Loss Causation and Quantitative Analysis of Data

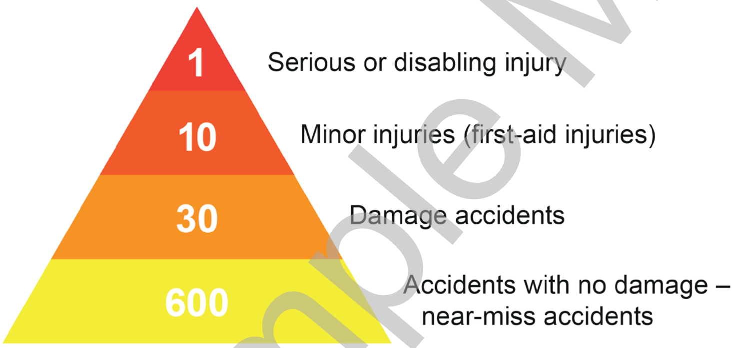
IN THIS SECTION...

- Explain different types of loss causation theories/models, tools and techniques, and how loss data can be analysed.

The Underlying Principles Connecting Causes with Outcomes

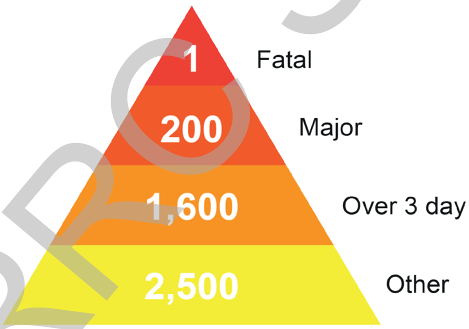
There is no shortage of data on incidents, such as accidents or near-misses. Some researchers have studied the figures in detail and concluded that there appears to be a relationship between the numbers of different types of accidents.

F. E. Bird used accident data to produce the following accident triangle:

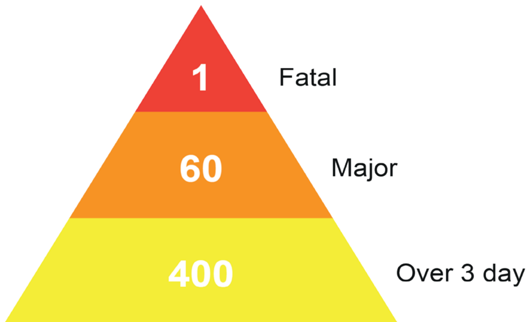


Bird's accident ratio triangle

Other researchers have produced similar accident ratio triangles:



Labour Force Survey 1990



Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) classifications

Heinrich's accident triangle

The actual figures vary between the different accident triangles but the important thing to note is that, for every major incident or fatality, there are many more less-serious or near-miss incidents:

- Whilst not every near-miss or minor incident involves risks which could actually have led to a serious incident or fatality, most incidents with the same causes have a range of possible outcomes.
- There is an underlying randomness to outcomes. It is invariably a matter of chance whether a given event results in injury, damage or a near-miss, i.e. near-misses could so easily become more serious incidents.
- More severe incidents will happen sooner or later if you leave it to chance, and therefore near-miss or less-serious incident data can be a useful predictor of accident potential.
- All events are due to failure to control – so we can learn from even minor incidents.

As a health and safety professional, you will probably have experienced the relief we feel when a near-miss occurs which *could* have been catastrophic but on this occasion it wasn't, we 'got away with it'.

The HSE publication *Investigating accidents and incidents* (*HSG245*) stresses the importance of remembering that feeling of relief, and investigating with the potential incident in mind and not the actual outcome that was experienced on the day. For example, if a pipe fails and chemicals are sprayed over the room, narrowly avoiding the worker, *don't* consider that a near-miss, brush it off and continue, as that could have just as easily been a catastrophic incident and therefore needs to be investigated with that level of rigour. This can be a challenge in established organisations where that has been the norm for some time, so clearly defining expectations in terms of reporting standards can be useful.

MORE...

