ACCIDENT AND INCIDENT ROOT CAUSE ANALYSIS

> "*On the occasion of every accident that befalls you,*
> *remember to turn to yourself and inquire what power*
> *you have to turn it to use.*"
>
> - Epictetus d. 135 AD

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COURSE AIMS & OBJECTIVES

Aims:

At the end of this course candidates should be able to:

- Investigate events which led, or might have led to an injury;
- Use techniques to identify the root causes of accidents and incidents
- Prepare formal reports and make logical and cost effective proposals to prevent a repetition.

Objectives:

Candidates will have a knowledge and understanding of:

Accident Prevention and Investigation

The principles of accident prevention and the root **causes** of accidents.

The procedures for investigating accidents to identify the root cause.

Different root cause analysis techniques.

Course Content

Recap Basic Accident Causation and Investigation
Human Factors in accident causation
      Human failure
           Active and Latent failures
           Errors and violations
      Job, individual and organisational factors affecting human reliability.
Advanced techniques for gathering information
Principles of sequence diagrams
      Event and causal factor analysis
      Multilinear Events Sequencing,
      etc.
Critical event identification
      Fault tree, barrier and change analysis
Advanced techniques for root cause identification
      "Tree techniques"
           MORT, etc.
      Checklist techniques
           TOR, etc.
Syndicates exercises to explore the above throughout the day.
Course Review.

ACCIDENTS AND INCIDENTS

Health and safety management is about the prevention of accidents and ill health, but what is an accident?
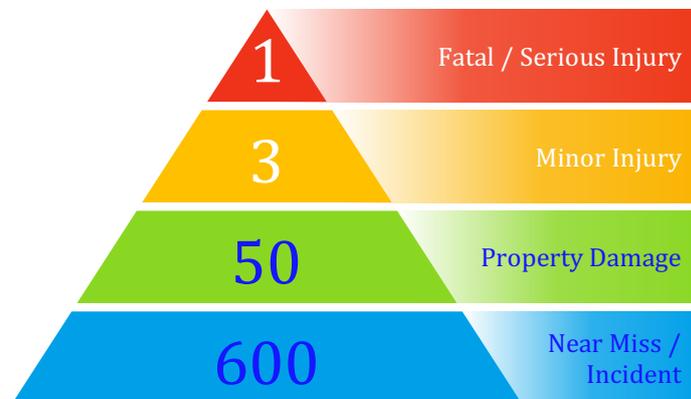
Accident

-       **The most common definition is:-**
        An unplanned, undesired occurrence which results in loss of any kind.

Incidents

The above definition of an accident does not include those events that **could** have caused loss. Such events are often called incidents, near misses, close calls or near hits. Whatever term we use it is purely chance that prevents an incident from becoming an accident. The severity of injuries or damage resulting from an accident is also often a matter of chance.

There have been many studies carried out to try to establish a relationship between accidents and incidents. These are illustrated by accident triangles or accident icebergs.

1	Fatal / Serious Injury
3	Minor Injury
50	Property Damage
600	Near Miss / Incident

Frank Bird

BASIC ACCIDENT OR INCIDENT CAUSATION.

There are always valuable lessons to be learned by investigating accidents, but our legislation requires employers to be pro-active – to identify hazards and to ensure they are adequately controlled. Any hazard not adequately controlled is "an accident waiting to happen".

Hazard - Something with the potential to cause harm.

Examples of hazards:-

Physical:	Moving parts of machinery, electricity, heat, noise, gravity
Chemical:	Carbon monoxide, sulphuric acid, asbestos,
Biological:	HIV virus, legionella, Hepatitis virus
Psychological:	Stress, shock, anxiety

Uncontrolled or poorly controlled hazards create unsafe acts and/or unsafe conditions and are almost always the result of underlying or organisational failures

Unsafe Conditions such as trailing cables, oil spills on floors, missing guards, unsecured ladders etc. are usually easy to spot during an inspection.

Unsafe Acts such as carrying passengers on a fork lift truck, grinding without goggles or climbing storage racks are more difficult to find during occasional inspections.

Many unsafe conditions are caused by unsafe acts therefore it is important to try to trace each unsafe condition back to its source.

Unsafe acts and unsafe conditions are almost always the result of **underlying failures**.

e.g. Lack of proper information or training, unsafe systems of work, poorly maintained or unsuitable equipment, poor planning, unclear responsibilities, poor supervision.

And these underlying failures are the symptoms of failure of management control which is the root cause of the majority of accidents.

Root Cause

There are many definitions but a most useful one is that used by Paradies and Busch (1988), that is:

The most basic cause that can be reasonably identified and that management has control to fix

Domino Theory

The Domino Theory of accident causation dates back to Heinrich in the 1930's. The theory has been developed over time by various writers and there are a few versions but the most widely accepted version is shown here.

A   B   C   D   E
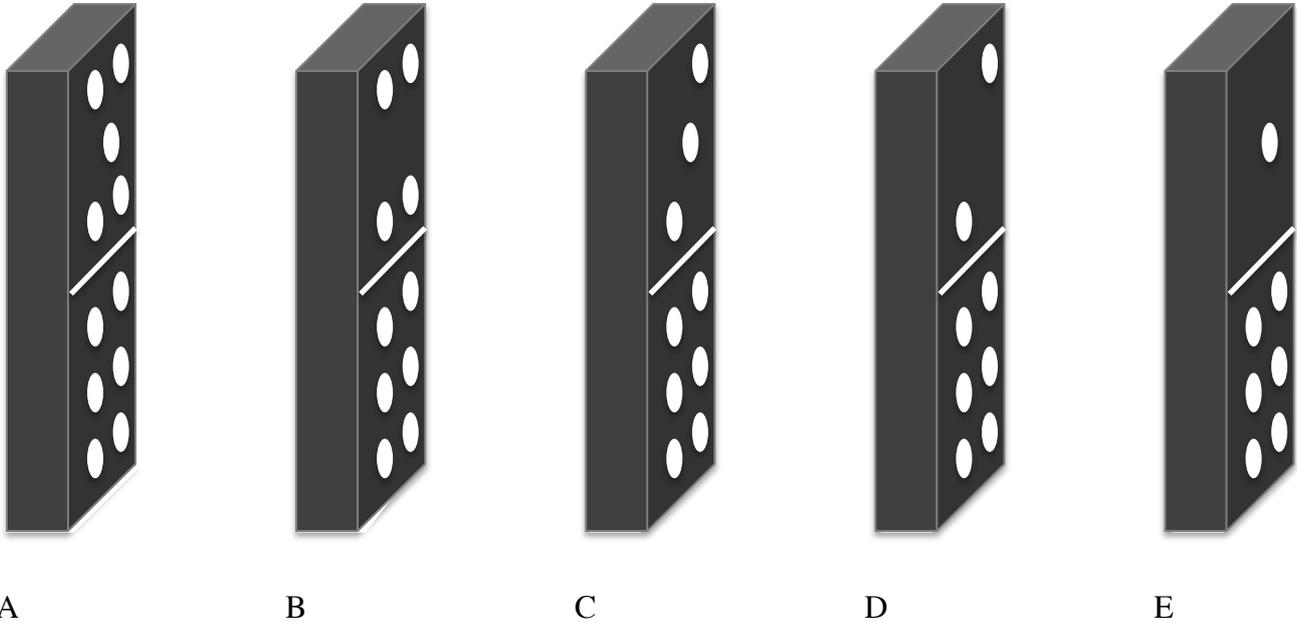
A = Lack of Management Control
B = Underlying Causes
C = Unsafe Conditions and/or Acts
D = Accidents
E = Injury, damage or other loss

The Injury domino is at the end of a line of dominoes and is the last to fall. The principle behind the theory is that the further back up the line of dominoes you concentrate your attention, the better the results. If you only react to accidents you will not deal with the unsafe conditions which cause them, by looking carefully at management control you can eliminate or reduce the underlying reasons that lead to unsafe conditions and acts.

