INCIDENT/ACCIDENT INVESTIGATION AND ANALYSIS

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INCIDENT/ACCIDENT INVESTIGATION AND ANALYSIS

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Amendments to 90/13

Section	Change
Main text and Appendix	Extensive revision and rewrite of all sections of document.

1 Introduction

Incident/accident investigation analysis and understanding the causes of such events is a critical element of safety management. For any organisation, the overriding purpose in carrying out incident investigation is to understand why an incident happened in order to improve the management of health and safety and prevent similar incidents happening in the future.

The graph below is based on EIGA members' work injury statistics (1992-2012) and it confirms the general experience that human behaviours and/or the person carrying out the task are frequently blamed as the cause for an incident. However, a more careful investigation often reveals that the underlying root cause of such incidents is generally a "lack of management control" due to inadequacies in the safety management system, standards, compliance, monitoring of work, etc.

2 Scope and purpose

The purpose of this document is to provide guidance in respect of the key elements of the incident/accident investigation process, i.e.:

- Collection of incident data;
- Classification, identification of loss and loss potential;
- Immediate and root cause analysis;
- Identification of appropriate control/improvement measures;
- Facilitate shared learning between departments and different company sites.

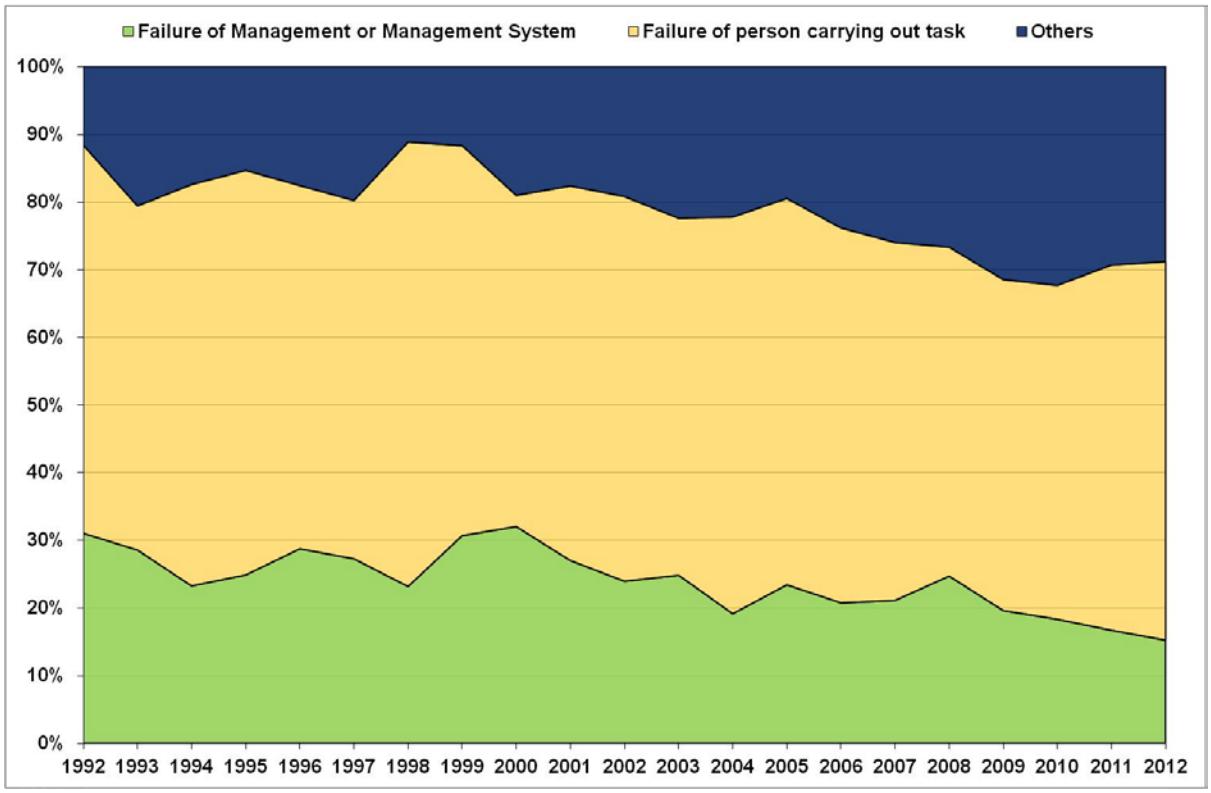


Figure 1: Causes of incidents resulting in lost time injuries (EIGA 1992 – 2012)

3 What are incidents/accidents?

3.1 Definitions

There are a number of definitions of what is meant by the terms accident and incident. More common definitions are:

Incident: An incident is an event that gave rise to an accident or had the potential to lead to an accident.

