SECTION 4 - ANALYSIS AND MAPPING TECHNIQUES

Flowcharting (including IDEF0)

Introduction

Process Flow Charting and Document Flow Charting are techniques that can be employed to provide a visual representation of a procedure. Flat text can be boring and an uninteresting way of describing a process; the reader is likely to lose interest and concentration. A picture can tell a thousand words - it can convey, in certain circumstances, a better graphical indication of the sequence and methods employed within a process. The flow chart can be used to describe a number of activities, sequence of tasks, the way documents flow around an organisation, a computer program etc. Once the chart has been completed, the Process Flow Charts can be employed to analyse all the activities involved in processes or systems. This may be used to explain why a process is done in a particular sequence or why a particular route was taken. The flow chart will also show the suppliers and customers of a particular task or activity. The flow charts can be used to determine the stages that require special quality control activities. With the flow chart being a comprehensive description of the process, identification of value added and non-value added activities and any unnecessary transportation and delays, becomes much easier. Boundaries can be added to the flow chart to denote when the responsibility for a particular set of activities changes from one person to another.

There are a number of different methods and approaches to representing a process using a flow charting method.

- ISO 5807 The specification for data processing flow chart symbols, rules and conventions.
- Cross Functional or Swimlane - A charting method that displays the process tasks, indicating the flow of information and materials across different departments. Sometimes known as swimlanes or document flow charting.
- IDEF0 - Integration Definition for Function Modelling. A method developed by the USA Air Force to graphically represent process activities, showing process activity inputs, outputs, controls and resources. IDEF0 - is the Integration Definition for Information Modelling.

When selecting the process charting method there are some considerations. What is being displayed; information, data or material? What will provide the information in a suitable format for the user? What level of detail is required? What is the business type (service, manufacturing, etc.)?

ISO 5807 - Process Flow charting

There are a number of different standards that can be used for the process flow symbols. ISO 5807 contains the most generally accepted symbols.

Process - Identifies the activity or task and contains a brief description of the work performed.
Decision - The point where a decision is made and the flow chart can slip into two paths. The paths are labelled true/false, yes/no etc. depending on the outcome.
Terminator - Identifies the beginning or end of the process.
Document - Where a document is required, used or created then this symbol can be employed.
Flow lines - Used to represent the next step in the process, connecting activities and tasks.
Connector - Used to indicate a connection between flow charts on separate pages.
Visual - When a computer is used to convey information this symbol can be used.

Guidelines for Process Flow Charting

1. Select the process or system to be examined.

2. Complete the Process Flow Chart shown in **Table 25** representing each of the activities diagrammatically with the appropriate symbol (See **Figure 61**). The table needs to be completed by discussion with the person most knowledgeable about the process under investigation (the person doing the job?).

Table 25 Process Flow Chart Form

Operation: Department: Name: Date:			
Stage	Symbol	Description	Remarks

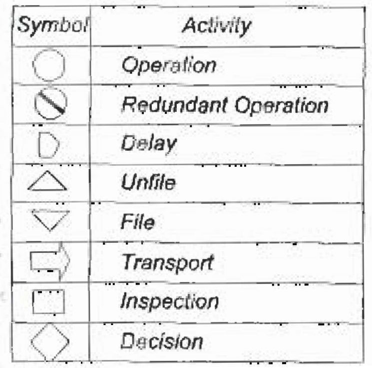

Figure 61 Process Symbols

Table 26 Activity Summary

Activity	No. of Activities	
	Current	Proposed
Operations		
Redundant Operations		
Delays		
Unfile		
Files		
Transports		
Inspections		
Decisions		
Total		

Examples of this type of Process Flow chart can be found in the section on Quality Planning - specifically a Service Quality Plan.

3. Critically analyse the chart to identify:

a. Whether the objectives of the process are being met? Are there any omissions or duplications?
b. Whether the activities are necessary? (Use the activity summary to show the number of current and proposed activities).
c. Whether the process is under control? (Where could the process go wrong and have all the necessary reviews or checks been included and are they being performed?).
d. Whether all the resources and information are available to perform the activities.
e. Whether there are any redundant operations and unnecessary delays.
f. Whether there are any non-value added activities (see section Non-Value Added Activities).

4. Complete **Table 26** indicating the current proposed number of activities, showing the savings made.

5. The finally completed flow chart then needs acceptance and approval by the appropriate authority.

Cross Functional Process Flow Charting

Introduction

This technique is very similar to Process Flow Charting but provides the facility to analyse the process flow of materials or information (paperwork) across different departments. Rather than use the term Cross Functional Flow Charts the shorter term swimlane, will be used.

Guidelines for Document Flow Charting

1. Select the process to be examined.

2. Complete the Swimlane chart. **Figure 62** shows a Swimlane chart for information or paperwork.

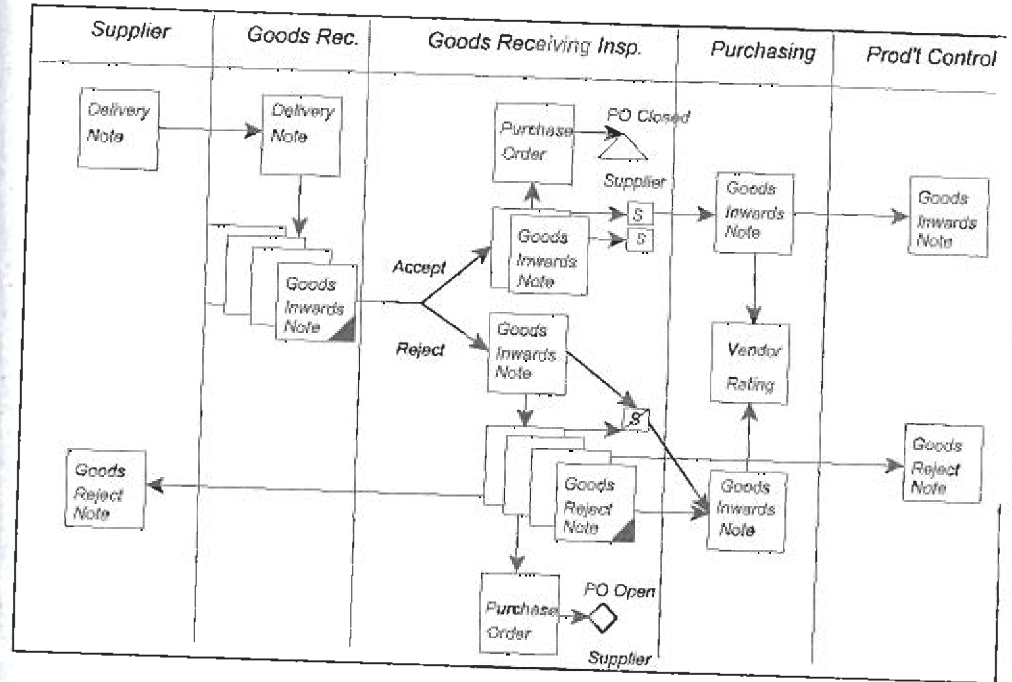

Figure 62 Document Flow Chart

Enter the name of each department, section or operator at the head of each column. Complete the chart by using a symbol to denote each stage and document employed. An arrow is drawn between the stages to indicate the flow of information around the departments. Other examples of Swimlane flow charts can be found in the section Business Process Analysis.

3. Analyse the Chart to identify:

a. Are the objectives of the procedure being met? (Are there any omissions or duplications?)
b. Are all the activities/documents necessary?
c. Is the procedure under control? (Where could the process go wrong? Have all the necessary reviews or checks been included and are they being performed?)
d. Are all the resources and information available to perform the activities?
e. Are there any redundant operations/documents and unnecessary delays?
f. Are there any non-value added activities?

IDEF0 or Input/Output Diagrams

IDEF0 means Integration Definition for Function Modelling (level zero). There are other levels but level 0 is the most basic. It is a Processes Flow charting method which is based around defining the process in terms of activity or task; inputs, outputs, controls and resources. These activities are then linked together to form the process and provide a process model.

Figure 63 shows the basic IDEF0 model.

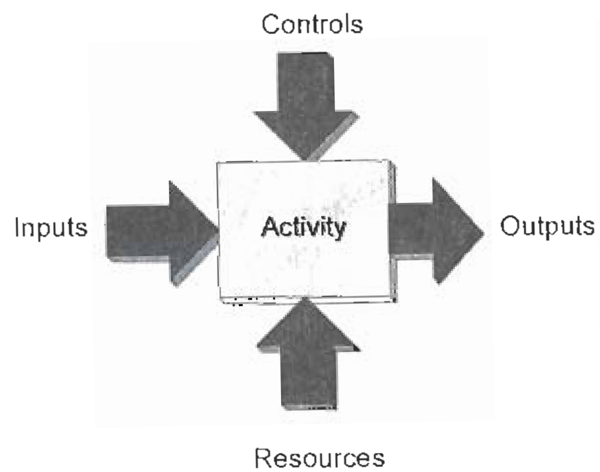

Figure 63 Basic IDEF0 diagram

As an example, **Figure 64** shows the process of making tea.