ACCIDENT PREVENTION

Accident investigation is therefore considered to be a reactive approach, it is unlikely to get to the root cause unless it is carried out very thoroughly. A proactive approach is to pay proper attention to management control by means of:

• setting clear policies, plans, aims and objectives
• clearly defined responsibilities
• well thought out procedures
• competent staff
• standards of performance
• measurement of performance.

The aim is to eliminate or reduce the opportunities for hazards to exist.

It can be seen that these are the fundamental principles of managing anything, not just health and safety. The principles of accident prevention are therefore a matter of being in control of what goes on and directing activities toward the desired outcome whilst minimising the risk of undesired outcomes - it is called MANAGING.

ACCIDENT INVESTIGATION

> *"I keep six honest serving men.*
> *They taught me all I knew.*
> *Their names are What and Why and When*
> *and How and Where and Who."*
>
> - Rudyard Kipling

There are a number of good reasons for investigating accidents

- To identify and eliminate the causes

- There is a statutory duty to report certain injuries, the report must include an account of the accident. (RIDDOR)

- To defend civil claims for compensation

- Employees Liability insurers require it

- To demonstrate concern about people's safety.

It is unwise to depend only upon accident investigations as a means of preventing accidents, nevertheless a lot can be learned from the thorough investigation of accidents. Any accident, or incident, is clear evidence of lack of control i.e. something has happened that should not have! Too often accident investigations fail to identify root causes because they:-

- only identify the cause of the injury, not the cause of the accident

- focus on the people or equipment that were at fault, ignoring the organisational controls that should have prevented them from being at fault

- look for a single cause when there may be several direct causes each of which resulted from some failure in the system of managing.

Multi Cause Theory

Accidents are often the result of the chance convergence of several indirect causes, each of which may result from several factors which need to be addressed.

Example

Late for an appointment, Mr Smith slips on a patch of oil. The accident report from would typically be completed as follows:

"Oil cleaned up with granules, Mr Smith should take more care in future."

A more thorough investigation might identify the source of the oil spillage as being a poorly maintained fork lift truck, subsequent inquiries might identify precisely what is wrong with the

maintenance procedures.

If Mr Smith was not taking proper care, why not? How can we ensure that he does so in future?

Why was the oil spillage not dealt with earlier, who is responsible for the area what are the procedures and standards, are they adequate? etc. etc.

The time and trouble taken to investigate an accident will depend upon the seriousness of the actual or potential damage or injury. However, every accident and near missshould be investigated and recorded.

GUIDELINES FOR INVESTIGATING ACCIDENTS

1. Immediately following the accident and dealing with any injured party, record as much information as possible. In some cases, it is helpful to take photographs or make sketches. Measure and record dimensions that may be relevant (e.g. distance from guard, weight of load, etc.)

2. Establish the facts about the accident and the sequence of events leading up to it by interviewing witnesses. Statements may be taken on a voluntary basis. Employees may wish to consult their Trade Union representative before giving a statement.

3. Examine contradictory evidence for reliability and relevance.

4. Try to arrive at conclusions about the likely cause or causes of the accident and the circumstances that contributed to the situation. Consider the:-

    - Planned system of work, procedures, etc. relating to
        o Any materials and substances involved
        o The environment where the work took place (lighting, noise etc)
        o The equipment, tools, etc. Arrange for a specialist inspection if necessary.
        o The injured person and any other individuals involved - age, training, experience, supervision, etc.

    If any of the above factors were defective or below standard in some way, try to establish why this situation existed.

5. Take immediate action where possible to prevent further accidents.

6. Complete an accident report in accordance with Company procedure for reporting accidents.

RECOMMENDING EFFECTIVE CONTROL MEASURES

An understanding of the principles of prevention and protection will help in the evaluation of the effectiveness of existing measures at the investigation stage, and will also assist in recommending further control measures required to reduce risk.

Any existing risk assessment should be reviewed after an accident to check that the control measures, were adequate.

As stated in regulation 3 of the MHSWR, risk assessment must be carried out by the employer in order to identify the measures to be taken to comply with the requirements of statutory provisions relevant to the organisation. The following now forms part of the MHSWR.

SCHEDULE 1 Regulation 4

GENERAL PRINCIPLES OF PREVENTION

(This Schedule specifies the general principles of prevention set out in Article 6(2) of Council Directive 89/391/EEC)[24]

(a) avoiding risks;

(b) evaluating the risks which cannot be avoided;

(c) combating the risks at source;

(d) adapting the work to the individual, especially as regards the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health;

(e) adapting to technical progress;

(f) replacing the dangerous by the non-dangerous or the less dangerous;

(g) developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment;

(h) giving collective protective measures priority over individual protective measures; and

(i) giving appropriate instructions to employees.

Almost every accident will involve an unsafe condition or conditions and some element of human error, such as unsafe acts or omissions. It is therefore essential to do as much as is reasonably practicable to prevent accidents and ill health by making safe the workplace, vehicles, plant, equipment, materials and procedures. This can be done by physical or mechanical means of hazard control (known as **safe place** controls) and by providing training, instruction and safe procedures (known as **safe person** controls). It is not good management (and will never be sufficient to avoid legal consequences) to do nothing about a hazard, leave it exposed and then simply put up a warning sign or tell people to be careful or just ask them to wear a hi-vis vest.

Safe place measures are physical or engineering measures intended to make safe the place of work and everything in it by using controls such as guards, local exhaust ventilation, level floors, good lighting and scaffolds.

Safe person measures are aimed at people, and attempt to raise perception of risk and increase skill. These include supervision, training, instruction, procedures and signs, and, as a last resort, personal protective equipment. This is a useful distinction for the assessor when considering risk control measures, as safe place controls are (generally) more effective than safe person controls in reducing risk. Also, it is almost always the case that for a particular hazard a mixture of controls will be needed in both categories to reduce risk as far as possible.

Safe Place Controls

One or (more usually) a number of safe place measures should be considered to control a hazard as a first step, before considering which safe person measures will be needed. (Most of the safe person measures will be necessary for all hazards.) The basic strategies for providing a physical or engineering approach to control hazards is often summed up as "ERIC" (where there are no specific legal requirements for particular methods of risk control such as COSHH).