The HSE publication *Investigating accidents and incident (HSG245)* is available to download from:

www.hse.gov.uk/pubns/hsg245.pdf

In order to prevent more serious incidents, emphasis should be placed on identifying and addressing the root causes of incidents; all too often the solutions that are implemented are sticking plasters which address the symptom but not the root cause and then incidents recur later. Root cause analysis is covered later in this Learning Outcome, but as an illustration consider an operator receiving a cut on their hand when using a blade. It may be easy to identify that the operator *should* have been wearing cut resistant gloves, they may well tell you this themselves and vow to wear them in the future, but is that the root cause? This particular worker may in future always remember to wear gloves, but their colleagues might not. The root cause is the 'why' – the management or system failings that allowed the event to occur, and correcting this keeps *everyone* safe, not just the individual worker.

Limitations

A final note on the accident ratio data studies, such as Bird's triangle, is that the data from these triangles has a number of limitations that you need to think about before trying to apply it:

- There can be inaccuracies in the statistics and data gathering; some minor events may go unreported; some high potential incidents could be seen as trivial, and as we have seen not every near-miss or minor incident involves risks which could actually have led to a serious incident or fatality.
- The most effective way to use the ratio studies is as a guide, rather than rigorously using the stated ratios. Obtain your accident numbers for each category then compare your 'triangle' to see if you do indeed have a triangle, or if you have a different shape altogether! If the shape obtained isn't a triangle, look at which level is out of line and take action to improve reporting in those areas in particular. The data does have to also be statistically significant; you need a certain amount of representative data for a meaningful comparison between your workplace and industry as a whole.
- Many of the basic accident studies consider 'operator error' as a cause of the incident, and whilst this may in part be true, it is somewhat limited in its usefulness. A better question would be 'why has the operator made the error?' and take steps to address the management failures that enabled that. This will be covered more in root cause analysis later.
- Incidents in these models are usually seen as a linear sequence of events stemming from a single cause: this is limited as we know most accidents are in fact multi-causal in nature.

MORE...

The limitations of Bird's Triangle have been outlined in the following article:

https://app.croneri.co.uk/feature-articles/bird-s-triangle-what-are-its-limitations

Loss Causation Theories/Models, Tools and Techniques

Domino and Multi-Causality Theories

One of the duties of the safety professional is to keep details of accidents and ill-health conditions and carry out investigations. The law requires certain accidents and occupational diseases to be reported. Often, the information that is recorded at the time of an accident is not adequate for the purpose of investigation into the cause, and so is certainly inadequate for the purpose of preventing the accident happening again.

For example, the report form may ask for the nature and cause of the injury. This could be written as:

- Nature of injury – cut finger.
- Cause of injury – caught on a sharp piece of metal.

The safety professional needs to know a lot more than this, such as:

- Which finger?
- How serious was the cut?
- Was this part of the normal job?
- Should it have been sharp?
- Should it have been there?
- How should it have been handled?

A good starting point in investigations is to consider the two basic theories for accident causation.

(Note that domino theory presents a simplified model, which considers only one cause of an accident; whilst this is not in the NEBOSH syllabus, it is briefly covered in order to better explain multi-causal theories.)

Single Cause (Domino) Theory

According to Heinrich:

> *'A preventable accident is one of five factors in a sequence that results in an injury. The injury is invariably caused by an accident and the accident in turn is always the result of the factor that immediately precedes it.'*

Source: Heinrich, H.W. *Industrial accident prevention: A scientific approach*, McGraw-Hill, New York (1931)

The analogy drawn is that an accident is caused in the same way that a row of dominoes topple – one event triggers the next which leads in turn to the accident. The only way to stop the accident is to remove a domino from the chain.

This work was then expanded on by Bird and Loftus and the model changed, but the theory remained the same: accidents are caused by a single chain reaction and in order to prevent the incident the chain of events needs to be broken. Since this work however, professionals have concluded that most accidents are not caused by a single event and are in fact multi-causal in nature, and therefore this is the model of accident causation we will focus on.

