NEBOSH National Diploma in Occupational Health & Safety

UNIT NDA

MANAGING HEALTH AND SAFETY

ELEMENT A2: LOSS CAUSATION AND INCIDENT INVESTIGATION

SAMPLE MATERIAL

(Material correct Autumn 2013)

nebosh
Approved centre
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RRC
27-37 St George's Road London SW19 4DS United Kingdom
T +44 (0)20 8944 3100 F +44 (0)20 8944 7099
info@rrc.co.uk www.rrc.co.uk Skype ID rrctraining

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Theories of Loss Causation

Key Information

- Incident studies have demonstrated that in any organisation there is a relationship between the number of major incidents and those with less serious outcomes.
- The Single Cause Domino Theory suggests that in an accident there is a sequence of events or circumstances that precede the harm, i.e.
  - Ancestry (i.e. upbringing).
  - Fault.
  - Unsafe act.
  - Accident.
  - Injury.
- Multi-causal theories suggest that preceding an incident there is a combination of causal factors at each level that may combine to lead to the loss event.
- Reason's model of organisational accidents states that for a major accident to occur a series of defences must be defeated for the hazard to lead to a loss event. Unsafe acts may cause the failure of the defences. Unsafe acts are made more likely by local conditions in the workplace.

Accident/Incident Ratio Studies

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 numbers of different types of accident.

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 1995 (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.

Analysis also shows that:

- 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.
- Near-miss/less serious incident data can, therefore, be a useful predictor of accident potential.
- All events are due to failure to control so we can learn from even minor incidents.

The data from these triangles has a number of limitations that you need to think about before trying to apply it:

- Not every near-miss or minor incident involves risks which could actually have led to a serious incident or fatality.
- Be careful comparing:
  - Different triangles.
  - Different definitions (e.g. lost-time accidents).
  - Different industries (with different types of risk).
- Statistical significance – you need a certain amount of representative data for a meaningful comparison between your workplace and industry as a whole.

Domino and Multi-Causality Theories

One of the duties of the safety practitioner 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 practitioner 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.

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."*

The five factors in Heinrich's accident sequence are summarised in the following table.

Heinrich's Accident Sequence

Accident Factors	Description
1. Ancestry and social environment	Recklessness, stubbornness, greed and other undesirable traits of character that may be passed along through inheritance. Environment may develop undesirable traits of character or may interfere with education. Both inheritance and environment may cause faults of person.
2. Fault of person	Inherited or acquired faults of person such as recklessness, violent temper, nervousness, excitability. These constitute reasons for committing unsafe acts or for the existence of mechanical or physical hazards.
3. Unsafe act and/ or mechanical or physical hazard	Unsafe performance of persons such as: standing under danger areas, careless starting of machines, removal of safeguards and horseplay; mechanical or physical hazards such as unguarded gears or points of operation, insufficient light, which result in accidents.
4. Accident	Events such as falls of persons, striking of persons by flying objects, etc. are typical accidents which cause injury.
5. Injury	Fractures, lacerations, etc. are injuries which result directly from accidents.

The major point that Heinrich makes is that a preventable injury is the natural culmination of a series of events or circumstances which occur in a fixed logical order. Here an analogy can be made with a row of dominoes placed on end such that if one falls it will cause the next to fall and so on throughout the series (see figure that follows). If one of the dominoes is removed then the chain of events will be halted. In the same way, consider Heinrich's accident sequence:

1. Ancestry and social environment.

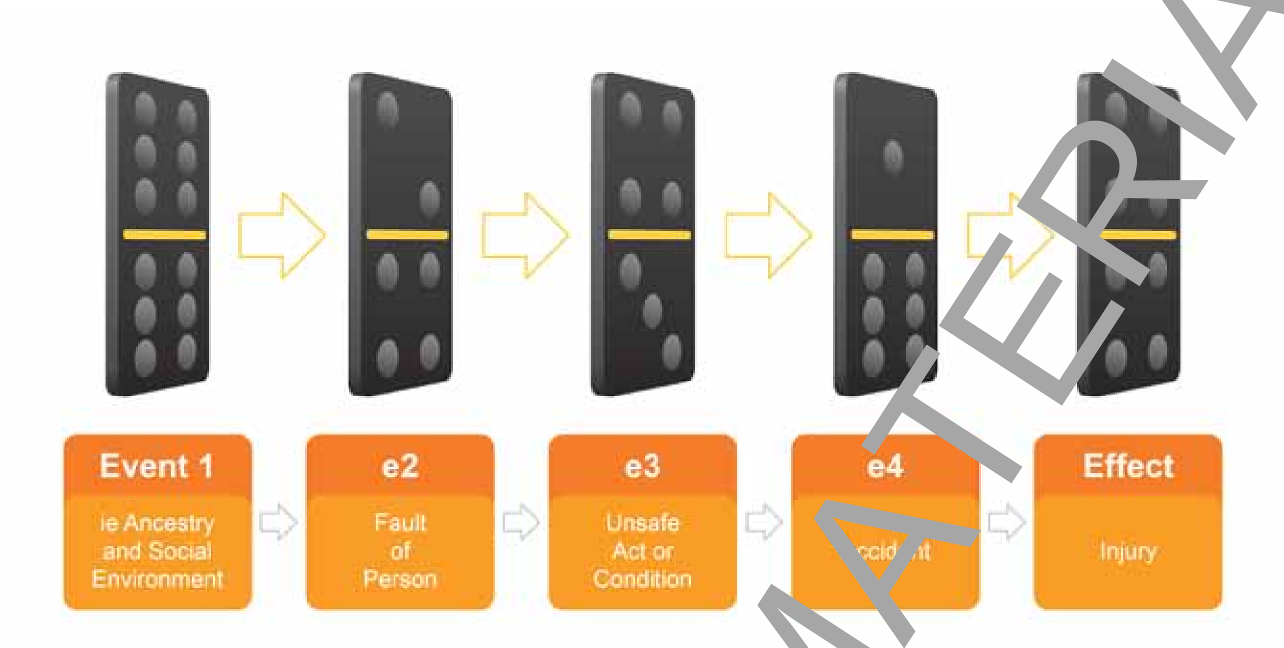
2. Fault of person.

3. Unsafe act and/or mechanical or physical hazard.

4. Accident.

5. Injury.

If this sequence is interrupted by the elimination of even one of these factors, then the injury cannot occur and the accident has been prevented. In the case of the accident sequence, perhaps the easiest factor to eliminate is Number 3, the "unsafe act and/or mechanical or physical hazard".



Heinrich's Domino Sequence

Bird and Loftus extended Heinrich's theory to take into account the influence of management in the cause and effect of accidents, suggesting a modified sequence of events:

1. Lack of control by management.
2. This permits the existence of basic causes (i.e. personal and job factors).
3. In turn, this leads to immediate causes (such as sub-standard practices, conditions or errors).
4. These are subsequently the direct causes of the accident.
5. Finally, this results in loss (which may be categorised as negligible, minor, serious or catastrophic).

This modified sequence can be applied to every accident and is of basic importance to loss control management.

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 so frequently occur; 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.