> Eliminate the hazard.
> Reduce the risk of the hazard at source.
> Isolate the hazard by

Enclosing it, or
By keeping people from it
Control exposure to the hazard – time or quantity

In planning to control risks, the measures selected should be as near as possible to the top of the hierarchy of control. Those measures at the top of the hierarchy reduce risk more effectively than those at the bottom and so the assessor should consider control measures in these terms. This approach should be adopted even if all specific legislative requirements have been complied with, as legislation generally sets minimum standards. Note that a combination of more than one may be necessary in many cases.

Safe Person Controls

As well as providing "ERIC" safe place controls to prevent accidents or to protect people from hazards, there will always be a need to provide safe person controls, (These are often added to the acronym as ERIC "**S**aves **P**eople" which stands for "Safe systems of work" and "Personal Protective Equipment")

These measures are required to ensure that the physical controls remain effective, to raise awareness, and to increase protection of the individual. For example, even if a hazard has been eliminated, training and instructions will be necessary to ensure that a solvent-based adhesive is not purchased by someone in an organisation who is ignorant of the decision to use only a water-based alternative. Safe person controls include the following:

- written procedure
- permits to work
- training
- provision of information
- instructions
- supervision
- personal protective equipment.

This list is in no particular order, **although personal protective equipment is always considered a last resort.**

Syndicate Exercise

A manufacturing Company has a large number of factory buildings on a large site. Two painters employed by a Contractor working, more or less permanently at the factory on a long term contract basis were asked by the factory production foreman to clean and paint the steel valley gutter between two pitched roofs. The roofing material was corrugated asbestos cement. They were also asked to look along the roof for signs of damage as the roof was leaking in wet weather.

The painters obtained a ladder and climbed to roof level. They walked along the valley gutter and noticed that part of the ridge capping to one of the roofs had been displaced. One of the painters walked up the roof to have a closer look at the ridge, taking care to step on the roof bolts. The roof gave way under him and he fell to his death to the floor 40 feet below.
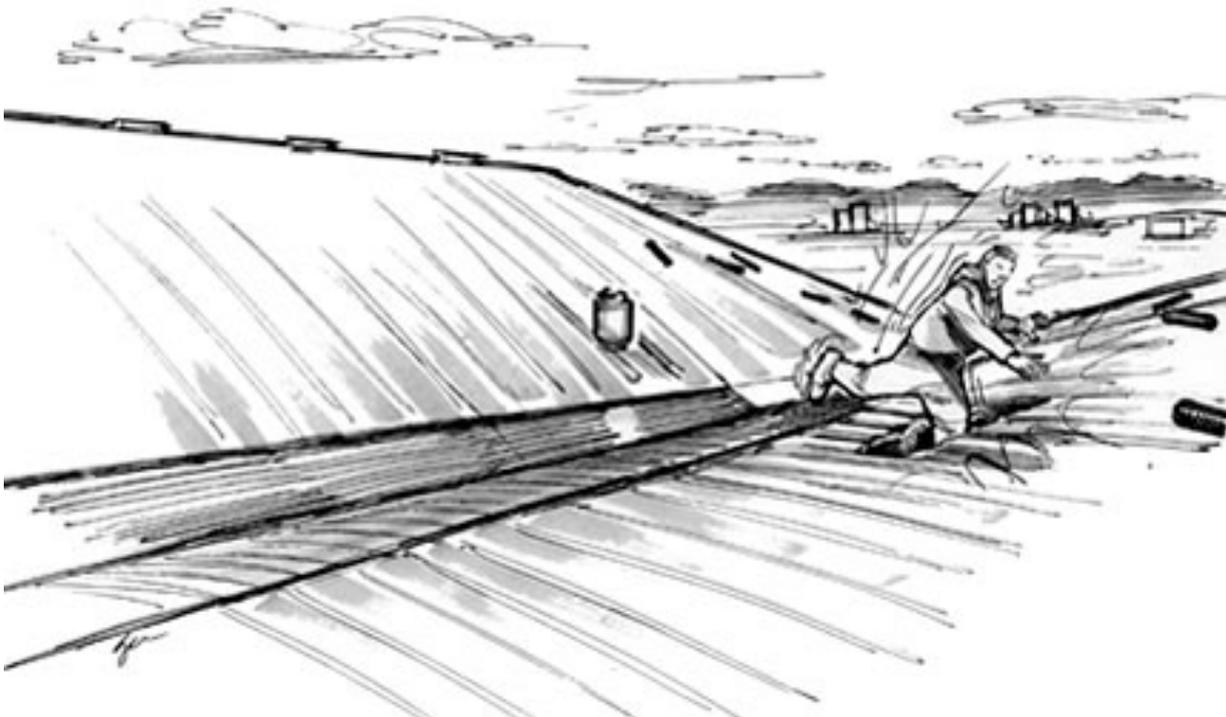
Consider this accident and answer the following.

(Note: It may help you to answer the questions below if you consider PEOPLE, PLANT, PLACE and PROCEDURES.)

1.   The direct causes (unsafe acts and conditions) of the accident.

2.   The underlying failures that led to the direct causes.

3.   The management system failures (root causes).

4.   The immediate actions that can be taken following the accident.

5.   The longer term actions that may be considered.

HUMAN FACTORS IN ACCIDENTS

> *"You must learn from the mistakes of others.*
> *You can't possibly live long enough to make them all yourself"*
> Samuel Levenson

WHAT ARE HUMAN FACTORS?

The traditional approach to health and safety was to concentrate on the 'hardware' aspects of work e.g. the plant, equipment, premises, substances etc. This approach is reflected in the legislation made under the Factories Act 1961 and earlier statutes.

It is now widely accepted that the majority of accidents at work are to some extent attributable to human as well as technical factors in the sense that actions (or inaction) of people initiated or contributed to the accidents.

HUMAN FAILURE

Any incorrect action by an individual is termed human failure and is often simply blamed on the individual who is 'guilty'. In fact the fallibility of individuals is almost entirely predictable.

Failures may be made by the injured person and/or others at the time of an accident – these are called **"Active Failures",** however many failures that cause accidents are made by decision makers such as managers, designers, etc. some time before an accident and are called **"Latent Failures".**

Failure to consider the human limitations of people to perceive, cope with, remember, process and act on information is expecting too much of people. Human failure can take the form of:-

Errors – where the person believes they are doing the right thing but is not.

Violations – where the person knows their actions are not in accordance with the rules or their training.