Multi-Causal Theories

There may be more than one cause of an accident, not only in sequence, but occurring at the same time. For example, a methane explosion requires:

- Methane in the explosive range of 5% to 15%.
- Oxygen, or air.
- Ignition source.

The ignition will only happen if these three events occur together. Each of the three events may, in themselves, be the end result of a number of different sequences of events. In accident investigation, all causes must be identified.

Usually simple accidents have a single cause, which is why such events occur so frequently; but the consequences tend to be of a minor nature. A major disaster normally has multiple causes, with chains of events, and combinations of events. Fortunately, they are rare occurrences.

The multi-causal model considers that there may be organisational, cultural, managerial, (etc.) causes that interact and result in an accident. The model is more complex than the single cause domino theory and can be used not only for accident investigation, but also to prevent accidents if the outcomes of monitoring activities are analysed. The model can also be linked to more advanced analysis techniques, such as fault trees and event trees. The downside is that they are more complex and therefore take longer to carry out.

Immediate, Underlying and Root Causes

There are various ways of classifying accident causes. When analysing accidents, it is common to distinguish between immediate causes and underlying causes. The latter are also sometimes called root causes. The term used can vary but the most important thing to remember is to look beyond the symptoms of the accident. You need to dig down beyond the obvious (immediate) causes to discover why it happened, or why it was allowed to happen. Usually, an accident occurs as a result of multiple chains of events; following these back will lead to underlying causes, tackling which can stop similar accidents happening again.

For definitions of immediate, underlying and root causes we will look to *HSG245*:

- *Immediate cause: the most obvious reason why an adverse event happens, e.g. the guard is missing; the employee slips, etc. There may be several immediate causes identified in any one adverse event*
- *Underlying cause: the less obvious 'system' or 'organisational' reason for an adverse event happening, e.g. pre-start-up machinery checks are not carried out by supervisors; the hazard has not been adequately considered via a suitable and sufficient risk assessment; production pressures are too great, etc.*
- *Root cause: an initiating event or failing from which all other causes or failings spring. Root causes are generally management, planning or organisational failings.*

Source: *Investigating accidents and incidents: A workbook for employers, unions, safety representatives and safety professionals (HSG245)*, HSE, (hse.gov.uk)

We will now look at unsafe acts and conditions in more detail.

An unsafe act is human performance which is contrary to accepted safe practice and which may, of course, lead to an accident. Unsafe conditions are basically everything else that is unsafe after you take away unsafe acts. So, this is the physical condition of the workplace, work equipment, the working environment, etc., which might be considered unsafe and could therefore foreseeably lead to an accident if not dealt with.

A collapsed floor could lead to a worker being injured

Note that an unsafe act or unsafe condition could alone result in an accident. For example, 'messing around' is an unsafe act which could take place in otherwise safe conditions, but could nevertheless result in an accident. Similarly, a person could be working in a perfectly safe manner, using safe equipment and materials, but suffer injuries as a result of the collapse of a floor riddled with woodworm and dry rot. (You could argue, however, that the collapse of the floor was due to an unsafe act, i.e. failure to inspect the floor and supporting joists and to calculate the floor loadings.)

The faults themselves generally arise because of inappropriate attitudes, lack of knowledge or skill, or physical unsuitability.

