a brainstorming session, the group leader may ask each member, in turn, to suggest a cause. It is essential that the leader should allow only 'causes' to be suggested for it is very easy to slip into an analysis of the possible solutions before all the probable causes have been listed. As suggestions are made, they are written onto the appropriate branch of the diagram.

Again, no criticism of any cause is allowed at this stage of the activity. All suggestions are welcomed because even those which eventually prove to be 'false' may serve to provide ideas that lead to the 'true' causes.

Step 5. Incubate and analyse the diagram

It is usually worthwhile to allow a delay at this stage in the process and to let the diagram remain on display for a few days so that everyone involved in the problem may add suggestions. After all the causes have been listed and the cause and effect diagram has 'incubated' for a short period, the group critically analyses it to find the most likely 'true causes'.

It should be noted that after the incubation period the members of the group are less likely to remember who made each suggestion. It is, therefore, much easier to criticize the ideas and not the people who suggested them.

If we return to the tea-bag example, the investigation returned to the various stages of manufacture where data could easily be recorded concerning the frequency of faults under the headings already noted. It was agreed that over a two-week period each incidence of wastage together with an approximate amount would be recorded. Simple clip-boards were provided for the task.

The break-down of fault frequencies and amount of waste produced led to the information in the table below.

Category of cause	*Percentage wastage*
Weights incorrect	1.92
Bag problems	1.88
Dirt	5.95
Machine problems	18.00
Bag formation	4.92
Carton problems	11.23
Paper problems	56.10

From a Pareto analysis of this data, it was immediately obvious that paper problems were by far the most frequent. It may be seen that two of the seven causes (28 per cent) were together responsible for about 74 per cent of the observed faults.

A closer examination of the paper faults showed ‘reel changes’ to be the most frequent cause. After discussion with the supplier and minor machine modifications, the diameter of the reels of paper was doubled and the frequency of reel changes reduced to approximately one quarter of the original. Prior to this investigation, reel changes were not considered to be a problem – it was accepted as inevitable that a reel would come to an end.

Tackling the identified causes in order of descending importance resulted in the tea-bag waste being reduced to 0.75 per cent of usage within nine months.