These can both be subdivided into further categories. (see next page)
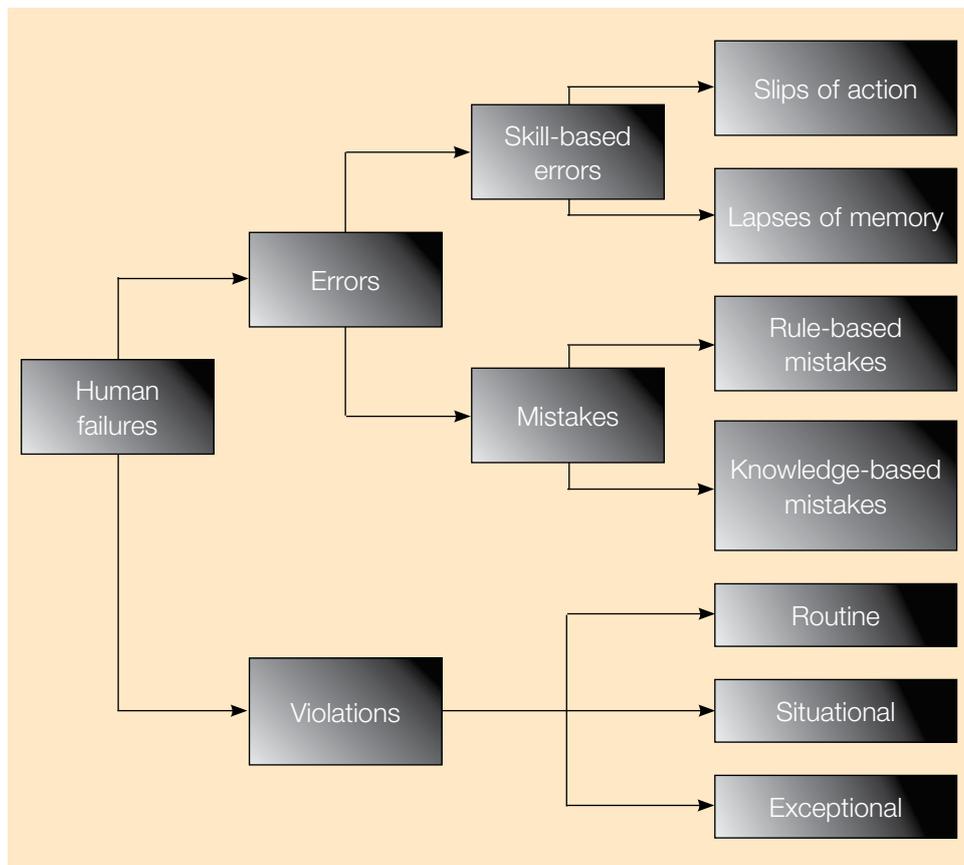
(HSG 48 – Reducing error and influencing behaviour. HSE 1999)

Dismissing human failure as careless or blameworthy behaviour is futile. Evidence of human error in accident investigation should lead to future preventive actions in the same way that evidence of mechanical failure would do. More pro-actively, the possibility and consequences of human error should form an important part of job safety analysis and risk assessment.

INFLUENCES ON BEHAVIOUR

How safely people behave at work is influenced by three factors
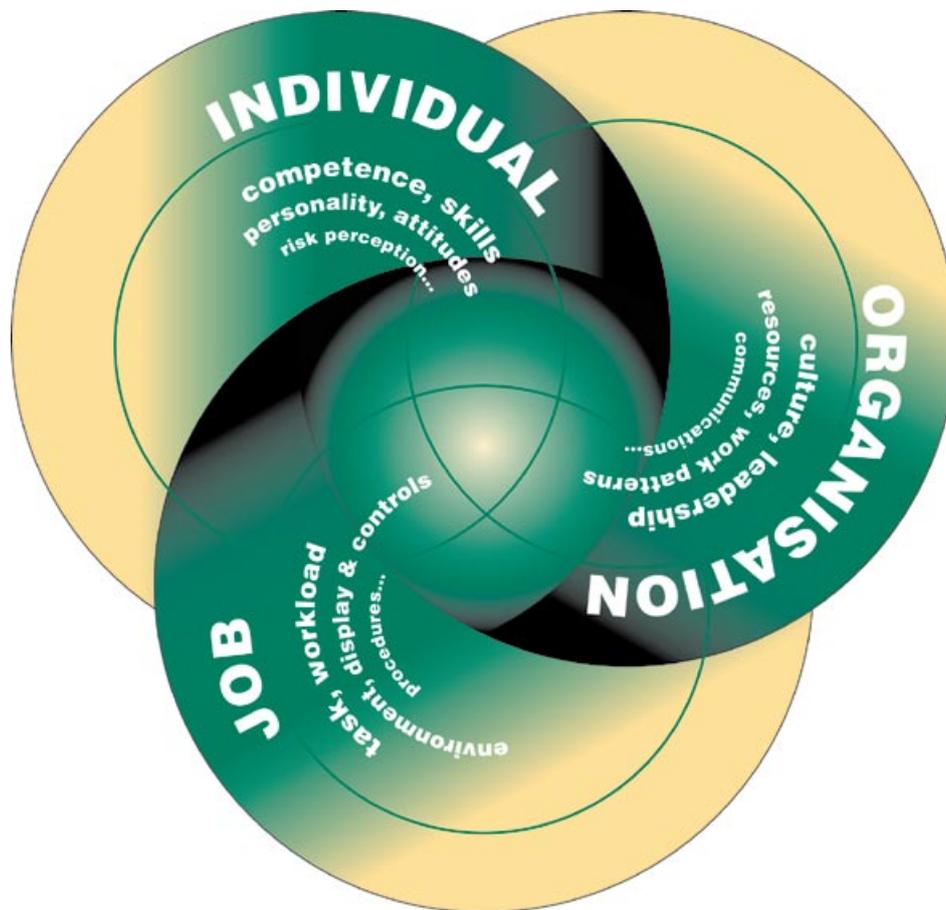
(HSG 48 – Reducing error and influencing behaviour HSE 1999)

THE ORGANISATION

Those who have worked in more than one organisation will be aware that attitudes and patterns of accepted or 'normal' behaviour vary enormously. The extend to which the organisation's climate support health and safety is known as 'a safety culture'. This is defined by HSE as:-

'the product of individual and group values, attitudes, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety programmes.''

Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficiency of preventive measures.'

Where poor safety cultures exist, individual or isolated attempts to improve health and safety are likely to meet with apathy or even resistance. In such organisations, strong commitment to health and safety is likely to be found only in the safety department.

THE JOB

Ergonomics

Work and the workplace are often planned only with the needs of the process or product in mind. Problems arise because people then have to try to adapt to unsuitable conditions. The ergonomic approach is to design equipment, plant, layout, tasks and other aspects of the work environment taking into account the mental and physical capabilities of the people who will be doing the job.

Major considerations include:

The Extent of Decision Making

The need to make decisions provides interest and stimulation up to a point. Beyond that point it becomes stressful. The likelihood and possible consequences of incorrect decisions must also be considered. This will depend on:-

•   the capabilities of the individuals
•   the complexity of job
•   the degree of automation
•   individual perceptions of risk
•   the level of encouragement to seek assistance
•   the availability of information and assistance.

Design of Work Equipment

The controls and information displays provided with work equipment should be designed not only for physical ease of use, but also to minimise the likelihood of errors being made. This should include:-

•   adequate and clear information about faults and emergencies
•   visible and understandable information displays
•   feedback and confirmation following operators actions
•   logical layout of controls
•   controls operating in a consistent and expected way.