Reason's Model of Accident Causation

TOPIC FOCUS

Latent and Active Failures

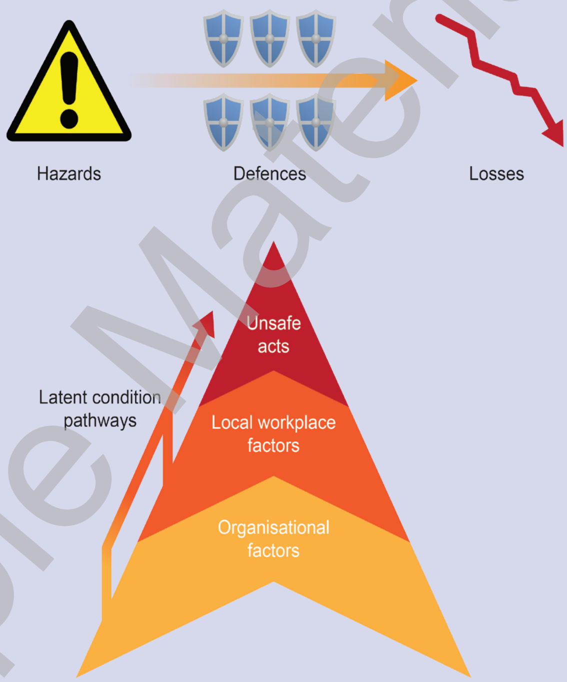
Rather than using the words 'immediate', 'underlying' or 'root' causes, the terms 'latent' and 'active' failures are also commonly used.

Following research into a series of disasters, James Reason (an occupational psychologist) has developed a model of accident causation for organisational accidents. An organisational accident is rare, but if it happens, it often has disastrous consequences (e.g. Piper Alpha, 1988). Reason's model shows that organisational accidents do not arise from a single cause but from a combination of active and latent failures.

In the model there are a series of defence barriers between the hazard and a major incident. These not only prevent the incident (e.g. containment of the hazard, safe operating procedures, etc.) but also provide warning of danger (e.g. an alarm) and mitigate the consequences (e.g. means of escape). These multiple layers characterise complex technological systems, such as a chemical plant.

However, the barriers are not perfect and can be defeated.

Active failures are one cause for the barriers to be defeated.



Adapted version of Reason's model of accident causation

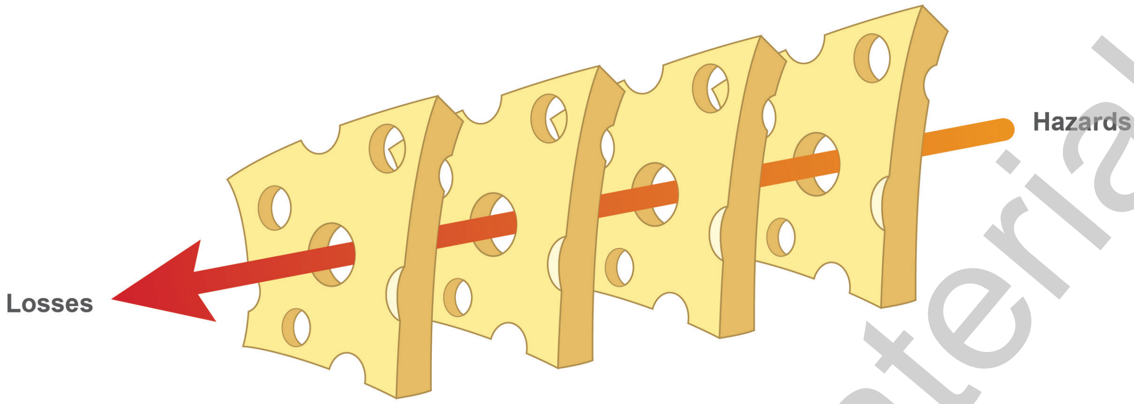
Active failures are those unsafe acts which have immediate effects on the integrity of the system and are usually committed by those directly involved in the task. Such individuals often suffer directly as a result of the incident and may often be blamed as well. The cause of the failure will be due to an error (accidental) or a violation (deliberate). Such unsafe acts are made regularly but few will cause the defences to be penetrated, an example being the chemical plant operator who opens a valve allowing a hazardous substance to escape.

The model then shows that the local workplace factors influence the chance of an unsafe act occurring. In the case of the hazardous substance escape, this may be due to a lack of supervision or training, maintenance failure, unworkable procedures, etc.

According to the model, the local workplace factors are affected by decisions made at a strategic level by senior management, government, regulators, manufacturers, etc. In the case of senior management, this might be a lack of recognition of the importance of occupational health and safety, which will be reflected in the culture of the organisation by the behaviour that is considered acceptable. The management may give safety a low priority with no commitment and minimal funding. These failures at strategic levels, both in the organisation and the external environment, are described as **latent failures** because they remain dormant and possibly unrecognised until they interact with local factors, unsafe acts and work environments, and increase the likelihood of an active failure.