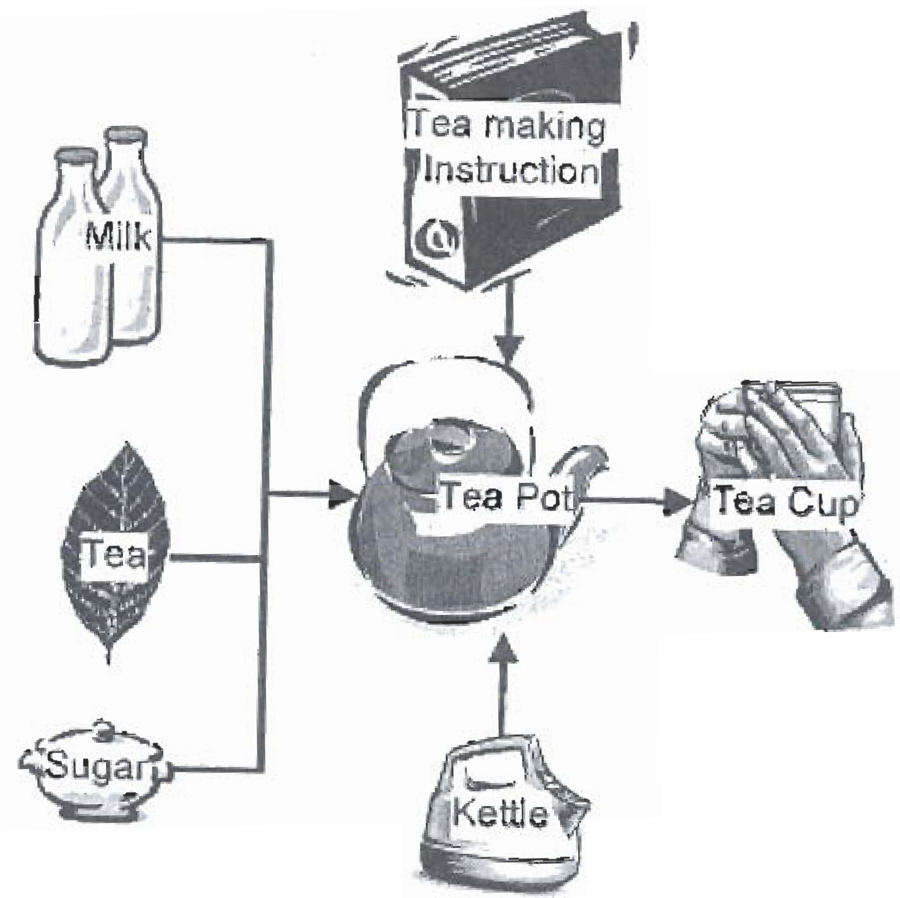

Figure 64 Making Tea

Now using IDEF0 format, **Figure 64** would become as show in **Figure 65**.

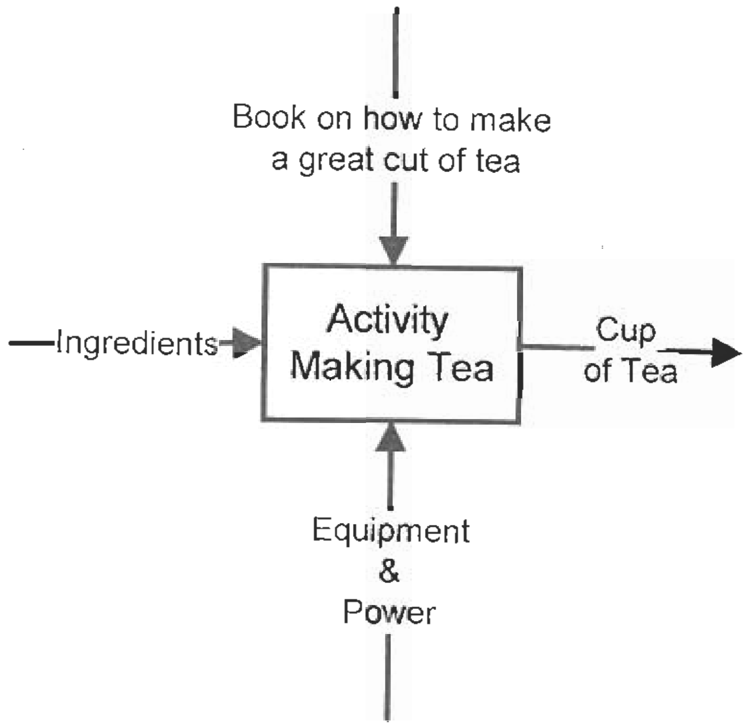

Figure 65 IDEF0 version of making tea

The arrows represent:
Inputs - Items that are used (consumed) in the activity.
Resources - Items that are used or employed in the activity but are not consumed by the activity.
Controls - Items that ensure that the activity is performed correctly for quality.
Output - The product of the activity.

The box represents
Activity - The box that is labelled with task to be performed, using the verb (making) and noun (tea) approach.

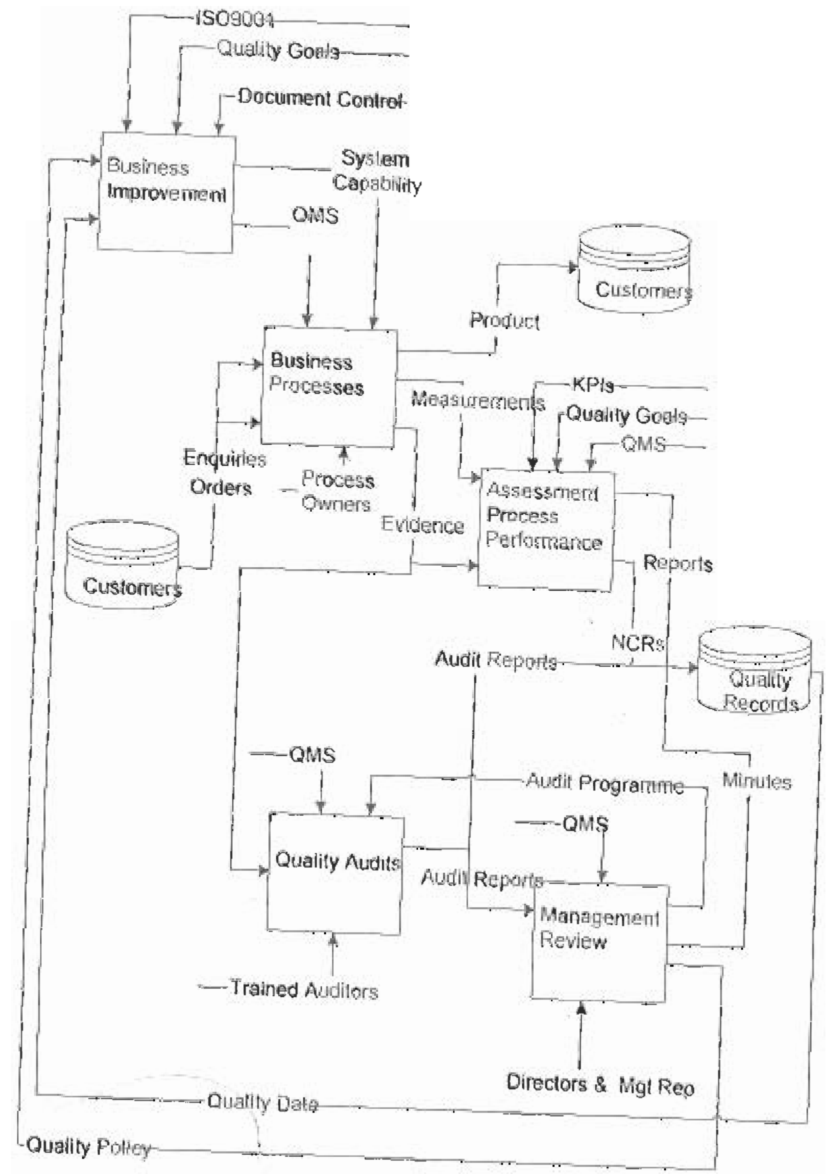

Figure 66 Quality System Model in IDEF0 Format

Figure 66 shows how a Quality System model would look if drawn in IDEF0 format. The diagram uses the same methodology of inputs, outputs, controls, resources and the verb/noun approach to describe the activities. In the bottom right hand corner of each box is the activity reference number. The process activity information can be entered into a database which, together with process performance data, can be used to measure process performance. The sort of process data that could be in each record of the process activity database includes:

- Time to complete conforming activities
- Time to complete any nonconforming activities - See Cost of Quality
- Activity waiting time
- Activity queuing time
- Activity action time - See Business Process Analysis
- Benchmarking data to compare performance against similar processes.
- Target setting and Key Performance Indicators (KPIs) - See Performance Measurement and Benchmarking.

Next is another example of IDEF0, in this case it is a software process.