Procedures and Instructions

Written procedures are often ignored or misinterpreted. Instructions must be:-

•   clear and unambiguous and understandable to the users
•   checked for clarity and workability by means of feedback
•   monitored for compliance by means of auditing.

The Working Environment

Unsuitable physical working conditions (heat/cold, lighting, noise etc.) can affect people's attitudes

and undermine any attempt to develop a safety culture. The physical stresses imposed by poor working conditions will also reduce people's ability to work effectively and think clearly. Poor working conditions can therefore have an indirect contribution to accidents in addition to the more obvious direct health risks. The physical environment of work must:-

- be maintained to identified standards
- be monitored

Work Patterns

Shiftwork and 'unsocial hours' working can affect the way in which people act at work. The natural rhymes of the human body may well result in individuals being more vulnerable at certain times of the day. What is more certain is that extended hours of work are likely to result in fatigue which is a contributory factor in many accidents. There are few statutory controls on the number of hours that may be worked, but this factor should be taken into account when assessing risk.

THE INDIVIDUAL

Individual employees at all levels will have different habits, attitudes, skills, personalities, knowledge, physical and mental capabilities, also some of these characteristics will change from time to time as people are influenced by all sorts of factors including:

- age and physical condition
- stress
- motivation, job satisfaction
- home life
- ambition, job security

Attitudes

The response of individuals in a given situation is termed their attitude. Attitudes are formed by many factors including inherited personality traits, anxieties, experiences, expectations and behaviour learned from others. Many of these factors are outside the control of an organisation once an individual has been recruited. The culture of the organisation and the relationships between individuals and their colleagues, their managers and the organisation itself have a profound influence upon attitudes. Attitudes can be changed for the better or worse.

Motivation

The force which stimulates an individual to do something is termed motivation. Rules are not motivation, the desire to comply with rules is a measure of motivation. Unfortunately there are often forces at work which tend to motivate people into unsafe action. The possibility of saving time coupled with a strong though ill founded belief that, "I will get away with it" provides ample motivation for people to drive through amber traffic lights. The need to maximise the motivation for safe action whilst reducing any temptation towards unsafe action is paramount in developing **safe person strategies.** Participation and involvement in safety improvement can provide motivation. Emphasis of the positive benefits of safe behaviour is often more influential than continuous reminders about injury and ill health.

Training

Training and competence will obviously affect peoples ability to work safely and avoid accidents.

Perception

People tend to have mistaken and unfounded perceptions of risk. These are based on an individual's own limited experience. This creates the view that "if I have survived this long I will continue to survive" or "I have always got away with it before". This feeling of invulnerability seems to be directly related to the extent to which the individual is in control. Many people therefore feel safer when driving a car than when flying in a aircraft - they feel in control Perceptions of risk are also rationalised when convenient, people find excuses to justify unsafe behaviour when it suits them. Wedging open fire doors on a warm day, not wearing seat belts on the grounds that 'I may become trapped in a burning vehicle or drive into a lake' are both examples of rationalisation of known unsafe behaviour. Raising people's perception of the risks created by unsafe behaviour forms an important part of safety training.

Mental and Physical Capabilities

The limitations of machines and equipment are well known and are generally taken to ensure that equipment is not used beyond its capability. One of the fundamental principles of ergonomics is that people also have limitations, both physical and mental. Care to avoid subjecting people to mental or physical demands that are outside their limitations is an important aspect of work design and management.

ADVANCED TECHNIQUES

These can be divided into techniques used to gather information and to determine the **sequence of events** or **critical factors** involved and techniques developed to analyse the **root causes**.

SEQUENCE OF EVENTS

Events and Causal (or Conditional) Factors Charting: A process that first identifies a sequence of events and aligns them with the conditions that caused them. These events and respective conditions are aligned in a time-line. Events and conditions that have evidence are shown in solid lines but evidence is not listed; all others are shown in dashed lines. After this representation of the problem is complete, an assessment is made by "walking" the chart and asking if the problem would be different if the events or conditions were changed. This leads to causal factors that would then be evaluated using a tree diagram (discussed below).

Before starting the sequencing diagram it is necessary to define the end of the incident sequence. It is also be necessary to define the start point of the incident, but this may not become apparent until the investigation is underway. Typically, the diagrams start at the end point and work backwards identifying the most immediate contributing events first.

Basic construction principles for sequence diagrams are as follows
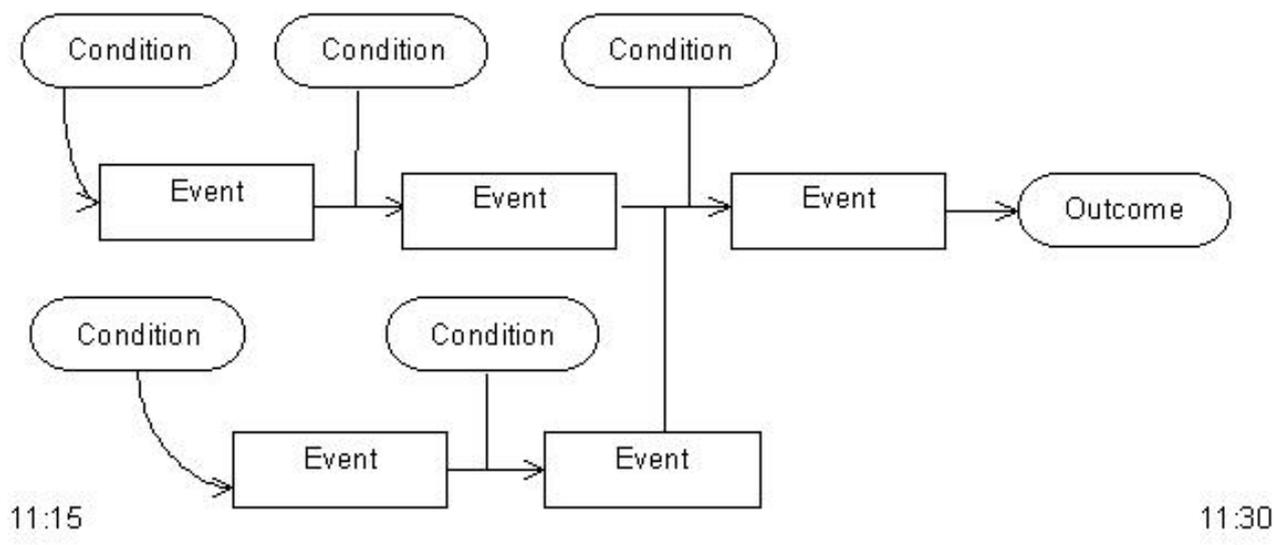
Chart Format

- All events are enclosed in rectangles, and conditions in ovals
- All events are connected by solid arrows
- All conditions are connected to other conditions and/or events by dotted   arrows
- Each event or condition should be based upon valid evidence or, if   presumptive, shown by dotted rectangles or ovals
- The primary sequence of events is depicted in a straight horizontal line   (bold arrows are suggested)
- Secondary event sequences are presented at different levels
- Relative time sequence is from left to right