Systems Theory

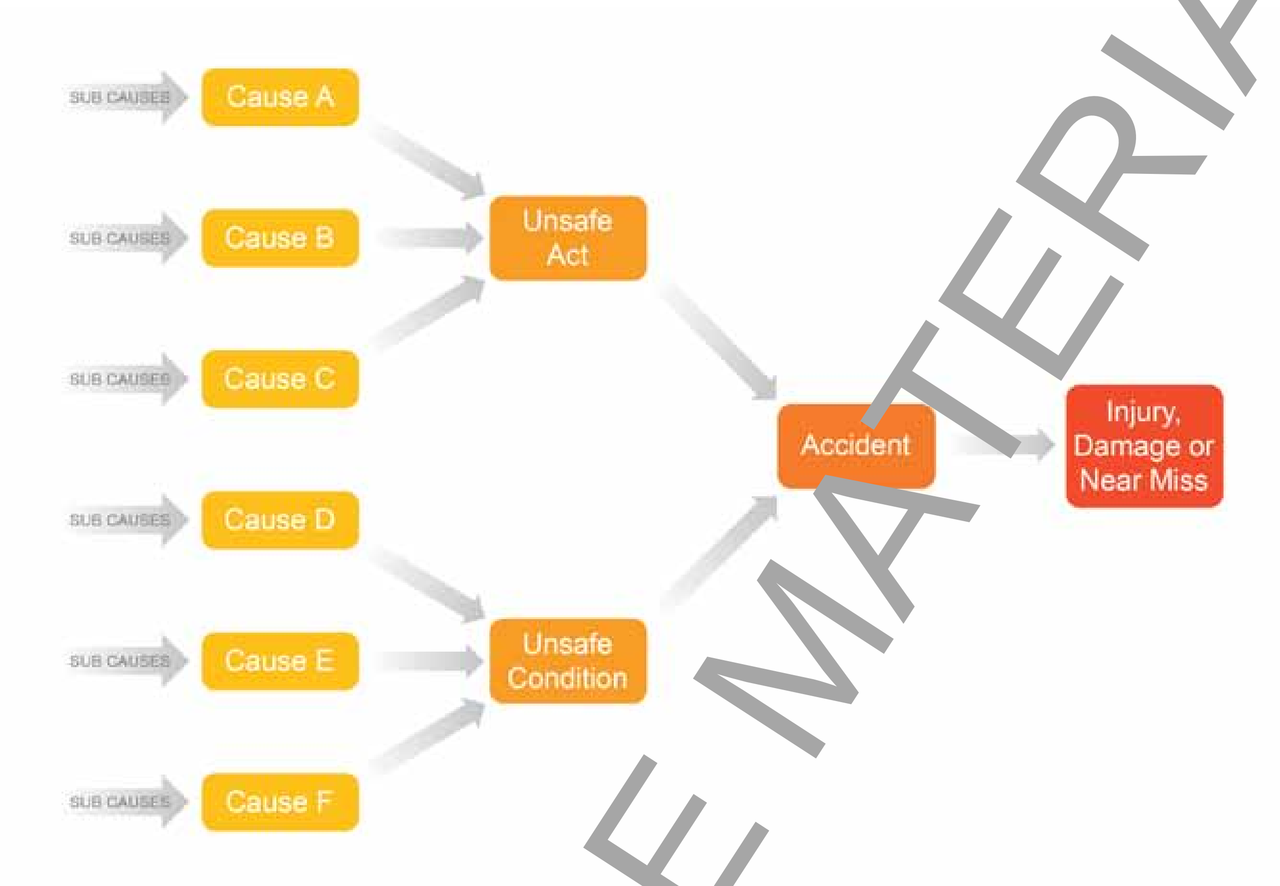
This is another way of looking at a multiple cause situation.

Factories and processes can be viewed as systems, i.e. an assembly of parts or components connected together in an organised way to perform a task, with inputs and outputs and various kinds of control mechanisms.

A systems approach is often useful in simplifying complex operations. Part of the system can be taken as a 'black box', with only the inputs and outputs considered.

System failures are prevented or minimised by components which cannot fail, by backup systems, or by redundancy built into the system (see Element A4). Accidents happen in our system because it includes fallible components such as machines and human beings. The system is operating in the failure mode.

You can see the essential features of the multiple causation approach in the following figure.



Features of the Multiple Causation Approach

Immediate, Underlying and Root Causes

There are various ways of classifying accident causes. Remember that the same term may be used by different people to mean different things – you can check this for yourself by doing an Internet search on the above three terms. For consistency, we will use the terminology in the HSE guidance, *Investigating Accidents and Incidents*, HSG245:

- **Immediate cause** refers to the direct cause of the accident, i.e. the actual agent of injury or damage, such as the sharp blade of the machine.
- **Underlying causes** are the less obvious reasons for the incident - the unsafe acts and unsafe conditions, such as the guard being removed.
- **Root causes** are the ultimate failings from which all other failings arise - typically management and organisational failings such as failure to train people properly or failure to assess risks.

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.