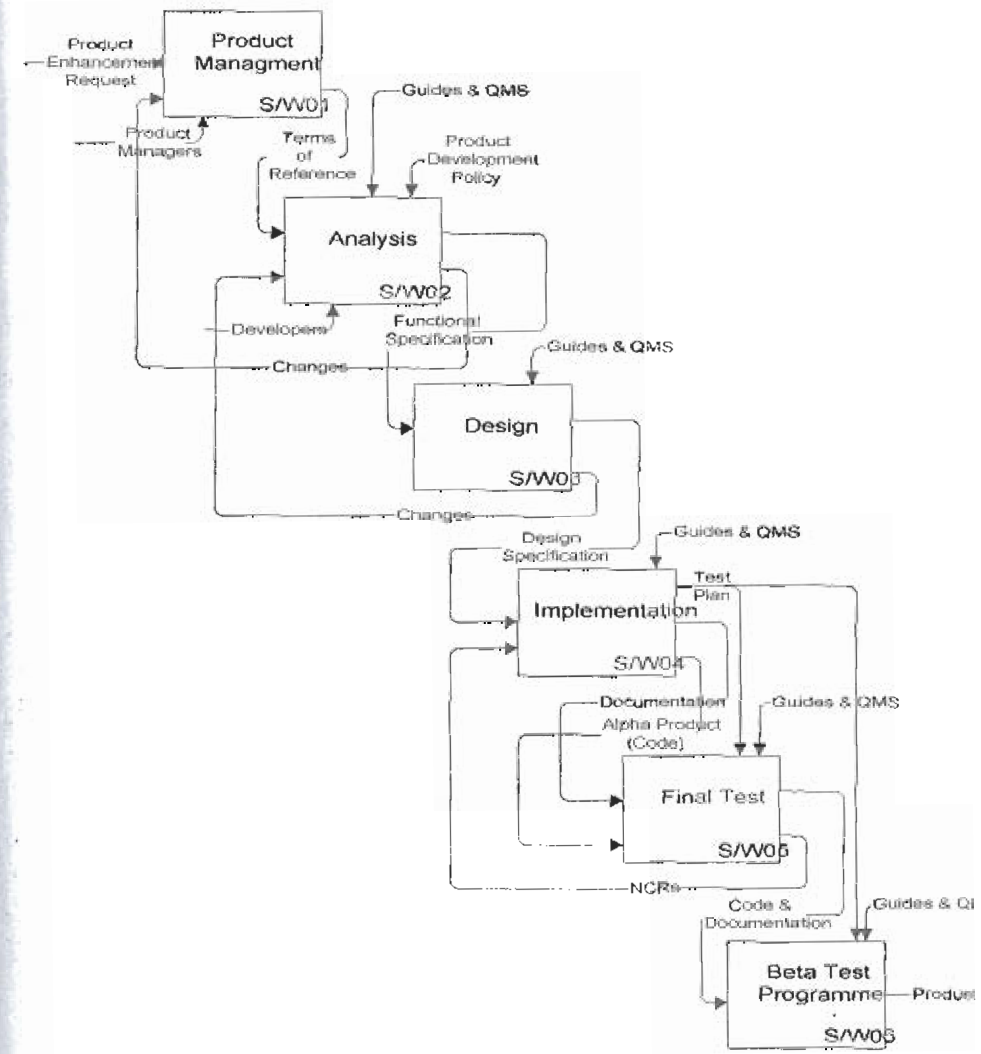

Figure 67 Example of a Software Process in IDEF0 form

In this example an input/output table has been provided below. These tables can b useful addition to the IDFE0 process flow chart. Where the flow chart can sh diagrammatically the process sequence, it is sometimes difficult to show the corr level of detail. In this situation an Input/Output table can be used to further descri the detail of the process. For example, in the Input/Output table the process use attention is drawn to the availability of certain guides and codes of practice, terms reference, software coding, etc.

#	Activity Description	Activity Input	Activity Output	Activity Control and/or Resource
SW01	Product Management	Product Enhancement Request	Product Development Policy Product Terms of Reference (ToR)	Guide for ToRs
SW02	Analysis	Product Development Policy Product Terms of Reference	Functional Specification	Guide for a Function Specification
SW03	Design	Functional Specification	Design Specification Documentation synopsis	Guide for Design Specifications
SW04	Implementation	Design Specification Documentation synopsis	Test Plans Preliminary Test results Documentation Code	Guide for Test Plans Documentation Guide Code writing code of practice
SW05	Final Test	Test Plans Code Documentation	Test Results NCRs Accepted code	Testing Code of Practice
SW06	Beta Programme	Accepted code	Product	

Risk Analysis Techniques (including Fault Tree Analysis)

There are numerous techniques available for risk analysis, some of the most popular techniques are described in the following pages.

Risk analysis is a preventive approach to determine the potential risk associated with a product, service, project or process. Typically, the aims of risk analysis are to identify the potential risks, quantify and determine an appropriate course of action to eliminate or mitigate the effects of the risk. In the case of products, not only will the organisation want to produce attractive products, the organisations need to continually strive to improve, not only the range and performance of the product, but also evaluate new techniques that prevent any possibility of customer problems (safety). The techniques listed below address these aims and objectives. Each technique has its own particular strengths and weaknesses and is often used in specific circumstances and applications.

1. Hazard Analysis Critical Control Points (HACCP) see page 199
2. Hazard and Operability study (HAZOP) see page 200
3. Failure Mode and Effects Analysis (FMEA) sometimes known as Failure Mode, Effects and Criticality Analysis (FMECA) see page 201
4. Fault Tree Analysis see page 208

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1. Hazard Analysis Critical Control Points (HACCP)

Hazard analysis like the other analysis techniques is a preventive approach aimed at avoiding problems. The approach for Hazard Analysis Critical Control Points (HACCP) consists of:

- i Description and assessment of the hazards associated with all stages in the process, from raw material to delivery of the finished product.
- ii Identification of the critical control points.
- iii Establishment of procedures to monitor and regulate the critical control points.

One major problem of this analysis is that no account is taken of the likelihood of occurrence, the seriousness of the failure, and the likelihood of detection. The analysis also does not rank the risk or exposure to problems, not just health and safety issues but also problems of waste, inefficiency and rejects. The technique also tends to concentrate on the process and there is a need to analyse the product as well. The technique is often used to identify any possible health or safety problems with the product and its method of development, production and delivery. While this technique is successful in helping to catalogue logically the issues surrounding health and safety it is felt that the analysis could go further, not only in terms of ensuring health and safety but also possibly improving the overall performance of the product and process.

2. HAZdard and OPerability study (HAZOP)

This technique tends to be applicable to the operation of facilities and plant, detailing the controls necessary to ensure the continued safe operation of the facilities. The HAZOP study is carried out by using guide words. These words are to identify all deviations from the objectives of the facility or plant, which will have undesirable effects on safety or operability. The overall aim of the study is to identify any potential hazards.

The HAZOP study report should contain:

- i Technical information about the facility, its design and operation of the plant or installation.
- ii Details on how safety will be managed.
- iii Information about the particular hazards of the plant or installation. These hazards will need to be systematically identified and documented by means of safety studies.
- iv Information about the safety precautions taken to prevent major accidents, together with the emergency provisions that should be taken if a safety problem or accident occurs. The object then is to reduce the effects of such accidents or safety problems.

This study will require the compilation of operating manuals. These operating manuals will need to describe:

- i Operation, control and safety procedures and instructions, including procedures for the management of changes in technology, operations and equipment.
- ii Adequate maintenance and monitoring of key operations.
- iii Adequate inspection and repair.
- iv Proper training of workers and contractors.

Part of the study will also be to determine the possible causes of accidents. This analysis of hazards should lead to the identification of potential hardware and software failures, process and design deficiencies and human error. The study should also determine what action is necessary to counteract these failures (including abnormal/normal operation, e.g. start-up and shut-down).

Such causes could include: component failure, corrosion, temperature, malfunction o control and safety devices, deviations from normal operation, failure in the monitorin of crucial process parameters, human and organisational errors, incorrect repair o maintenance work, etc.

A HAZOP study should be performed by a multi-disciplinary expert group, alway including personnel familiar with the installation.

One problem with this (HAZOP) approach is that it tends to concentrate on the plan and facilities and not the process or the product. It does not provide the ability t identify areas of waste and inefficiency.

3. Failure Mode and Effects (and Critically) Analysis (FMEA or FMECA)

Introduction

Failure Mode and Effects Analysis (FMEA) is a logical technique used to identify and eliminate possible causes of failure. The technique requires a sequential, disciplined approach by engineers to assess systems, products or processes in order to establish the modes of failure and the effects of failure on the system, product or process. This is to ensure that all possible failure modes have been fully identified and ranked in order of their importance. The FMEA discipline requires the engineers to document their evaluation with regard to the failure mode, effect and criticality. The analysis work can be applied at any stage; design, manufacture, test, installation or use, but is best performed at the design stage. In a simple system the study may be performed on the total system or product but with more complex systems it may be necessary to break the product down into various sub-systems or sub-assemblies.

The addition of the "C" in FMECA refers to the criticality analysis and risk priority number generated when carrying out this analysis. The calculation of the risk priority number is included in the Guidelines for FMEA.

The reason for FMEA

With ever increasing demands to ensure that QUALITY is achieved **RIGHT FIRST TIME** then still greater pressures are placed on the Design Engineer. This is to ensure that the Engineer's design performs consistently, reliably and safely throughout the life of the product, thus providing a quality product that completely meets the demands of the customer. Designers are only human, they can make mistakes and have off days just like everyone else. FMEA ensures that any inadequacies in the design are quickly identified, preventing the possibility of releasing sub-standard products. Product testing will of course help identify any design deficiencies. There are however, possible limitations with this approach:

i) if the product fails the trial, then the modified and hopefully improved design will need to be retested - this can lead to inefficient use of resources.

i) tests and trials can usually only be performed on a limited number of products, consequently all the possible variations in specification and build standard cannot always be evaluated. Using small samples may also not be sufficiently accurate to predict field failure rates, particularly when attempting to identify causes of potentially low field failure rates (½ or 1%). These missed potential failures may result in the need for product recall or the issuing of advisory notices, (particularly in the case of safety critical failures). This can be not only expensive but also damaging for both the company and product's credibility and reputation.

So FMEA provides the potential for:

i) Reducing the likelihood of service failures
ii) Reducing the chance of campaign changes
iii) Reducing maintenance and warranty costs
iv) Reducing the possibility of safety failures
v) Reducing the potential of extended life failures
vi) Reducing the likelihood of Product Liability claims

With FMEA the emphasis is on removal of the likely cause of any potential failures. However, FMEA can also indicate to the Engineer the features in the design which require sophisticated quality control monitoring, possibly with the use of Statistical Quality Control (see section Statistical Quality Control).

Responsibility for FMEA

The analysis can be performed by either the Design, Manufacture or Quality Engineer, but the most suitable is the person who knows the system, product or process best. The Design Engineer is the person most likely to conduct this analysis as they have the most complete knowledge of the product and can therefore best anticipate the failure mode and the effect of the failure modes. The FMEA technique can be completed by an individual but is best carried out as a team exercise led by the engineer responsible for the product or sub-assembly. The team could include the Designer, Quality Engineer, Manufacturing Engineer, Customer and where appropriate any sub-contractors.

Some benefits of the application of FMEA can be:

i) Identifying potential and known failures
ii) Identifying the cause and effect of such a failure mode
iii) Ranking the identified failure modes in terms of risk factor
iv) Following up or taking action on the potential failure modes
v) Providing detailed documentation for the purpose of quality audit
vi) Checking on the FMEA decisions in the event of a major failure
vii) Making clear the accountability for the system, product or process

Limitations of FMEA

FMEA involves a considerable amount of time and labour resource in performing the study but in any case, this is only time that would need to be spent in order to satisfactorily evaluate the design. Conducting an FMEA does require the completion of paperwork but at the end of the analysis documentary evidence is available proving an assessment was performed. Even after completing an FMEA, it may be that the key design failures may have been overlooked by the team and failures still occur. However, the likelihood of such an event has been reduced. It may also be that after completing the FMEA no action is taken regarding the potential failures identified. This may be the case but clear responsibilities for taking action will have been established.