Criteria for Events Description

- Events must describe an occurrence, not a condition
- Events must be described with one noun or verb
- Occurrence must be precisely described
- Events must describe one discrete action
- Events should be quantified when possible
- Events should range from beginning to end of the accident sequence
- Each event should be derived from the one preceding it

CRITICAL EVENTS

Change Analysis: A six-step process that describes the event or problem; then describes the same situation without the problem, compares the two situations and writes down all the differences; analyses the differences and identifies the consequences of the differences. The results of the change analysis is the cause of the change and will frequently be tied to the passage of time and, therefore, easily fit into an Events and Causal Factors Chart, showing when and what existed before, during and after the change. Change analysis is nearly always used in conjunction with an

Barrier Analysis: An incident analysis that identifies barriers used to protect a target from harm and analyses the event to see if the barriers held, failed, or were compromised in some way by tracing the path of the threat from the harmful action to the target. A simple example is a guard on a circular saw. The saw blade is the threat, the guard is the barrier, and the target is a human. If the guard somehow fails and a human is injured, the barrier analysis would seek to find out why the barrier failed. The cause of this failure is then identified as the root cause.

Energy Trace & Barrier Analysis (ETBA), or "Barrier Analysis" as it is usually called, is used to produce a clear set of episodes, or subjects, for MORT analysis. It is an essential preparation for MORT analysis.

Energy Flow or harmful Agent, adverse environment condition	Target Vulnerable person or thing	Barriers & Controls to separate Energy and Target

Table 2. Barrier analysis format

"Energy" refers to the harmful agent that threatens or actually damages a "Target" that is exposed to it. Although "Energy" and Energy-Flow are the terms most often used, harmful agents can include environmental conditions (e.g. biohazards, limited oxygen).

"Targets" can be people, things or processes – anything, in fact, that should be protected or would be better not disturbed by the "Energy". MORT defines an accident in terms of loss, so at least one of the targets in the accident sequence has to be valuable. However, incidents (sometimes called near-misses or near-hits) are also of interest.

The "Barrier" part of the title refers to the means by which "Targets" are protected from "Energies". As well as barriers (the nature of which is purely protective), the analysis also

focuses on work/process controls as these also provide protection by directing energies (and targets) in a safe manner.

Very often, an accident reveals a number of events where energies met targets in unwanted interactions; Barrier Analysis seeks to trace meticulously all of these interactions and make them available to analysis. This means that a Barrier Analysis table may have several rows, each row corresponding to a distinct episode of energy interaction with a target.

Procedure for Barrier Analysis

Requirements: Technical understanding of the system in which the incident occurred and enough information about the sequence of events to allow analysis to begin.

Objective: To account for all unwanted exchanges of energies and to make these available to subsequent analysis within the investigation.

Description:

1) Familiarise yourself with available information (including site if accessible)
2) Determine scope: limit to just those interactions producing harm/damage or include near-misses as well?
3) Create three columns (as shown in table 3)
4) Start in the TARGET column and identify a target that was harmed or damaged (or, if you are looking at near-misses, a target exposed to harm). Identify the energy flow (or harmful agent...) that is acting and describe it simply and with precision in the ENERGY FLOW column.
5) Next, consider the BARRIERS and CONTROLS that should have stopped or limited the interaction between Energy and Target.
6) Repeat this process for another unwanted energy exchange.
7) Review the list of targets for any omissions.
8) Number rows (each row is an episode of energy flow threatening or damaging a target) in chronological order. There should be continuity: do the events follow from one another?

9) Prioritise rows for analysis using MORT (e.g. *** = most important, * = least important)

Energy Flow or harmful Agent, adverse environment condition	Target Vulnerable person or thing	Barriers & Controls to separate Energy and Target
These may be energies (and harmful agents...) designed to do work in the work process or extraneous energies that act from outside the process. Be meticulous as this stage of the analysis. Energy exchanges can be in the 'reverse direction' (e.g. exposure to cold, loss of pressure). If there are multiple targets for a given energy flow, state each interaction in a separate row.	Targets can be valuable (i.e. a person or asset) or not. The reason for including targets that have no intrinsic value is to ensure the continuity and completeness of the analysis. Try to identify all targets involved in the incident (this leads to a clear insight into the state of risk control). Every target mentioned should be accompanied by a word or phrase that identifies the attribute altered. E.g. "Smith (bruised arm)", or "Car (near-side door crumpled)". Note that the object or actor that corresponds to a target at one point in the analysis may also play other roles.	Barriers are means of separation present solely for protective purposes. Controls are means of channelling energy or substances to do work (and provide protection as a by-product). Controls also limit the exposure of targets. It is most effective to identify physical barriers (including time & space barriers) and controls that have their effect at the coal face/shop floor. MORT analysis will tease out the procedural and upstream issues; do not force them. Include absent barriers & controls that should have been present according to an explicit standard or justification.

Table 3. Barrier Analysis Headings, annotated with guidance

ROOT CAUSES

Why-Why Chart: One of many brainstorming methods also known as the "Five-Whys" method. This is the most simplistic root cause analysis process and involves repeatedly asking "why" at least five times or until you can no longer answer the question. Five is an arbitrary figure. The theory is that after asking "why" five times you will probably arrive at the root cause. The root cause has been identified when asking "why" doesn't provide any more useful information. This method produces a linear set of causal relationships and uses the experience of the problem owner to determine the root cause and corresponding solutions.

Tree Diagrams: This type of root cause analysis is very common and goes by many names such as Ishikawa Fishbone Diagram, Management Oversight and Risk Tree Analysis (MORT), Human Performance Evaluations System (HPES), and many other commercial brands. These methods use a predefined list of causal factors arranged like a fault tree.

They are sometimes called "Pre-Defined Fault Trees." The American Society for Quality (ASQ) and others often call these categorical methods "Cause-and- Effect Diagrams." All categorisation methods use the same basic logic. The premise is that every problem has causes that lie within a pre-defined set of categories. Ishikawa uses Manpower, Methods, Machinery and Environment as the top-level categories. Each of these categories has sub-categories and sub-sub- categories. For example, within the category of Manpower, we may find Management Systems; within Management Systems we may find Training; and within Training we may find Training Less Than Adequate; and so on. These methods ask you to focus on one of the categories such as People and

in reviewing what you know of your event choose some causal factors from the pre- defined list provided. Each categorical method has its own list of causal factors.

After reviewing the list for each category, you are asked to vote on which causal factors most likely caused your problem. After some discussion, the most likely ones are voted on and called root causes. Solutions are then applied to these "root causes" to prevent recurrence. Each commercial brand has a different definition of root cause, but it is generally a cause that you are going to attach a solution to that prevents recurrence. Some of these methods refer to themselves as "Expert Systems" and also provide pre-defined solutions for your problems.