Accident: Accident is an undesired event giving rise to death, ill health, injury, damage or other loss.

Lost Time Injury: An occupational injury which prevents the employee or contractor from reporting to work on at least one full workday or shift (and not necessarily the next regularly scheduled day or shift) following the incident.

Near-miss: An unintended incident NOT leading to injury or damages, but which under different circumstances could have become an accident.

Loss: May be defined as the effects of any accident, e.g.: injury, ill-health, death, stop production, damage to plant, damage to machinery, damage to the environment.

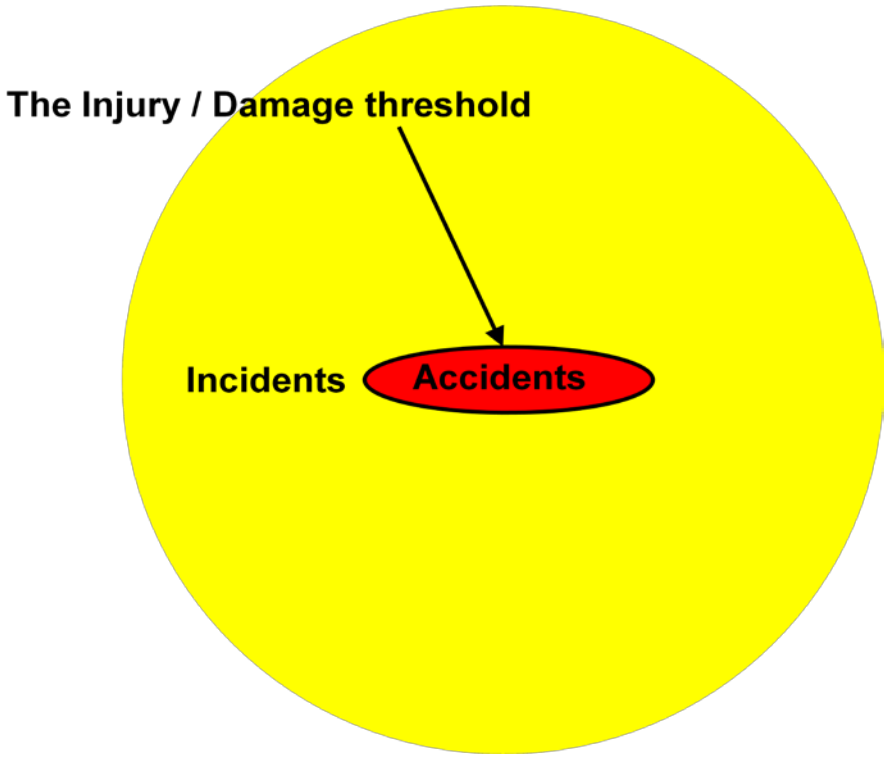


Figure 2: Incidents and accidents

3.2 Accident ratio

A number of studies have been carried out showing the relationship between the number of accidents involving fatal injuries, non-fatal injuries, property damage and near misses.

One of the very first to apply a scientific approach to accident analysis was American industrial safety pioneer William Heinrich. In the 1930's he used empirical data to propose that in a workplace, for every accident that causes a major injury, there are 29 accidents that cause minor injuries and 300 accidents that cause no injuries. This is known as the Heinrich triangle (Fig 3).

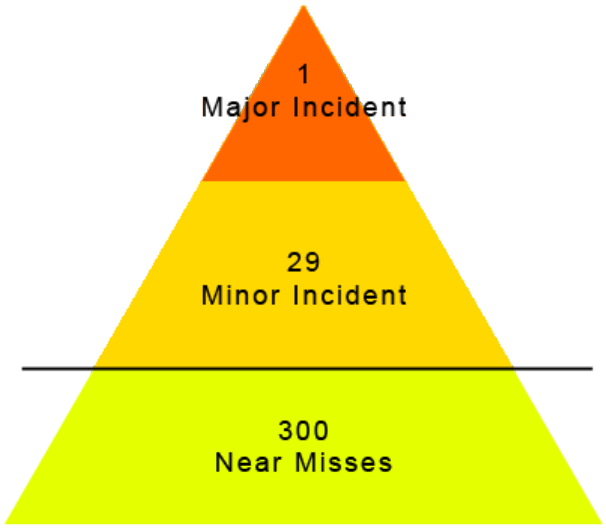


Figure 3: Heinrich Triangle

In 1969, a study of industrial accidents was undertaken by Frank Bird, Jr., who was then the Director of Engineering Services for the Insurance Company of North America. Bird analysed 1,753,498 accidents reported by 297 cooperating companies. These companies represented 21 different industrial groups, employing 1,750,000 employees who worked over 3 billion hours during the exposure period analysed. The study revealed the following ratios in the accidents reported:

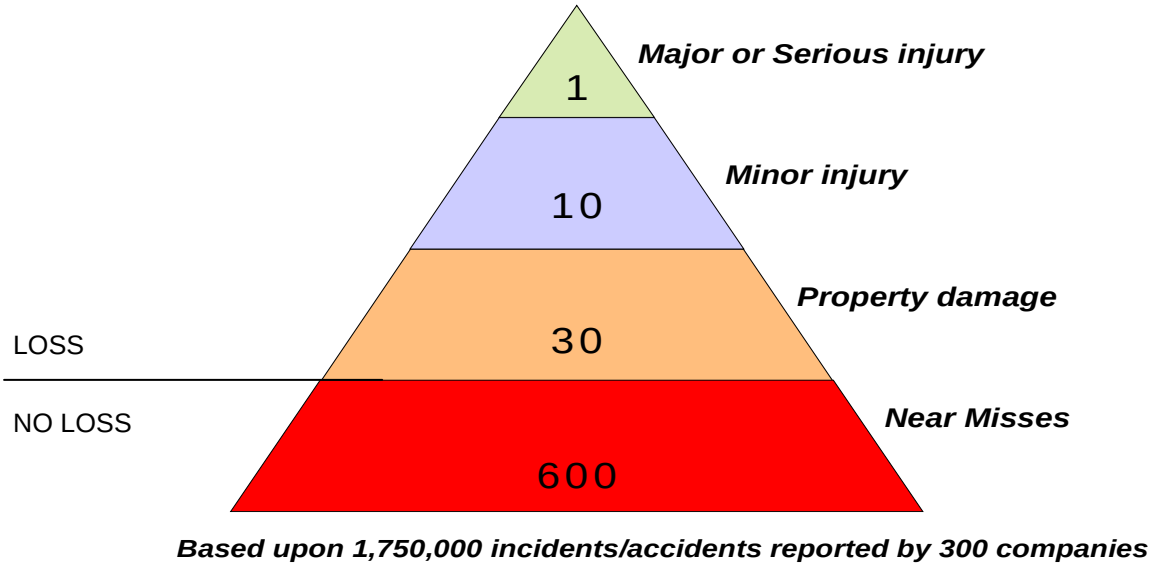


Figure 4: Bird Accident Triangle

There are 2 points to note here:

- That the ratios detailed in the triangle represent accidents reported and incidents discussed with the interviewers and not the total number of accidents or incidents that actually occurred;
- That the data was compiled in 1969 and represents the state of safety management and conditions in the study group at a specific point in time. Management systems, theory and organisation focus on health and safety has changed significantly since that time.

However, by illustrating Heinrich and Bird's triangles it is not the intent to set down firm ratios between different types of incident, the significant point is that major injuries are rare events and that many opportunities are afforded by examining the more frequent, less serious events to take actions

to prevent the major losses from occurring. Furthermore, good safety practice holds that these actions are most effective when directed at incidents and minor accidents with a high loss potential.

In 2003, ConocoPhillips Marine conducted a similar study demonstrating a large difference in the ratio of serious accidents and near misses. The study found that for every single fatality there are at least 300,000 at-risk behaviours, defined as activities that are not consistent with safety programs, training and components on machinery. These behaviours can include bypassing safety components on machinery or eliminating a safety step in the production process that slows down the operator. With effective machine safeguarding and training, at-risk behaviours and near misses can be diminished. This also reduces the chance of the fatality occurring, since there is a lower frequency of at-risk behaviours.

Principally the severity of the outcome of an accident more often depends on an organisation's ability to identify hazards and at risk behaviours and control the associated risks properly. All organisations have by nature a tendency to focus and allocate resources to accident investigations at the top of the triangle but, as indicated above, there are numerous free learning opportunities for effective control and improvement at the base of the triangle and major efforts must be put in this area.