When the gaps created by active failures align with those created by the latent conditions, the opportunity exists for a serious outcome.

Swiss Cheese Model



Swiss cheese model

In the Swiss Cheese model, an organisation's defences against hazards are modelled as a series of barriers, represented as slices of the cheese. The holes in the cheese slices represent weaknesses in individual parts of the system, and are continually varying in size and position in all slices. The system as a whole produces failures when holes in all of the slices momentarily align so that a hazard passes through holes in all of the defences, leading to an accident.

Root Cause Analysis Tools

'5 Whys'

The '5 Whys' model is a brainstorming technique in which you start with the incident and ask 'why?'. The thought process is drawn as a mind map or a causation tree but simply captures the responses to the question 'why?' as a chain. (Note: there doesn't have to be 5 'whys', there may be more or less depending on the questions asked.)

For example:

Dave fell from the scaffold (the incident) – WHY?

1. Because there was no guard rail on that bit – WHY?
2. Because it had been removed to allow a load to be lifted up – WHY?
3. Because loading is done by telehandler – WHY?
4. There was no lift – WHY?
5. Lifts are expensive.

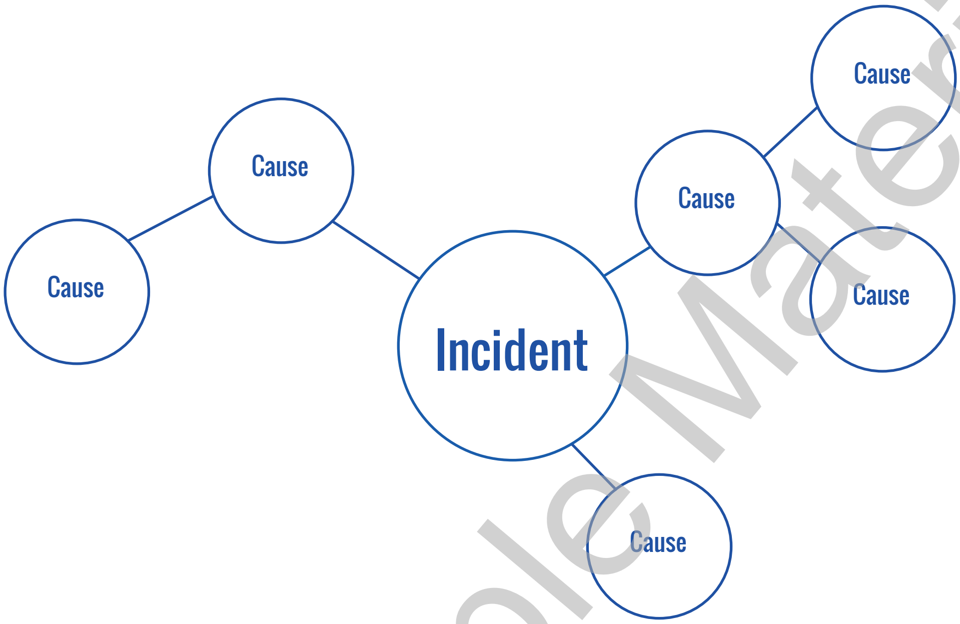
Going back to the incident again:

Dave fell from the scaffold (the incident) – WHY?

1. Because he wasn't clipped on to the scaffold – WHY?
2. Because harnesses aren't always worn – WHY?
3. Because they are seen as awkward and slow the job down – WHY?
4. Because there is pressure to get to the next job.

Traditionally, the safety professional would identify that the harness wasn't worn, conclude that this was the fault of the worker and discipline the individual. A better approach would be to ask why the worker feels such time-pressure and reinforce that safety is more important; perhaps reviewing with management to understand whether the pressure is real or perceived, and what can be done to address it.