Storytelling Method: This is not really a root cause analysis *method* but is often passed off as one, so it is included for completeness. It is the single most common incident investigation method and is used by nearly every business and government entity. It typically uses predefined forms that include problem definition, a description of the event, who made a mistake, and what is going to be done to prevent recurrence. There is often a short list of root causes to choose from so a Pareto chart can be created to show where most problems come from.

Realitycharting: A simple causal process whereby one asks why of a defined problem, answers with at least two causes in the form of an action and condition, then asks why of each answer and continues asking why of each stated cause until there are no more answers. At that time, a search for the unknown is launched and the process is repeated several times until a complete cause and effect chart, called a Realitychart, is created showing all the known causes and their inter-relationships. Every cause on the chart has evidence to support its existence or a "?" is used to reflect an unknown and thus a risk. All causes are then examined to find a way to change them with a solution that is within your control, prevents recurrence, and meets your goals and objectives. The result is clear causal connections between your solutions and the defined problem. Because all stakeholders can see these causal relationships in the Realitychart, buy-in of the solutions is readily attained.

MORT ANALYSIS

Good investigations are built on a secure picture of what happened. MORT analysis needs this as a basis. Analysis using an appropriate "sequencing" method such as Events & Conditional Factors Analysis (ECFA+) can be effective and provides a detailed picture of the events comprising the accident. Using Energy Trace and Barrier Analysis is the way to connect MORT analysis to the events of the accident. Therefore, as soon as the factual picture allows it, carry out an Energy Trace and Barrier Analysis.

Procedure for MORT Analysis
Requirements:
> Two people (ideally)
> Technical Understanding of system in which incident occurred
> Sufficient description of sequence of events to allow analysis to begin
> MORT Charts and coloured pens – Red, Blue, Green
> Means to keep notes of: "blue" items for further enquiry; justification for "red" and "green" items.

Objective: To understand how specific targets were exposed to harm, damage or unwanted change and to explain this in terms of risk management.
Description
1) Choose an event from your Barrier Analysis and write it on the MORT chart above SA1

"Incident"

2) Perform SA1 analysis

a) Begin at SB1 ("Harmful energy flow...")

b) Above SB1, state the energy flow

c) Proceed through chart top to bottom, left to right, as shown in Figure 6

i) Code RED (applicable and a contributory factor) or GREEN (applicable but did not contribute to the accident) only with evidence and an explicit standard of judgement.   Cross out with BLACK if a branch is not applicable.

ii) Code BLUE if evidence or required standard is uncertain

iii) Maintain your list of further enquiries as you go

iv) Write any provisional Assumed Risks into the table on the MORT Chart

d) Explore M-branch either

i) Ad-hoc, during SB3 analysis, or   ii) When SB3 ("Controls & Barriers LTA") completed

3) If needed, choose another event from your Barrier Analysis a) Use fresh MORT chart   b) Repeat step 2

4) When all required SA1 analyses are complete

a) Note on the barrier analysis an events that have not been subject to MORT analysis

b) Move to SA2 – Amelioration

c) Move to M-Branch and explore (adhoc or in sequence) in the light of the SA2 analysis

d) Review Provisional Assumed Risks

5) Review MB4 (Risk Management Assurance Programme) in the light of the analysis so far

6) Review the M-branch issues, taking the overview

TECHNIC (TECHNIQUE) OF OPERATIONS REVIEW (TOR)

Overview

TOR analysis was initially developed by Weaver (1973) as a training tool to assist with the prevention of incidents. It has subsequently found application as an investigatory technique for the identification of root causes associated with incidents and accidents.

TOR analysis is presented in a work sheet format. It is a group technique requiring participants to progress through the work sheet answering yes or no to a series of questions. A condition of TOR analysis is that the group reaches a consensus on the answers to the questions.

TOR analysis was utilised for over a decade by policy holders of a US insurance company before being made commercially available.

Structure

The TOR worksheet is divided into eight functional areas, namely:

1. Coaching

2. Responsibility

3. Authority

4. Supervision

5. Disorder

6. Operational

7. Personality Traits

8. Management.

Between five and eight numbered statements of systemic failures are listed under each functional area. To the right of each statement is a series of numbers. This is a system of cross referencing and the numbers direct the analysis team to other related statements.

Down the middle of the work sheet are listed all of the reference numbers of the

statements of systemic failures. This is used as a checklist to quickly appraise whether all the statements have been considered.

Conducting an Analysis

TOR analysis is generally described as a group technique (Hallock and Weaver, 1990; Weaver, 1987) although it could be conducted by an individual.

Once an incident has occurred and the facts concerning the incident identified, these facts may be analysed using TOR analysis. If a group approach is to be used, then members of the group need to be selected and a leader chosen from within the group to direct the analysis and keep it moving. There are four basic steps in the TOR analysis process:

• Establish the facts.

• Trace the root causes.

• Eliminate insignificant causes.

• Identify realistic actions.

Establish the Facts

Within the group the facts of the incident must first be established, understood and agreed. Once this has been achieved the group is ready to move on to the next stage.

Trace the Root Causes

To begin tracing the systemic failures through the TOR worksheet the group must decide on the prime (or main) error that caused or allowed the incident to happen. The TOR worksheet is centred on the management and supervisory factors in an operating system. It is necessary for the group to come to a consensus on this start point. An example of a prime error could be 'Failure to investigate and apply lessons learned from similar mishaps'.

Having identified the prime error, the leader circles the reference number on the trace guide within the work sheet and underlines all those numbers that are cross referenced by the prime error. These are known as possible contributing factors and are drawn from the original functional areas. The group considers all the possible contributing factors and decides whether or not they were relevant to the particular incident being investigated. The group leader then circles the numbers on the trace guide of those possible contributing factors

considered to be relevant and crosses out those that are not. The group then repeats this process for the factors cross referenced by those possible contributing factors considered relevant. This process continues until the trail is exhausted.   The circled factors represent the identified root causes to the particular incident.

Eliminate Insignificant Causes

Once the tracing process has been completed the group may be left with a list of ten or more root causes that were judged to have contributed to the incident. The group must now discuss these in more detail to reduce the list to a more manageable size by assessing the significance of the factors identified.

Identify Realistic Actions

When the problem areas have been identified and reviewed, the group must then identify realistic corrective actions that can be taken. If the group consists of employees from the shop floor not all the actions will be under their immediate control. It is for the group leader to raise the issues identified to more senior management through the appropriate organisational channels e.g. reporting forms, safety committees etc.

TOR WORKSHEETS

1.   Coaching

10.	Unusual situation, failure to coach (new man, tool, equipment, process, material, etc.)	**44, 24, 62**
11.	No instruction. No instruction available for particular situation	**44, 22, 24, 80**
12.	Training not formulated or need not foreseen	**24, 34, 86**
13.	Correction. Failure to correct or failure to see need to correct	**42, 20, 30**
14.	Instruction inadequate. Instruction was attempted but result shows it didn't take.	**15, 16, 42**
15.	Supervisor failed to tell why	**44, 24, 83**
16.	Supervisor failed to listen	**11, 81**
17.		
18.		
19.		