Guidelines for FMEA

The key stages in any failure mode and effects analysis on a design, product or system are detailed below and should be followed in conjunction with **Table 27** shown at the end of this section.

1. Logistics

The system, sub-system or item and the FMEA team members need to be selected. All the relevant information needs to be collated: examples, drawings, customer brief, field failure information etc.

2. Header details

Complete the details at the top of the form including the name of the Engineer who performed the study and is responsible for the design. Include the revision status of the drawing and the FMEA. *Note, if the study was performed by a team the the name of the team leader.*

3. Part, Process or System name and number

Complete details regarding the part, process or system name and number.

4. Describe the function

The engineer must identify as briefly as possible the function of the part, component or system being analysed. The question needed to be asked is: "What is the purpose of this part?"

5. Describe the anticipated failure mode

The engineer must consider how this part could fail to complete its intended function. For example, could it break, bind, corrode, wear, deform, leak, short, etc. It is important at this stage, that the engineer should be asking the question: "How could it fail?" not whether or not it will fail.

6. Describe the effects of failure

The engineer must describe what the effects of failure on the final component or the assembly would be. The question, "What will happen as a result of the failure mode described?" needs to be posed. Will the component or assembly be inoperative, intermittent or noisy, inefficient, not durable, inaccurate etc?

7. Cause - describe the cause of failure

Anticipation as to the cause of failure is necessary at this stage. What is being sought is which set of conditions or factors can bring about the failure mode? For example:

- could a foreign body jam the mechanism?
- would poor or wrong material cause the mechanism to break?
- would poor soldering cause the wire to short or cause an open circuit?
- made outside specification or unable to achieve specification?

The engineer must analyse what conditions could bring about the failure mode.

8. Estimate the frequency of occurrence of the failure

Here it is necessary to estimate the probability that a failure mode will occur. This estimation will be evaluated on a scale of 1 to 10. A one would indicate a very low probability of occurrence, ten would indicate near certainty of occurrence. The engineer needs to assess the probability of an occurrence based on his knowledge and experience of the product. The following evaluation scale is used:

1	=	1 in 1,000,000 chance of occurrence
2 & 3	=	1 in 100,000 chance of occurrence
4 & 5	=	1 in 10,000 chance of occurrence
6 & 7	=	1 in 1,000 chance of occurrence
8	=	1 in 100 chance of occurrence
9	=	1 in 10 chance of occurrence
10	=	100% chance of occurrence

9. Estimate the severity of failure

At this stage it is necessary to determine the likely severity of failure and again the scale of 1 to 10 is used, where a one would indicate a minor nuisance and ten would indicate severe consequences such as a high voltage shock. An estimate must be made of the severity of the failure. The engineer must consider the consequence of failure using the following severity scale:

1	=	unlikely to be detected
2	=	25% chance of service call
3	=	50% chance of service call
4	=	75% chance of service call
5	=	100% chance of service call
6	=	failure on installation or first use
7	=	failure results in customer complaint
8	=	failure results in a serious customer complaint
9	=	failure results in a fire, accident or injury
10	=	failure results in non-compliance with statutory safety standard or a fatality

10. Estimate the detection of failure

An estimate must be made of the probability that a potential failure will be detected before it reaches a customer. Again the evaluation scale of 1 to 10 is used. A one would indicate a very high probability that failure would be detected before reaching the customer and ten would indicate a very low probability that the failure would be detected in-house and therefore is likely to be experienced by the customer. E.g. If a 100% conclusive test is performed on the component, it is unlikely that the fault will reach the customer and is therefore assigned one. Alternatively if no checks are performed then it is highly likely that, if faulty, the defective product will reach the customer and is therefore assigned ten.

1	=	failure will be detected
2	=	80% chance of detection
3	=	70% chance of detection
4	=	60% chance of detection
5	=	50% chance of detection
6	=	40% chance of detection
7	=	30% chance of detection
8	=	20% chance of detection
9	=	10% chance of detection
10	=	no chance of detection

11. Calculate the risk priority number

By multiplying together the assessed likelihood of occurrence, severity and detection, the risk priority number (rpn) is found. The highest number being 1000, the smallest number being 1. From this number it is possible to determine which the high priority items are in terms of failure mode. The higher the risk number the more critical the component or item failure is.

12. Corrective action

The basic purpose of failure mode and effects analysis is to highlight the potential failure mode so that the engineer can take steps to eliminate or reduce the risk. At this stage it is necessary to analyse the risk number and determine what appropriate action is necessary. Obviously a high risk number would indicate immediate action, a low risk number may be ignored or could require some minor checks to be included.

13. Follow up

Having determined what the appropriate corrective action should be it is now necessary to perform a further FMEA to ensure that the resulting risk number has been reduced to an acceptable risk. It is also advisable to confirm at some future date that the proposed action has been successfully and effectively implemented.

Table 27 FMEA Form

Product: Component Name: Component Number: Revision Number: Effect on Purchasing: Yes/No					Engineer: Dates: Report Number: Sheet of Sheets: Revision Number: Last Updated:				
Part, Process or system name & number	Function	Possible Failure Mode	Effect of Failure	Cause of failure	Occurrence	Severity	Detection	Risk	Remarks/ Action taken

4. Fault Tree Analysis

Introduction

Fault Tree Analysis (FTA) is a powerful, widely-recognised method for determining system reliability and possible risks. It is a logical technique for analysing and deducing the various combinations of hardware and software failures and human errors that could result in the occurrence of specified undesired events (usually referred to as the top event) at the system level. The deductive analysis begins with the top event, then attempts to determine the specific causes of this top event. The main objective of FTA is to determine the probability of this top event. The calculation involves system quantitative reliability information, such as failure probability or failure rate. FTA provides key information regarding the likelihood of failure and the means by which failure could occur. Focussing on and refining the results of the FTA can be used to minimise risk and improve system safety and reliability.

Definitions and Fundamentals

Top Event: The double box contains the description of the system level fault or undesired event. The Top Event appears only once at the end or the top of the tree and must be measurable, definable and inclusive of all lower events. The input to the Top Event double box is from a logic gate. The top undesired event is often the fault which upon occurrence results in complete failure of the system and is considered catastrophic failure.

Figure 68 Top event

Fault Event: The rectangle should contain a brief description of the fault event such as combustible material or source of ignition. Fault events should appear at the output or input of a logic gate.

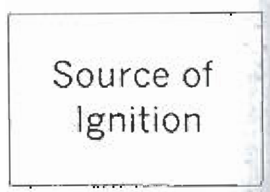


Figure 69 Fault Event

Event Probability: The event probability figure is defined as the probability of being in a failed state or of failure to respond (possibly in the case of an operator). These figures are defined at the component level and are usually in the form of number of faults per year, e.g. EP = 0.02 faults per year. Further up the tree, the figures are calculated from combining the inputs to the AND/OR gates.

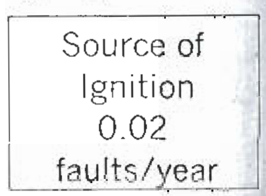
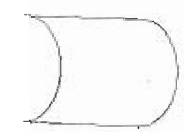


Figure 70 Event Probability

$$\text{AND } P_{and} = P_1 \times P_2 \times P_3 x \ldots P_n$$
$$\text{OR } P_{or} = P_1 + P_2 + P_3 + \ldots P_n$$

Fault Tree Logic Gates: AND/OR gates are used to describe the relationship between the input and output events in a fault tree. The main gates used in FTA are described below.

Description	Symbol	Truth Table: Input A	Truth Table: Input B	Truth Table: Output
AND Gate. The AND gate indicates that the output occurs if all of the input events occur.		T T F F	T F T F	T F F F
OR Gate. The OR gate indicates that the output occurs if at least one of the input events occur.		T T F F	T F T F	T T T F

Fault Tree Analysis Process

a. Determine the scope and depth of the FTA.
b. Determine the system level faults.
c. Describe all events which cause this system level fault.
d. Continue to describe each lower level fault and their immediate causes, until at a component level, failure or human error can be attributed to the fault. It is usually best to complete each tree branch until component level is reached before starting a new branch.
e. Construct the fault tree using the block diagram.
f. Determine probability of each event.
g. Combine probability input to AND/ OR gates as follows:
AND $P_{and} = P_1 X P_2 X P_3 X \ldots P_n$
OR $P_{or} = P_1 + P_2 + P_3 + \ldots P_n$
until the top event probability is determined.
h. Evaluate what action can be taken to reduce the probability or eliminate the likelihood of the top event occurring.

Example of a Fault Tree Analysis for a Mixing Plant

Figure 71 shows a facility for mixing and heating two chemicals. One of the chemicals has the potential to catch fire and explode. An explosion could be caused by the inflammable material being ignited. Two materials, 1 & 2, are fed through a series of valves. The first being an isolation valve, the second controls flow rate to the heated mixing vat.