Simply put, this is the technique children use to find out about the world. Anyone who has spent any time looking after young children also knows there can be MANY more than 5 whys!



5-Whys Model

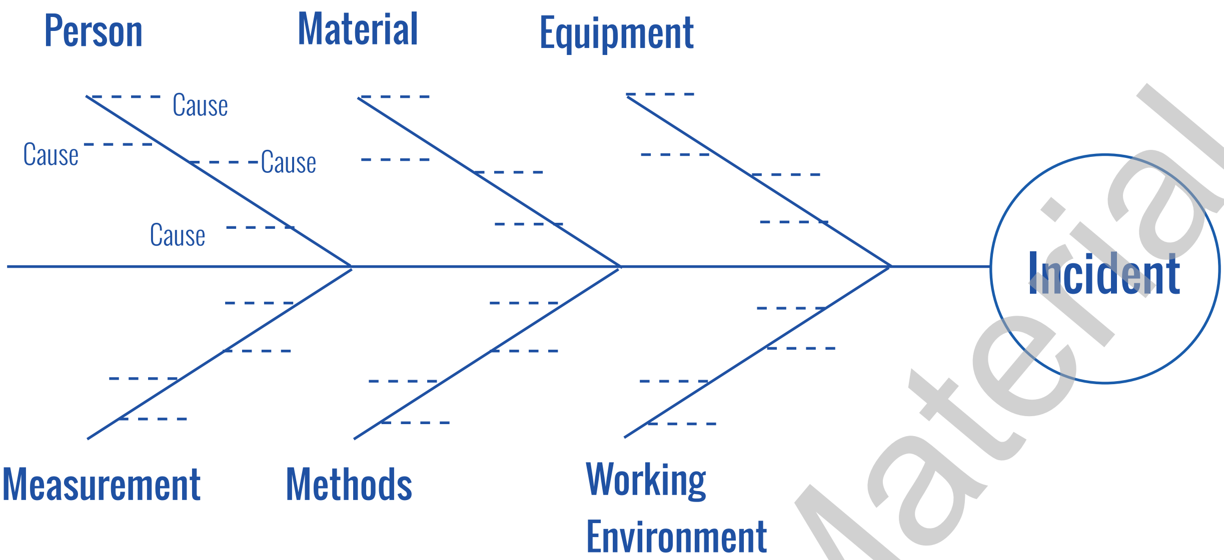
Fishbone Diagram

Fishbone (or Ishikawa) diagrams are another tool used to visualize the causes of a problem and from there, identify root causes. They are called 'fishbone' as when drawn, the main structure looks like a fish skeleton.

The problem is first defined and that is drawn at the head of the fish.

A long arrow is drawn as the backbone with main spines running from the backbone. These will be the broad causes of the problem. Suggested standard causes can be used, such as: Person; Materials; Equipment; Methods; Measurement; and the Working Environment. These can be anything that the team feel to be relevant, and can of course be added to.

The team then brainstorm causes, which are added to the spines and root causes are then identified.