2.   Responsibility

20.	Duties and tasks not clear	**44, 34, 14, 53**
21.	Conflicting goals	**80**
22.	Responsibility, not clear or failure to accept	**26, 14, 54, 82**
23.	Dual responsibility	**47, 34, 13**
24.	Pressure of immediate tasks obscures full scope of responsibilities	**36, 12, 51**
25.	Buck passing, responsibility not tied down	**44**
26.	Job description inadequate	**80, 86**
27.		
28.		
29.		

3.   Authority (Power to Decide)

30.	Bypassing, conflicting orders, too many bosses	**44, 13**
31.	Decision too far above the problem	**36, 83, 85**
32.	Authority inadequate to cope with the situation	**81, 83**
33.	Decision exceeded authority	**20, 26, 14**
34.	Decision evaded, problem dumped on the boss	**36, 14, 85**
35.	Orders failed to produce desired result. Not clear, not understood, or not followed	**40, 46, 13, 15**
36.	Subordinates fail to exercise their power to decide	**26, 12, 83, 85**
37.		
38.		
39.		

4.   Supervision

40.	Morale. Tension, insecurity, lack of faith in the supervisor and the future of the job	**15, 56, 64, 80**
41.	Conduct. Supervisor sets poor example	**13, 84**
42.	Unsafe Acts. Failure to observe and correct	**24, 11, 52**
43.	Rules. Failure to make necessary rules, or to publicise them. Inadequate follow-up and enforcement. Unfair enforcement or weak discipline	**25, 36, 12, 52**
44.	Initiative. Failure to see problems and exert an influence on them	**22, 34, 30**
45.	Honest error. Failure to act, or action turned out to be wrong	**10, 12, 15, 81**
46.	Team spirit. Men are not pulling with the supervisor	**40, 21, 56**
47.	Co-operation. Poor co-operation. Failure to plan for co-ordination	**23, 25, 15, 66**
48.		
49.		

5.   Disorder

51.	Work Flow. Inefficient or hazardous layout, scheduling, arrangement, stacking, piling, routing, storing, etc.	**41, 24, 31, 80**
52.	Conditions. Inefficient or unsafe due to faulty inspection, supervisory action, or maintenance	**21, 32, 14, 86**
53.	Property loss. Accidental breakage or damage due to faulty procedure, inspection, supervision, or maintenance	**43, 20, 80**
54.	Clutter. Anything necessary in the work area. (Excess materials, defective tools and equipment, excess due to faulty work flow, etc.	**44, 36, 80**
55.	Lack. Absence of anything needed. (Proper tools, protective equipment, bins, scrap barrels, janitorial service, etc.)	**44, 36, 80**
56.	Voluntary compliance. Work group sees no advantage to themselves	**40, 15, 41**
57.		
58.		
59.		

6. Operational

60.	Job procedure. Awkward, unsafe, inefficient, poorly planned	**44, 32**
61.	Work load. Pace too fast, too slow, or erratic	**44, 51, 63**
62.	New procedure. New or unusual tasks or hazards not yet understood	**43, 44**
63.	Short handed. High turnover or absenteeism	**80, 40, 61**
64.	Unattractive jobs. Job conditions or rewards are not competitive	**81, 46**
65.	Job placement. Hasty or improper job selection and placement	**80, 86**
66.	Co-ordination. Departments inadvertently create problems for each other (production, maintenance, purchasing, personnel, sales, etc.)	**45, 35, 13**
67.		
68.		
69.		

7. Personal Traits (When accident occurs)

70.	Physical condition - strength, agility, poor reaction, clumsy, etc.	**44, 26, 65**
71.	Health - sick, tired, taking medicine	**44, 24, 65**
72.	Impairment - amputee, vision, hearing, heart, diabetic, epileptic, hernia, etc.	**44, 24, 65**
73.	Alcohol - (if definite facts are known)	**80**
74.	Personality - excitable, lazy, goof-off unhappy, easily distracted, impulsive, anxious, irritable, complacent, etc.	**44, 13**
75.	Adjustment - aggressive, show-off, stubborn, insolent, scorns advice and instruction, defies authority, antisocial, argues, timid	**44, 13**
76.	Work habits - sloppy. Confusion and disorder in work area. Careless of tools, equipment and procedure	**44, 13**
77.	Work assignment - unsuited for this particular individual	**42, 65**
78.		
79.		

8. Management

80.	Policy. Failure to assert a management will prior to the situation at hand	**24, 81, 83**
81.	Goals. Not clear, or not projected as an 'action image'	**83, 86**
82.	Accountability. Failure to measure or appraise results	**36**
83.	Span of attention. Too many irons in the fire. Inadequate development of subordinates	**12, 86**
84.	Performance appraisals. Inadequate or dwell excessively on short range performance	**20, 65**
85.	Mistakes. Failure to support and encourage subordinates to exercise their power to decide	**36**
86.	Staffing. Assign full or part-time responsibility for related functions	**66**
87.		
88.		
89.		

Coaching	10	11	12	13	14	15	16	17	18	19
Responsibility	20	21	22	23	24	25	26	27	28	29
Authority	30	31	32	33	34	35	36	37	38	39
Supervision	40	41	42	43	44	45	46	47	48	49
Disorder		51	52	53	54	55	56	57	58	59
Operational	60	61	62	63	64	65	66	67	68	69
Personal Traits	70	71	72	73	74	75	76	77	78	79
Management	80	81	82	83	84	85	86	87	88	89

Self Assessment Questions
- Accident Prevention And Investigation

SAQ1   Define: (i)   An accident
                   (ii)   An incident
                   (iii) A hazard

SAQ2   Complete the missing 'dominoes'

        A   =   ?
        B   =   Underlying Causes
        C   =   ?
        D   =   Accident
        E   =   ?

SAQ3   List the following accident prevention techniques in order i.e.
        most proactive first, most reactive last – which domino(es) does each tackle?

        analysis of injury statistics
        developing safety policies
        accident investigation
        inspections
        audits

SAQ4   List four reasons for investigating accidents.

Self Assessment Questions
- Accident Prevention And Investigation Answers

SAQ1

Answer   (i)   An accident is an unplanned, undesired occurrence which resulted in loss of any kind.

              (ii)   An incident is an unplanned, undesired occurrence which had the POTENTIAL to result in loss of any kind.

              (iii)   A hazard is something with the potential to cause harm.

SAQ2

Answer   A   =   Lack of management control
                  C   =   Unsafe conditions/acts
                  E   =   Injury.

SAQ3

Answer   In order of most proactive to most reactive, (the letter indicates the appropriate domino that is being tackled.)

• developing safety policies	A
• audits	A, B & C
• inspections	C
• accident investigation	D
• analysis of injury statistics	E

SAQ4

Answer   Any four of the following would be correct

- To identify and eliminate the causes (most important reason)
- To comply with duties under RIDDOR
- To defend compensation claims
- Insurers require it
- To demonstrate concern about people's safety.