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 the result of the collapse of a floor riddled with woodworm and dry rot. (You could argue, however, that 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.)

According to the accident sequence we discussed earlier, unsafe acts and conditions are caused only by faults of persons, and these faults are created by the environment or are acquired by inheritance.

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

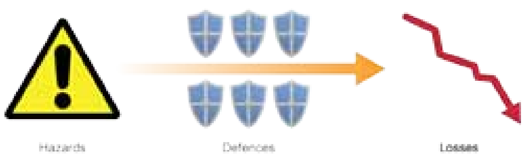
Reason's Model of Accident Causation

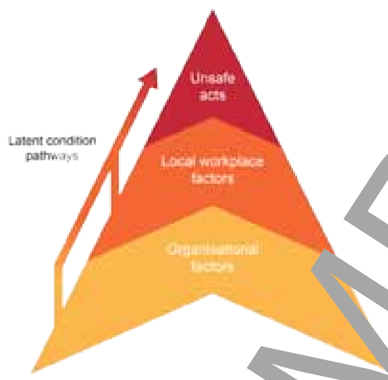
Topic Focus

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 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.





Adapted Version of Reason's Model of Accident Causation

In the model there is 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.

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Topic Focus

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

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 rarely 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 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 the 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 the local factors and the 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.

Categories of Unsafe Acts

Unsafe acts of persons may be categorised under the following headings:

- Operating without authority.
- Operating or working at an unsafe speed.
- Making safety devices inoperative.
- Using unsafe equipment, or using equipment unsafely.
- Unsafe methods, e.g. loading, carrying, mixing.
- Adopting an unsafe position or posture.
- Working on moving or dangerous equipment.
- "Messing/playing around", e.g. distracting, teasing, startling.
- Failure to wear safe clothing or personal protective devices.
- Lack of concentration; fatigue or ill-health.

From this list you can see that unsafe acts may either be deliberate violations (sometimes called 'active') or unintentional errors (sometimes called 'passive'). We discuss these 'human factors' in detail in Element A7.

Categories of Unsafe Conditions

The following categories describe unsafe conditions from which an accident may result:

- Inadequate guarding; guards of inadequate height, strength, mesh, etc.
- Unguarded machinery, or the absence of the required guards.
- Defective, rough, sharp, slippery, decayed, cracked surfaces.
- Unsafely designed machines, tools.
- Unsafe arrangements, poor housekeeping, congestion, blocked exits.
- Inadequate lighting, glare, reflection.
- Inadequate ventilation, contaminated air.
- Unsafe clothing, no goggles, gloves or mask.
- Unsafe processes - mechanical, chemical, electrical, nuclear.
- Hot, humid or noisy environment.

Revision Questions

1. Outline the five factors in Heinrich's accident sequence.
2. How does Bird and Loftus' theory of accident causation differ from Heinrich's?
3. According to Reason, what in an organisation are "latent failures"?
4. What important principle of accident causation theory do accident ratio studies illustrate?

(Suggested Answers are at the end of Unit A.)

Quantitative Analysis of Accident and Ill-Health Data

Key Information

- The amount of injury and ill-health in a population may be described by calculating the accident/incident frequency rate, the accident incidence rate, the accident severity rate or the ill-health prevalence rate.
- Bar charts, pie charts and line diagrams can be used to represent incident data in a graphical format.
- Statistical variation within a population may be described using a normal distribution.

Calculating Loss Rates from Raw Data

Jargon Buster

Incidence

Incidence reflects the number of new cases of a particular event in a population over a given time (e.g. a year) and is often used to describe accidents as each accident is a "new" event.

Prevalence

Prevalence is the total number of cases in a particular population as a proportion of the total population. It is often used to represent ill-health statistics and reflects not only new cases but also those who continue to suffer.

Topic Focus

In making comparisons between various industries, or between work areas in the same factory, it is useful to consider the commonly used injury ratios.

Accident Frequency Rate

This can be calculated from:

$$\frac{\text{Number of work-related injuries} \times 100{,}000}{\text{Total number of man-hours worked}}$$

It is a measure of the number of accidents per 100,000 man-hours worked.