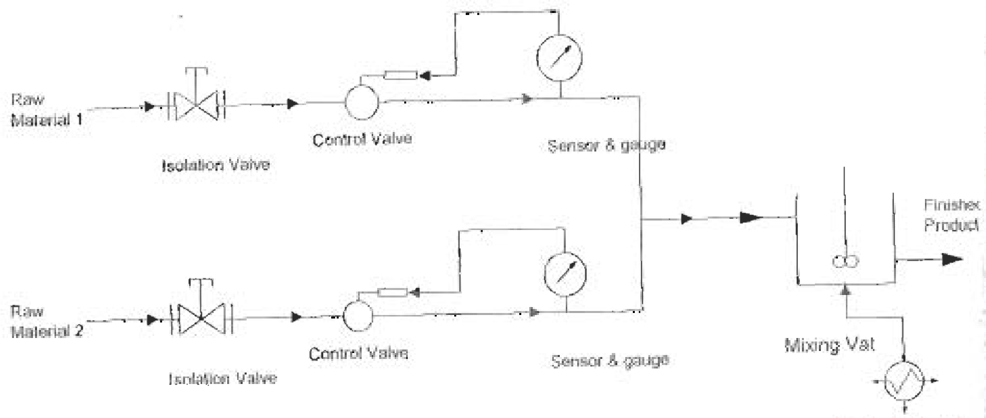


Figure 71 Chemical mixing facility

Figure 71 has been developed into a Fault Tree Analysis as shown in **Figure 72**

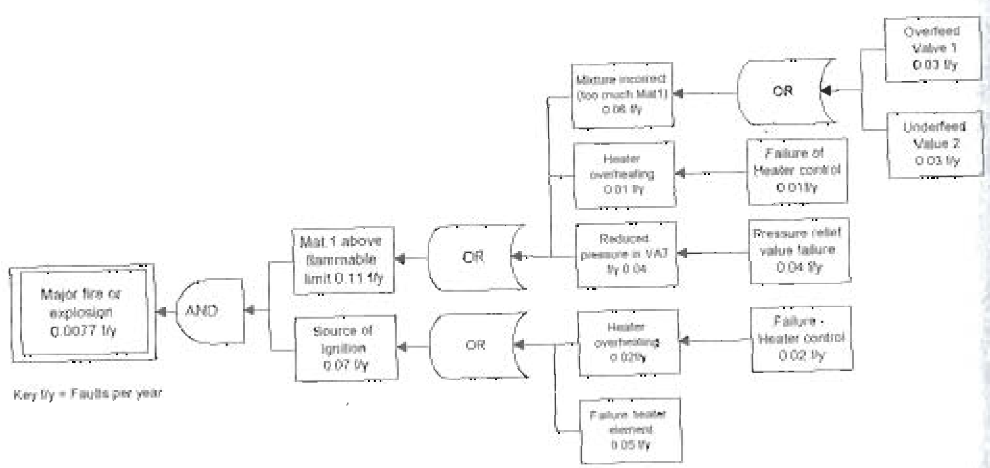


Figure 72 Fault Tree Analysis for Chemical Facility

The Top event probability is calculated to be 0.0077 faults per year, which whilst very **low may** be significant, it very much depends on the application and location of the **facility**. There are a number of actions that could be taken to reduce this risk.

Comments

This is a relatively simple fault tree and if the process was expanded to embrace the whole chemical mixing facility, a considerably more complex fault tree would result. The technique is heavily dependent on the accuracy of the data used for event probability and a good understanding of the specific process under investigation.

Implementing failure analysis

There are a number of approaches that can be adopted for the successful introduction of failure analysis. There are generally two elements to any failure analysis approach; initially a clear understanding of the responsibility and authority, then the creation of the failure analysis process, implementation and review of progress and evaluation of success. An understanding of the responsibility and authority should be established first as this will influence the approach adopted. In any event the approach adopted will require management commitment to the establishment of an environment dedicated to reliability and safety.

To achieve this:

i) Identify the authority, roles and responsibility of engineers or senior managers to complete any failure analysis.
ii) Ensure that failure analysis procedures are agreed and incorporated into any formal engineering or process manuals.
iii) The established procedures should not only clearly identify who holds overall responsibility for the failure analysis but make clear that this responsibility extends to ensuring that all recommended actions are carried out.
iv) Ensure that any resultant failure analysis actions and decisions are supported by documentary evidence justifying the action and confirming resolution or closure. Note; any design, project or process changes that have been implemented (as the result of a failure analysis), should be subjected to a further analysis on the new system.
v) The scope of the failure analysis should be made clear. Does it only apply to products or do all projects and processes needs to be included? Are all products, projects and processes subjected to this failure analysis rigour?
vi) Establish who will be involved in conducting the failure analysis.

vii) Ensure that the active participants in the failure analysis activity have been trained. Ensuring that the team members have a uniform comprehension of the FMEA methodology and rating system and a consistent interpretation of the words used in these scales.

viii) Be aware that ratings used in FMEAs are subjective and are only comparable within the subject and organisation being studied and cannot be directly compared with other.

Failure Analysis Selection

FMEA	Fault Tree Analysis
Assembles, subassemblies and sub-systems. Projects.	Large facilities and installation where catastrophic events are possible.
A large number of changes or variations in system functional outputs may lead to unacceptable conditions.	There is a possibility of multiple failure modes, including human errors, causing serious top event.
It is suspected that the system may produce unwanted or hazardous outputs and it is not known what these are.	A single system output giving loss of main function has been identified as being of prime importance.
The system contains new or unconventional items of equipment hardware (of known detailed design),and the effects of faults in this hardware are not fully understood.	A single unintended system output has been recognised as a possible and significant hazard.
The system contains very little or no redundant elements, standby equipment or alternative modes of operation.	The system contains an appreciable number of redundant elements, standby equipment or alternative modes of operation.
Determining the need for redundancy, design features increasing the probability of "fail safe" outcomes of failure, further derating and/or design simplification.	The fault "logic" within the system can be more conveniently represented in diagrammatic rather than tabular form.
The fault "logic" within the system can be more conveniently represented in statements on tabular form rather than diagrammatic form.	

Exercises

For a process of your choice complete an FMEA.

Nominal Group Technique and Brainstorming

Introduction

Brainstorming: The purpose of brainstorming is to generate as many ideas as possible that come from many different perspectives. The concept is that teams tend to generate more ideas than individuals. As individuals we may run out of ideas quickly. Brainstorming in teams is an effective way of obtaining more new ideas. One person's ideas may trigger ideas that others would not have thought of by themselves. It is in this way that the team build on each other's ideas which trigger off an individual's imagination. The technique is also useful in team building and cohesion. There are many ways in which brainstorming can be carried out.

Nominal Group Technique is a development of brainstorming into a problem analysis process. Nominal Group Technique (NGT), is based on a nominal group of 8 to 10 people, trained in NGT, from various functions and departments, with multi-disciplined backgrounds, who have assembled to collectively evaluate an issue, problem or opportunity for improvement. The NTG process uses all the advantages of brainstorming, i.e encouraging creativity and participation and avoiding social and psychological dynamics of group behaviour, which may inhibit group decisions. Thus, evading problems of individuals dominating the group and specific individuals doing all the *talking and the rest listening. This gets a participating group to* focus on very specific issues in a structured NGT process. Below is described the steps in a typical NGT process. Experience has shown following these steps and the brainstorming rules outlined in the next few pages, will greatly contribute towards a successfully managed meeting and valuable outcomes.

Figure 73 NGT

1. *Define the issue or problem.* The NGT leader creates a statement that predefines the issue that the group is to focus on. A copy of this problem statement is provided to each group member.
2. *Agree problem statement.* The group then evaluates the problem statement. The group is encouraged to restate and restate or clarify the statement in their own words. Care must be taken at this stage not to allow the possible vested interests to change the direction or main thrust of the stated problem. Once agreement is reached the statement can be augmented by the NGT leader inline with the group's wishes.

3. *Silent idea generation.* The group is then given time to think about the problem. Giving the individual time for focussed and uninterrupted thought in a creative setting. Each group member is encouraged without pressurising them to write down (Notebook style) as many idea associated with the problem as they can. Creating the correct, almost academic, quiet, library like atmosphere is important for mental concentration. During this period, which usually lasts about 10 to 15 minutes, no talking should be allowed.
4. *Round Robin Brain Storm.* The NGT leader, having ended the silent generation step, will advise the group that the need for creativity has not finished yet. Each group member now in turn calls out one of their ideas, to be written down by the NGT Leader. The NGT leader may request clarification from the individual idea provider, but the other group members should remain silent during this exchange. This step is continued until each member of the group has said "pass" ie. run out of ideas.
5. *Idea Clarification.* With all the ideas recorded on a flip chart or possibly using stick-it type notes around the room. The group members are then encouraged to seek clarification of each idea in turn and suggest amendments or additions, but not criticise. At this step the ideas can also be organised into similar themes or approaches. Setting a time limit can be helpful to avoid any unnecessary discussion, but each idea should be given equal opportunity.
6. *Voting and prioritising.* Each individual group member now anonymously identifies their top five ideas. Rating them on the basis of criteria such as practicality, feasibility, simplicity, applicability, validity, ease of implementation, suitability, cost, etc. Their top idea getting five points, the next four and so on. Once voting is complete the scores are added up for each idea. This ensures that no premature decisions are made and avoids dominance *by any strong group member. Now no decision has yet been made,* discussion can take place of the rankings. This is where group members have the opportunity to debate the voting and the suitability of the preferred ideas, preparing themselves for the final decision. Once this brief discussion stage has been completed, anonymous voting again takes place to finalise the ideas ranking. There is now a complete written record of the idea development and selection.

This NGT provides an excellent framework for idea generation and gives the group members sense of achievement. Hopefully, motivating them for the more difficult phases of idea testing and implementation.

Brainstorming Guidelines

The following guidelines have been created to help ensure a successful brainstorming session.

The team should be sitting in a room away from distraction. Identify the theme or problem that the team wishes to discuss. Sometimes it helps to brain storm something silly before attempting to brain storm the chosen theme, e.g. *How many uses for a brick?* This can make the team more relaxed. To get the best out of brainstorming there are some simple rules which have been found to work.

Rule 1 Encourage everyone to participate by presenting only one idea per "*turn.*" One way is by taking turns to suggest one idea at a time. If an individual cannot think of anything then say "pass."

Rule 2 There are no silly or bad ideas. So, team members should not put each other down by making them feel stupid. Encourage each other to say whatever comes into their heads.

Rule 3 Criticism or judgement is not allowed. Team members should not criticise the ideas of others. The idea is to be open minded and constructive.

Rule 4 Discussion of the ideas should not take place until after the brainstorming has finished. Accept everything without comment - it could trigger off new ideas.

Rule 5 Exaggeration and enthusiasm are helpful - there is no such thing as a crazy idea. Very often so-called crazy ideas lead to new ways of thinking and imaginative solutions.

Rule 6 Look for possible combinations of ideas, in this way the team may arrive at new ideas.

Rule 7 If you run out of ideas try using the six key words - What, When, Where, Why, Who and How.