Fishbone Diagram

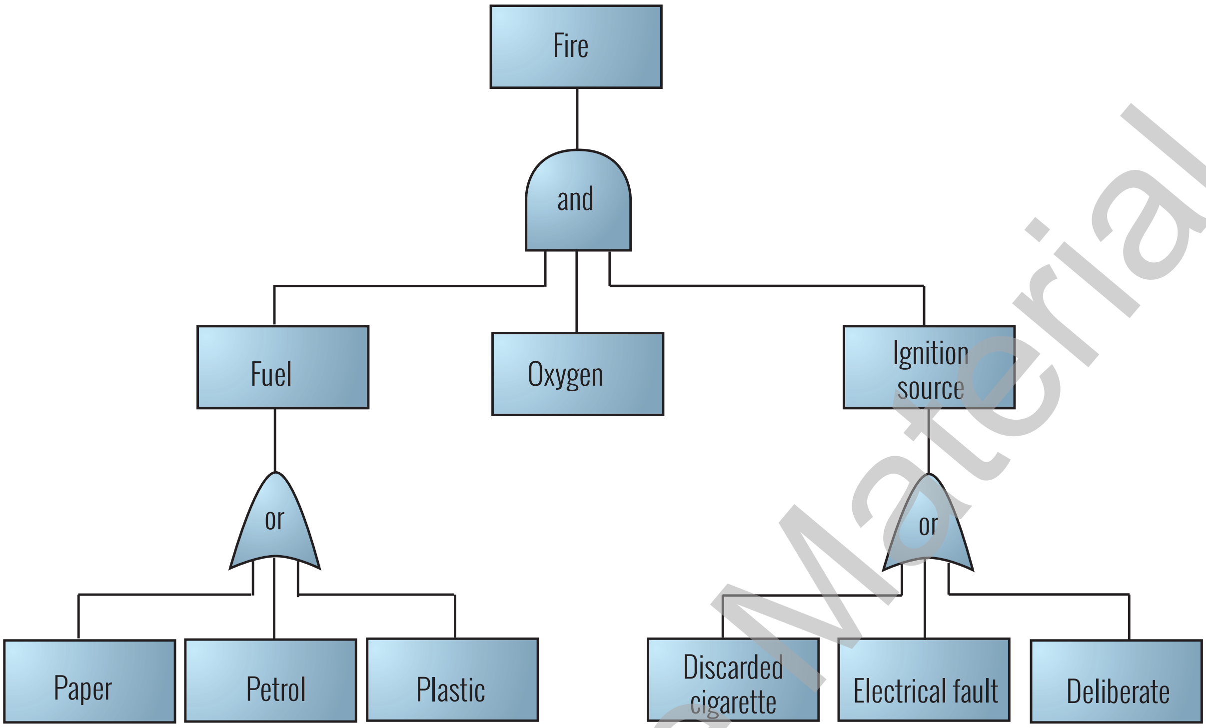
Fault Tree Analysis

In many cases, there are multiple causes for an accident or other loss-making event. Fault Tree Analysis (FTA) is one analytical technique for tracing the events which could contribute. It can be used in accident investigation and in a detailed risk assessment.

The fault tree is a logic diagram based on the principle of multi-causality, that traces all branches of events which could contribute to an accident or failure.

A fault tree diagram is drawn from the top down (like an upside-down tree). The starting point is the undesired event of interest (called the Top Event because it gets placed at the top of the diagram). You then have to logically work out (and draw) the immediate and necessary contributory fault conditions leading to that event. These may each in turn be caused by other faults and so on. Each branch of the tree is further developed until a primary failure (such as a root cause) is identified.

'Or gates' and 'and gates' are used when structuring a FTA. Simply put, when drawing the tree ask: 'Do you need A AND B AND C for that to occur? Or is it A OR B OR C?" Once you decide, draw the appropriate 'gate' as shown in the following diagram.



FTA of a fire

Event Tree Analysis

Unlike identifying the root causes of an event under consideration, Event Tree Analysis (ETA) is concerned with identifying and evaluating the consequences following the event. In FTA, the main event is called the Top Event, whereas in ETA it is called the Initiating Event.

Event trees are used to investigate the consequences of loss-making events in order to find ways of mitigating, rather than preventing, losses. The stages involved in carrying out an ETA are:

- Identify the Initiating Event of concern.
- Identify the controls that are assigned to deal with the Initiating Event, such as automatic safety systems, and other factors that may influence the outcome, such as wind direction or presence of an ignition source that would be important if there was an escape of a large amount of liquefied petroleum gas.
- Construct the Event tree beginning with the Initiating Event and proceeding through the presence of conditions that may exacerbate or mitigate the outcome. Unlike the Fault Tree, for each control there are only two possible outcomes, success or failure, so the control either operates as intended or it doesn't.
- Establish the resulting loss event sequences.
- Identify the critical failures that need to be dealt with.
- Quantify the tree (if data is available) to identify the likelihood or frequency of each possible outcome.