(Continued)

Topic Focus

Accident Incidence Rate

This is calculated from:

$$\frac{\text{Number of work-related injuries} \times 1{,}000}{\text{Average number of persons employed}}$$

It is a measure of the number of injuries per 1,000 employees measured over a defined period, e.g. a year.

Accident Severity Rate

This is:

$$\frac{\text{Total number of days lost} \times 1{,}000}{\text{Total number of man-hours worked}}$$

It is a measure of the average number of days lost per 1,000 hours worked and gives the average number of days lost per accident.

Ill-Health Prevalence Rate

'Prevalence' is a term often used to describe ill-health in terms of the proportion of persons who have the prescribed ill-health condition at a particular time. The rate is calculated as:

$$\frac{\text{The total number of cases of ill-health in the population} \times 100}{\text{The number of persons at risk}}$$

The calculation gives the percentage of the population with the disease.

Statistical and Epidemiological Analyses in the Identification of Patterns and Trends

Statistics is concerned with systematically collecting, organising and interpreting numerical data. Epidemiology looks at occurrences of disease in different groups of people and tries to identify a cause and prevention/control strategy. The size of groups looked at can be quite small, e.g. comparing the incidence of a disease between two factories, or very large, in which comparisons are made between the populations of different countries. Epidemiology is so-called because it was initially concerned with the study of epidemics (a widespread outbreak of an infectious disease). Both types of analysis are useful in identifying patterns and trends and giving an insight into any necessary remedial action that may be required to overcome a particular problem.

Accident and incident data can be used to measure whether performance is improving or deteriorating and to compare data over time, e.g. this year's figures with last year's. This trend analysis, however, can be affected by a number of factors other than whether the safety management systems in place are effective. For example, an increase in the amount of work carried out by an organisation may lead to more accidents but this does not necessarily mean that the safety performance has deteriorated. In the same way, a reduction in work may lead to a reduction in accidents whether or not there are any changes to the safety management practices.

The simplest method of trend analysis is to plot on a graph the number of accidents or incidents against time. The measure of time used, e.g. monthly, quarterly, annually, should be considered, as different time periods may show the trend better than others. It is also possible to include a measure of severity, e.g. by plotting the number of days lost through sickness, or the costs of damage/repair.

Epidemiological analysis may identify a pattern in data distribution but it does not in itself give information on why the pattern is occurring. The pattern must then be analysed to determine whether causal factors can be identified and remedial action taken. Epidemiology is used to identify problems which would not be apparent from single incidents, e.g. to establish whether a number of individual cases of food poisoning are linked and, therefore, may constitute an outbreak.

It is only possible to carry out an epidemiological analysis when the same type of information is available for all of the accidents being analysed. Typical data dimensions include location of accident, time of accident or nature of injury, etc. Single dimension analysis looks at just one dimension, e.g. location of accident/incident. The analysis would involve looking for deviations from what would be reasonably expected. For example, if work was spread evenly over a number of sites (with all sites being of comparable size and carrying out similar jobs) then you would expect that the numbers of accidents at each site would be evenly spread. Peaks and troughs should be investigated.

You can see that the different types of analysis may identify different patterns or trends which are useful in identifying what is happening within an organisation and can help to identify what actions must be taken to improve safety performance.

Presenting and Interpreting Loss Event Data

We will consider some typical ways in which data can be presented in this section.

Histograms

'Histogram' is the name given to a particular type of bar chart. It is the diagram used to illustrate a frequency distribution and it always has the following features:

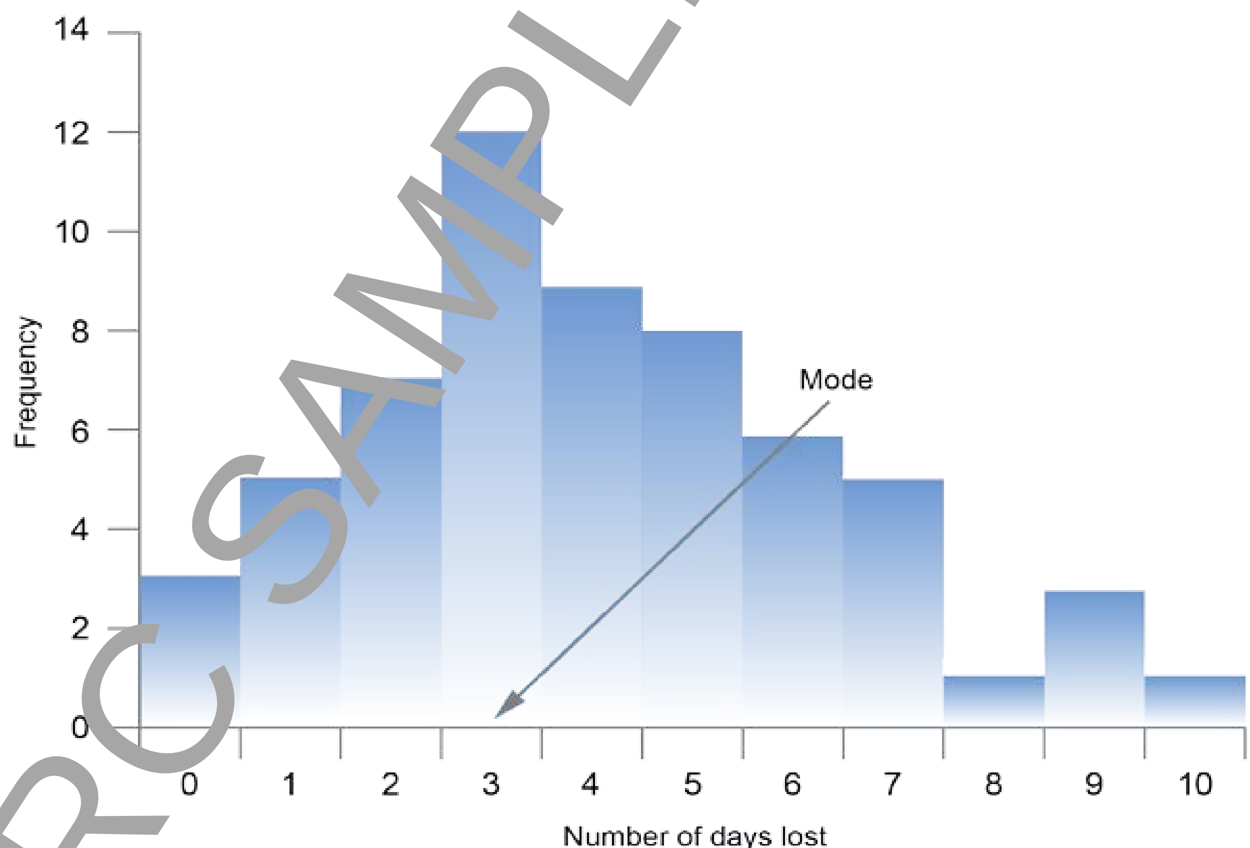
- All the columns touch each other.
- Both axes have scales:
  - The horizontal axis carries the **variable** under consideration.
  - The vertical axis shows the **frequency** with which the values of the variable occur.
- The bars are all the same width but the values of the variable need not begin at zero, i.e. the first column of the histogram need not touch the frequency axis.

Example 1

The following table shows the **simple frequency distribution** of the number of days' absence caused by 60 lost-time accidents. (Columns 1 and 2 form the frequency distribution, columns 3 and 4 are calculated as shown from the frequency distribution.) The histogram (the next figure) is based on this table.

Days Lost per Accident

Days lost per Accident x	No. of Accidents Causing Lost-Time f	Man-Days Lost fx	Cumulative Frequency f_{cum}
0	3	0	3
1	5	5	8
2	7	14	15
3	12	36	27
4	9	36	36
5	8	40	44
6	6	36	50
7	5	35	55
8	1	8	56
9	3	27	59
10	1	10	60
Totals	60	247	-



Lost-Time Accidents Causing Specified No. of Days' Absence

(Note: The "mode" is the most popular frequency, i.e. 3 days.)