Rule 8 Build on other people's ideas where possible.

Rule 9 Record all the ideas.

There are different types of brainstorming, some are listed below. It can also help to return to the problem at some later date - *Incubation.*

Table 28

Brainstorming Approaches	
Advantages	Disadvantages
Free Style: The team calling out ideas to be written down (usually on white board or flip chart, by the team leader).	
i) Spontaneous ii) Can be more creative iii) Possible to build on each others ideas	i) Strong personalities may dominate the session ii) Can be confusing; listing ideas and too many talking at once
Round Robin: Each team member in turn calling out their idea to be written down.	
i) Difficult to dominate the session ii) Discussion tends to be more focussed iii) Everyone is encouraged to take part with equal sharing and participation iv) Possible to build on each others ideas v) Tolerates conflicting ideas	i) Difficult to wait one's turn ii) Loss of spontaneity iii) Embarrassing if cannot think of any ideas - puts participants under pressure iv) Reluctance to pass v) Not as easy to build on others ideas
Notebook Style: Each team member writes on a pad or sheet of paper their own ideas, later to be collated by the team leader.	
i) Ensures anonymity if sensitive topics are to be discussed ii) Can be used with very large groups iii) Not necessary to speak iv) Provides time to think v) Focussed and uninterrupted thought vi) Avoids competition and status differences vii) Encourages each member to search for ideas viii) Avoids conformity pressures	i) Not possible to build on ideas of others ii) Some ideas may not be legible, understandable iii) Difficult to clarify ideas iv) Not possible to hear or see ideas

Exercise: Brain storm
"Why do improvement teams sometimes fail?"

Benchmarking and Performance Measurement

Introduction:

All organisations need to establish and quantify the key factors with which to monitor their quality performance. It is not enough to believe that the organisation's quality performance has always been satisfactory. Agreement needs to be reached as to what the key factors are by which to judge the organisation's quality performance. What is the organisation's current performance against these factors and how can the current quality performance be improved? If measures of Quality Performance are not established and monitored, then adverse and possibly catastrophic trends may not be identified with possible dire consequences for the organisation concerned. Juran talks about breakthrough and control to new levels of quality performance; organisations that can achieve this objective will always be successful because they will continually be making never-ending improvements.

Quality Performance measures need to be established, not only at a corporate level but at all levels throughout the organisation, even down to an individual unit or person. Quality Performance measurement is one of the most important ways of improving the quality performance of organisations. If the current quality performance is not known then improvements can only be subjective and not quantifiable.

Having established and measured an organisation's or department's performance indicators these values need to be compared (benchmarked) against recognised leaders or pacesetters. This is to determine if the current performance is of the correct standard (*World Class*).

Guidelines for Benchmarking:

Firstly, there is a need to agree the necessity for establishing quality performance measures with senior management. The necessity of establishing quality performance measurement then needs to be communicated to all levels throughout the organisation to gain commitment and understanding for the need to continually make improvements in quality performance. Departmental Purpose Analysis and Customer/Supplier investigations can be used to help convince personnel of the need for quality performance measurement. The TQM team needs to agree the performance measurement.

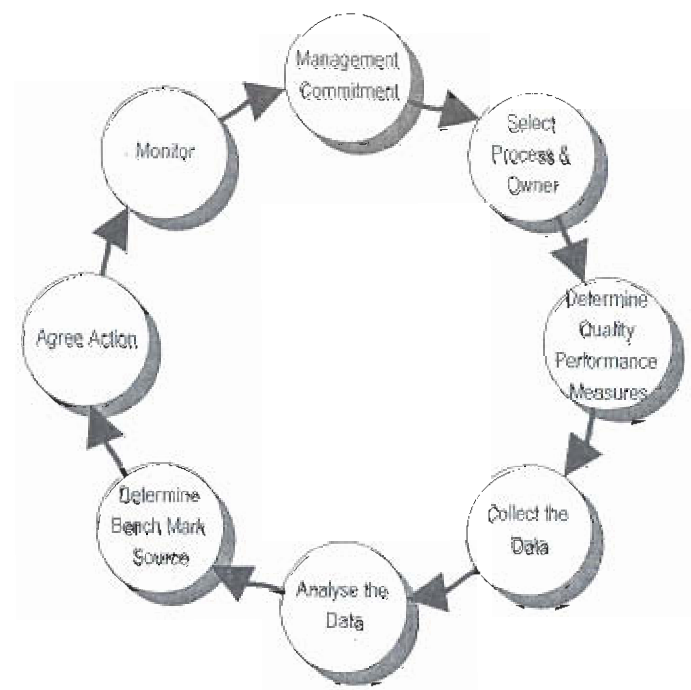


Figure 74 A Benchmarking Sequence

Next, the actual processes that need to be monitored have to be established and agreed. Having established the process to be monitored then the factors critical to success need to be determined.

These critical success factors or quality performance measurements should be:

i) Suitable for the particular process, department or organisation evaluated.
ii) Consistent, so that there is no doubt about the method of calculation of the performance measure and so that the data for performance measurement can be accurately and reliably obtained.

iii) Clear and owned by a particular group or cell so that responsibility or ownership for achieving the performance criteria understood.
iv) Easily and regularly calculated, usually numbering between 3 and 7 performance measures.
v) Clearly defined start and finish.
vi) Defined direction not a solution.
vii) Achievable and within the group's capability.
viii) Possibly determined from the customer/supplier relationship and the department's purpose analysis.

The performance measurement categories can be broken down into two main categories, quantifiable "Hard Standards" and non-quantifiable (subjective) "Soft Standards". These categories can be broken down still further in terms of:

- customer satisfaction; product and service performance, reliability, complaints and claims
- process efficiency; scrap, rejects, wasted time, change, rework, labour and process utilisation
- environmental losses; pollution, unsatisfactory performance, disposal and decommissioning, waste of resources both human and energy.

"Hard Standards" are measurable such that an agreed performance target can be set. Examples of such standards could be:

Cost	a.	Costs per item, transactions per employee
Quality	b.	Number of rejects, failure rates, complaints
Service	c.	Average response and down time, lead time, delivery time

"Soft Standards", although not always directly measurable, are equally important as hard standards. These soft standards can make the difference between an existing customer returning, obtaining a new customer or placating a dissatisfied customer.

An example of soft standards could be the way in which the service engineer deals with the customer. This can often make the difference between the customer renewing their service contract and the customer advising possible new customers of the excellent service the customer has received. Or alternatively, the poor service the customer has received which may result in the customer not returning and advising potential future customers of the unsatisfactory service.

Soft Standards can include:

Personnel style	a.	Friendly, helpful, positive approach
Efficient Service	b.	Anticipate needs, be flexible, provide clear information, professionalism
Concern	c.	Manage problems - when troubles do occur understanding the customer's difficulties and help to resolve the problem.

Data collection: Having determined the quality performance standards that need to be monitored, the next stage is to agree how to quantify the current performance level and to start to collect the data on a regular basis. The data collected could include:

- customer satisfaction; which could be quantified by surveys of both existing and potential customers (see example of the customer satisfaction survey). Surveys of competing products and services. Analysis of service and product performance in terms of reliability, numbers and types of complaints and claims.
- process efficiency; by monitoring scrap, rejects and rework levels. Analysis of processes to determine wasted time, labour and process utilisation, examination of the number of changes. (See Cost of Quality).
- environmental losses; waste of resources, human and energy, could be quantified and monitored by employee surveys, interviews (e.g. exit or leaving interviews) and energy audits.

Analysis: With the current performance level determined, the TQM team or departmental personnel need to agree new targets. These new targets can either be agreed with the customer (internal or external), or alternatively, the targets may be based on other recognised leaders or pacesetters - the organisations that are seen as being World Class or best in class. This information can be obtained from; surveys (customer and competition), technical journals, review of advertisements etc.

Obtaining the Benchmark Source: There are a number of possible benchmark sources. *Internal Benchmarking;* against a similar national or international division. This is the easiest, as access to the required information should be relatively straightforward. *Industrial Benchmarking;* against the competition. This is obviously more difficult as competitors are unlikely to be keen on releasing commercially sensitive information. However, Trade Associations can be helpful but information scientists can provide useful information. Alternatively, recruiting staff from the competition could provide a more effective route. There are also best practice clubs now available, which share approaches and information.

Action Plan & Monitoring: Having obtained what is seen as being a suitable target then work can commence towards establishing an action plan for improving the performance to meet the new performance criteria.

Departmental Purpose Analysis

Introduction

Departmental purpose analysis is used to clearly understand the relationship between your department, the supply departments and user/customer departments. This analysis can extend all the way down to individuals.

The analysis will ensure:

- The department's objectives coincide with the company's objectives and plans
- The inter-relationship between internal customers and suppliers is clearly understood
- The levels of performance are understood, agreed and achieved.

A good example of this is the secretary/manager relationship. When the manager dictates a letter to the secretary, the secretary becomes the customer. The manager (the supplier), needs to supply all the information and provide all necessary resource for the secretary to successfully accomplish the task.

Subsequently, the secretary completes and returns the letter to the manager. Here the manager becomes the customer. The secretary (the supplier), needs to supply a finished product, which completely satisfies the manager's requirements and needs. The manager's requirements could include: time taken to complete the letter, letter layout, grammar and spelling. (See **Figure 75**).

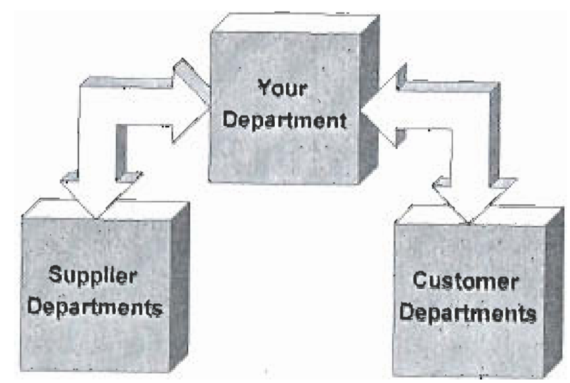


Figure 75 Internal Customers

This supplier/customer process can be extended to include everyone within the organisation from the person receiving the customer's order through to the person delivering the product or service to a satisfied customer. In this way each person in the process can be seen as an important link in a chain of events. Any breakdown or quality failure at any stage or link in the sequence will have an immediate and catastrophic effect on the process as a whole and the delivered product or service. The next person in the process is a customer of the previous person's work. As an example of this approach, possibly instead of the inspector inspecting each stage in the process, the next person in the process could be seen as the customer. The supplier or deliverer will need to completely check their own work to ensure customer satisfaction. The customer or receiver will check the incoming work as well as their own outgoing work.

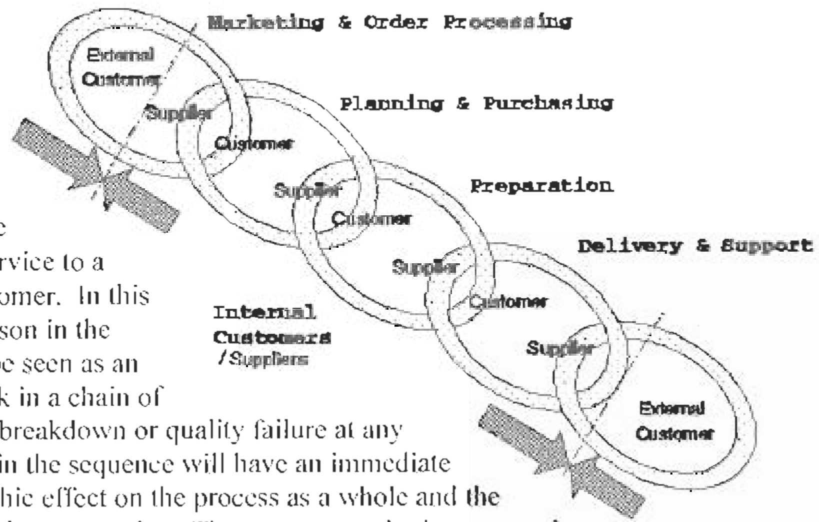


Figure 76 Customer/Supplier Chain

Figure 76 shows such a process in action. Initially from the external customer's requirements to Marketing (and hopefully a customer's order). Having reviewed and accepted the order, the next step in the chain is for Order Processing (an internal supplier) needs to supply Planning & Purchasing (an internal customer) with sufficient information. This information should be adequate (e.g. complete, accurate, reliable etc.) for Planning & Purchasing to satisfactorily complete their task in the chain. Next Purchasing (the internal supplier) to supply Preparation (the internal customer) with all the materials and facilities Preparation requires. This chain is then continued until delivery and handover to the satisfied external customer.

Departmental Purpose Analysis is an opportunity to evaluate the contribution of all departments to the overall quality performance of the organisation. For example the people in the indirect areas 'indirects' (e.g. Planning and Purchasing, Administration, Training - areas that do not directly add value) may feel that they cannot contribute to the overall quality performance of the organisation. The 'indirects' may feel that this contribution can only come from the people in the direct areas 'directs' (e.g.

manufacturing, test) - areas or functions that add value. The proportion of the salary bill is often split 60% indirect/40% direct. In monetary terms for a salary bill of £1M this means £600K is spent on indirects and £400K on directs - are the directs getting £600K worth of support from the indirects? If not why not? If not what are the indirects doing about providing value for money - Departmental Purpose Analysis? Departmental Purpose Analysis gives the opportunity to show how these indirect areas can contribute.

To assist in investigating the customer/supplier relationship the technique **Departmental Purpose Analysis** can be employed. Establishing:

- Are we doing the RIGHT tasks?
- Are we doing tasks RIGHT?
- Can we do the RIGHT tasks better?

Initially, the overall approach is to establish that the department is performing the right tasks - the tasks its customers needs (what are the department's customers needs?).

Secondly, to establish that the department is completing the tasks correctly - fulfilling the needs of the customer (what are the characteristics that the customer needs fulfilling?).

Finally, to establish if it is possible to do the tasks even better - is it possible to improve the performance of the department (what are the quality performance measures for the department, what are the important factors to achieve customer satisfaction?).

Guidelines for Departmental Purpose Analysis

Definitions

Internal Customer: People or departments inside the organisation who receive the output (product or services) from the supplier (your) department.
External Customer: People or departments outside the organisation who receive the output (product or services) from the supplier (your) department.
Customer needs: The actual products or services the customer is prepared to pay for (right tasks).
Customer Characteristics: An interpretation of products or services that the customer needs into specific individual attributes of the product or service. (Customer specification)
Quality Performance Level: The performance that the customer requires from the product or service provided.

Note: Although reference ***is made throughout*** *this section to the department, this analysis can equally be* ***performed by an individual****.*

Table 29 Right Tasks

Are we doing the right tasks?	
List the Suppliers (Inputs).	List the Customers (Outputs).
Detail what is passed to the department (inputs). The information, material, products and services provided.	Detail what is passed onto the customers (the outputs). The information, material, products and services provided.
Detail all the departmental tasks - the purpose of the department.	
Confirmed by Suppliers:	Confirmed by Customer:
Name:	Name:
Date:	Date:
Title:	Title:
Department:	Company:

Are we doing the right tasks?

Using **Table 29**:

a. Detail the names of all the departments customers and suppliers. It may help to detail all the various tasks performed by the department.

b. Detail the output from the department. What are the products produced, what is the information or data supplied, what are the services provided?

c. Establish the purpose of the department. What does the department exist for, what are the aims and objectives of the department?

d. What are the tasks of the department? What work is performed to bring about the output from the department?

The tasks listed ***do not need to be detailed specific tasks but an overview*** *of the major activities within the department.*

e. Compare the departmental purpose with the department tasks:

- are they compatible?
- are there any inconsistencies?
- are all the departmental purposes fully addressed?
- are there any customer requirements that have been overlooked?
- are there any non-value added activities which can be eliminated? (See Non-Value Added Activities)

f. Identify which of the tasks are of highest priority.

g. Having established the above information, it is essential that the customer has the opportunity to confirm its accuracy and emphasis and to formally accept the agreed level of service.

To assist in detailing the suppliers and customers the diagram (**Figure** 77) can be drawn to show the inputs to the department (process) and the outputs from the department (process).

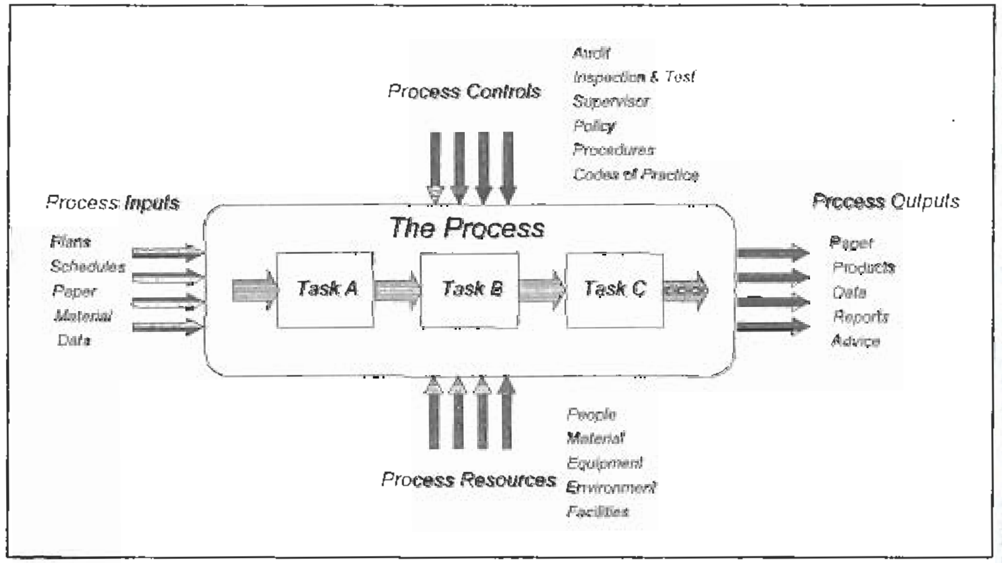


Figure 77 Process input/output diagram

Are we doing the tasks right?

Having established that only the right tasks are being performed then it is necessary to compare the actual practice with the customer specification. The activities, tasks and sequence that follows coincides with what the customer needs. **Table 30** opposite can be used in conjunction with this procedure.

Table 30 Tasks Right

Customer:	
Need	Specification or Characteristic

h. For each internal or external customer identified decide; what are the customer needs, what does the customer require in terms of a product or service?

Once these needs have been listed, how can these needs be characterised, what is the specification that the customer requires? Break down each need into specific characteristics or customer specifications.

i. Examine what is currently supplied to the customer, with what the customer needs. Are the current priorities the same as the customer priorities? For example, for the Purchasing Department the priority may be the placing of a £1M contract, whereas the Purchasing Department's customer may see the delivery of a £2.00 bolt, which is stopping production, the priority.

j. Confirm the tasks are being performed correctly and in the proper sequence, (is there an agreed method, is the method documented?). Internal quality audits may help.

k. Review any problems or complaints that the customer has identified and which are not being corrected or addressed.

Again the input/output diagram shown **Figure 77** can be used by adding to the diagram the controls and the resources necessary for the department (process) to successfully complete all the right tasks.

The output from this departmental purpose analysis stage can be to establish some Service Level Agreements (SLA) or an informal contract between the supplier and customer departments. These SLA can define a specification which the supplier commits to meet. Establishing these SLA can be a useful vehicle for debate between the internal customer and internal supplier. SLA give the opportunity for the internal customer to express clearly the level of performance expected from the internal supplier, rather than just saying things must improve, e.g minimum response time 1 hour, maximum down time 5 hours. They actually place some measurable target or performance figures against which the supplier can be judged, not only for current and future reference but against external performance, i.e. the performance of similar external bodies that do similar work (Benchmarking). How does the supplier's performance compare with the performance of an outside agency or contractor? How does the supplier's performance compare with departments doing similar activities in other organisations? Would it be cheaper and would a better service be provided by buying in the service?

Can we do the right tasks better?

Having established that the customer needs are completely understood and that the right tasks are being performed correctly, then improvements need to be made to the task efficiency. This establishes what factors need to be measured, what the current level of quality performance is and what quality performance level the customer demands and deserves.

l. Determine what factors need to be measured, e.g. average time to complete an activity, average cost of each task, average service level provided. In real terms, for the Purchasing Department, this could be average time to place an order, average time to receive goods, costs per transaction, cost per order placed. **Table 31** shows how **Table 30** has been extended to include the Quality Performance Levels required by the customer and the actual Performance Level achieved. (See section Performance Measurement)

Table 31 Tasks Better

Customer:			
Need	Specification or Characteristic	**Performance Level Required**	**Performance Level Achieved**

m. Having established appropriate performance criteria, the current quality performance level needs to be determined. Taking the Purchasing Department as an example again, this could be average time to place an order - six weeks, average time to receive goods - six months, costs per transaction or cost to place an order - £50 perorder. On this basis is the customer getting a satisfactory service from the Purchasing Department - would it be considered world class, is it possible to do better?

Note: Although this is for the Purchasing Department it could just as equally be applied to the Marketing, Administration or other departments.

n. These current performance levels can now be compared with what the customer requires or deserves. What performance does our customer require? Can the requirements be met, can the performance be improved still further?

o. Can tasks be combined to make the job more efficient? (See section Process Flow Charting)

Root Cause Analysis

Root cause analysis is a relatively new methodology that is currently evolving and has yet to be formalised, i.e. there are currently no established standards for it. Like other subjects covered by this book, it is not magic; "there is no silver bullet". It is the application in a different way of a series of well known, commonsense techniques. It is these techniques which when used in a different combination can produce a systematic, quantified and documented approach to the identification, understanding and resolution of underlying causes of under achieved quality in organisations. Below is a definition which encapsulates the main points of this technique:

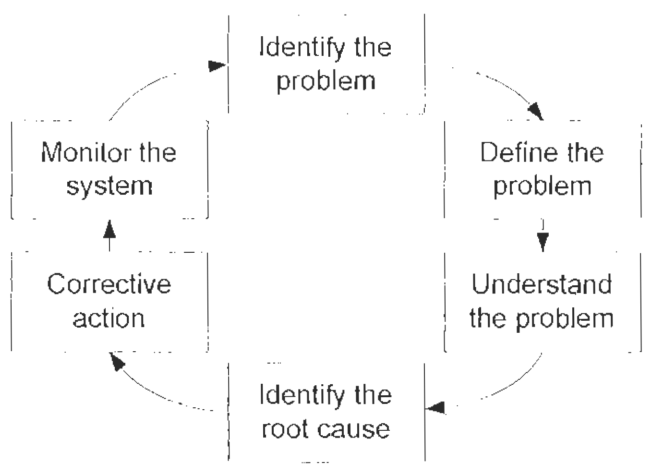


Figure 78 Root cause analysis cycle

'An objective, thorough and disciplined methodology employed to determine the most probable underlying causes of problems and undesired events within an organisation, with the aim of formulating and agreeing corrective actions to at least mitigate, if not eliminate, those causes and so produce significant long term performance improvements.'

Carrying out a root cause analysis

Root cause analysis is not just a problem solving technique. It is an overall approach to the identification, understanding and resolution of underlying causes of under achieved quality in complex organisations.

Root cause analysis is a four-phase process:

- Phase I: Problem identification
- Phase II: Problem description
- Phase III: Cause analysis
- Phase IV: Solution development

Phases I to III need to be carried out by one person or team whilst Phase IV should usually be carried out by a second team. Unlike many quality or TQM initiatives, root cause analysis is often better undertaken, particularly in Phase IV, by the people carrying out the processes following training in the techniques to be used. It is not the preserve of the Quality Manager alone. Like others however, for it to succeed, there must be an acknowledgement by the top management of the organisation that there are problems that need to be addressed and a commitment to providing the access and resources necessary to do so.

Phase I: Problem identification

In order to identify problems, the person or team carrying out the root cause analysis process must have full access to all areas of the organisation, with the freedom to communicate, where necessary, with others outside the organisation. It is also essential that there is complete visibility, i.e. they must be able to see all aspects of the situation with personal bias totally removed. In any process within an organisation, specialists associated with it are inevitably going to view it from their point of view; the manager, production engineer, store manager etc. All these subjective views need to be put aside and the overview clearly seen.

Strategies for fact gathering will include looking at customer complaints, interrogating the accounts including credit records, interviews, workshops etc. The objective is to gather as much information as possible on problems or quality deficiencies. Selection is carried out in the next phase.

Phase II: Problem description

The second phase, carried out by the same person or people conducting the first, is to fully describe the information collected. The criteria for including problems in the analysis need to be fully understood. These will include the use of flowcharts, critical incidents, spider charts, purpose and application matrices and problem understanding checklists.

Phase III: Cause analysis

Once fully described the information needs to be analysed into types. Strategies for analysis are the use of various tools, either separately or in work groups, to establish internal causes, external causes and their separate or combined effects. Root causes also need to be separated from other causes.

Cause analysis tools that may be used are histograms, pareto charts, scatter charts, relation's diagrams and affinity diagrams. Some but not all of these would be used according to their suitability in particular circumstances. Following this the cause and effect stage has been reached and the effects and therefore potential root causes, can be identified. Tools for this are cause and effect charts, matrix diagrams and the "five whys" or the "why, why" chart.

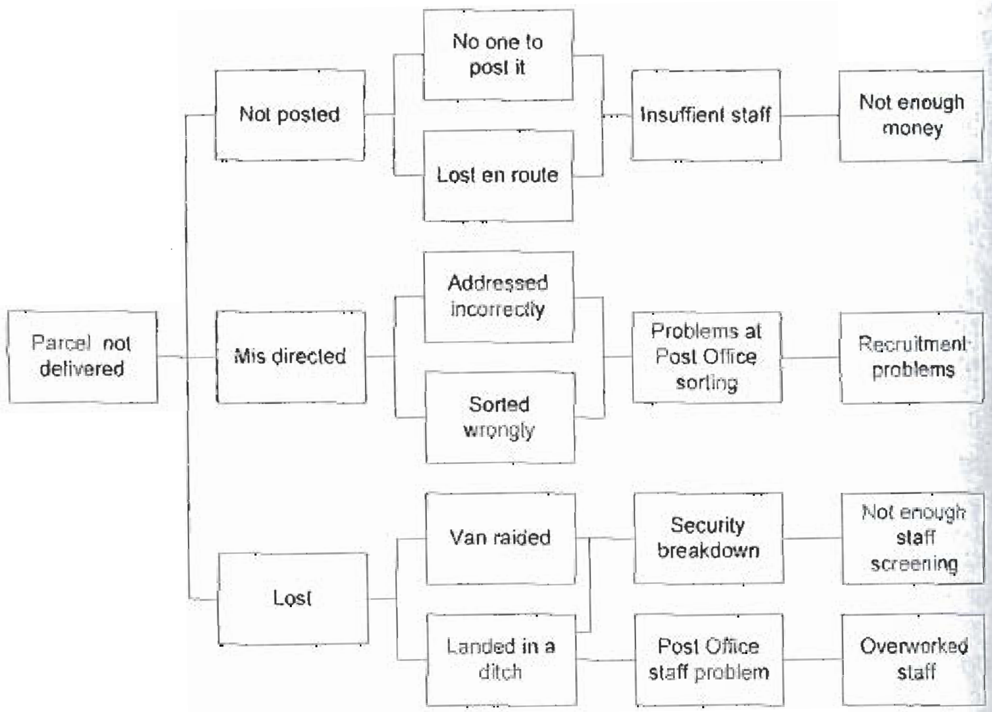


Figure 79 Why, why chart

Once identified problems need to be fully understood and ranked using techniques similar to risk analysis, i.e.

a. Identify the causes.
b. Weight the causes according to occurrence (O) 1 to 4 (where 4 occurs most often).
c. Weight the causes according to severity (S) of consequences 1 to 4 (where 4 produces the most severe consequences).
d. Calculate O x S = index for each cause.
e. List causes according to their indices to give a prioritised action list.

Severity →

#	**1**	**2**	**3**	**4**
1	1	2	3	4
2	2	4	6	8
3	3	6	9	12
4	4	8	12	16

Frequency of Occurrence →

The causes are then addressed in order.

Phase IV: Solution development

The last phase, solution development, is often done by either a different person or team. Having fully identified the problem, the solution may be developed by those who know more about the specific processes involved. Potential solutions need to be developed and presented to the decision makers and the comparative benefits and cost effectiveness of all prevention options shown.

In some circumstances the organisation may not be in control of the root cause. If this is the case then ways may need to be found to either circumvent the cause or to mitigate its effects. This will entirely depend upon the circumstances.

Another point to consider is the difference between interim action and corrective action. Solution of the root cause should result from corrective action that fully addresses the problem. Interim actions may however provide a "quick fix" which needs to be followed up by the former to ensure that the problem does not reoccur.

The last function is to ensure that controls are in place to hold the gains made. They should assure the solution prevents recurrence of the root cause.

Summary

There are a number of proprietary software and training packages available for carrying out root cause analysis, primarily from the United States where the imperative has been health and safety critical organisations, e.g. health and the petrochemical industry. The technique has yet to be applied widely in the UK.

In conclusion, root cause analysis should be the objective and systematic process of gathering and ordering all relevant data about counter quality within an organisation. It should identify the internal causes that have generated or allowed the problem and produce an analysis for decision makers that gives the comparative benefits and cost effectiveness of all prevention options. To accomplish this the analysis methodology must provide visibility of all causes and understanding of the nature of the causal systems they form, together with a way to measure and compare the causal systems and should have a visibility of all internal opportunities for the organisation to control the systems.

SECTION 5 - OPTIMISATION TECHNIQUES