While identifying potential loss and addressing its causes before anything actually happens is beneficial to both people and the business, thorough and effective accident / incident investigation is equally important, as part of a preventive programme, in identifying and understanding the underlying hazards / at risk behaviours and how they interact to cause the accident in the first place.

Figure 5: Hidden cost of accidents

One further point to note is the potential cost benefit of good quality incident investigation to the business. Clearly nothing is more important or more tragic than the human aspects of accidental loss, i.e. injury, pain, sorrow, disability, death. Considering this overriding human element with the potential for profit improvement, you have the best of both worlds - prevent harm and improve business performance. Figure 5 (based on a publication by the UK Health and Safety Executive report on 'The Costs of Accidents at Work') illustrates many of the hidden costs of accidents which come straight out of profit.

4 Accident (Loss) Causation Theory

4.1 Models

There are many models that have been developed to describe the principle of Accident Causation. However, the common theme is that there are a number of factors (acts, conditions, situations, omissions, etc) that are linked in a consequential chain and that all these factors must be present for the accident to occur.

One of the more common models is to consider these factors as slices of “Swiss cheese” (see Figure 6). The holes in the cheese slice represent areas of deficiency related to the specific factor, e.g. deficiencies in training or procedures. When the slices are arranged together any situation where the holes overlap (line-up) to provide a continuous path through the cheese then represent potential for any hazard to result in an accident. When holes are blocked, this represents situations where one or more factors present an effective barrier under the given set of conditions, although the presence of holes indicates an inherent weakness in the control measures.

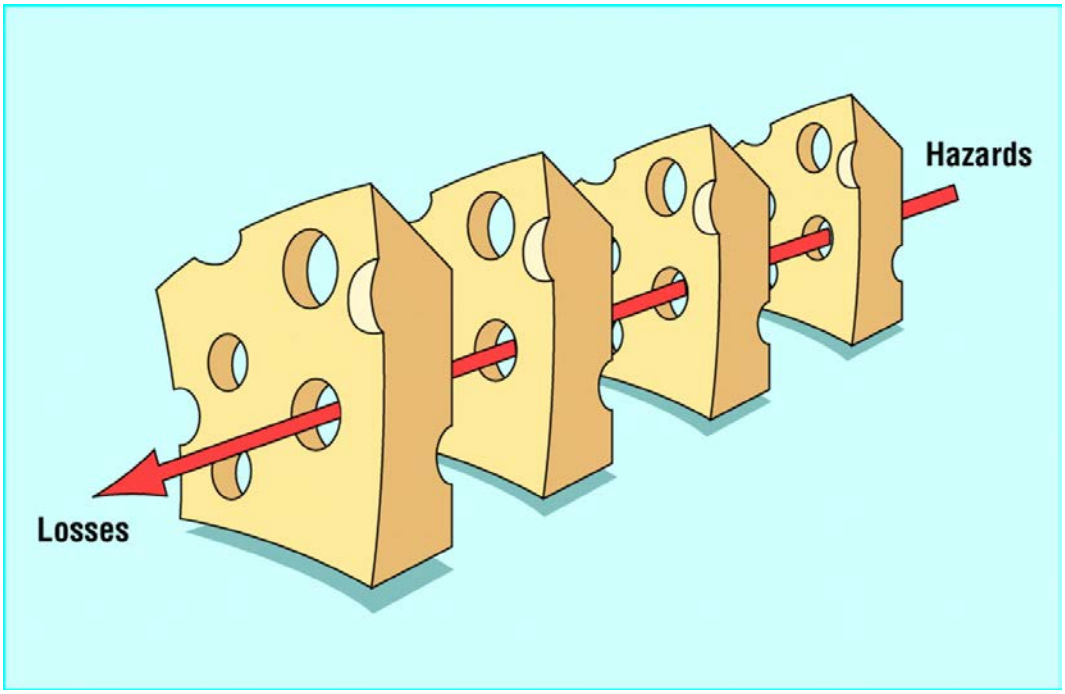


Figure 6: Swiss Cheese accident model

A more sophisticated model is to consider these factors as a series of dominos defined as indicated in Figure 7. This model was first postulated by Heinrich and further developed by Bird.

In this model the LOSS occurs because of the incident; the incident occurs because of a series of IMMEDIATE CAUSES; these immediate causes have an underlying set of BASIC (root) CAUSES; the basic causes are the result of some form of LACK OF CONTROL.

Therefore the lack of control, exercised through the management system, standard, or compliance measure, is the first domino to fall (fail) resulting in the fall of the subsequent dominos and ultimately leading to the incident/loss.

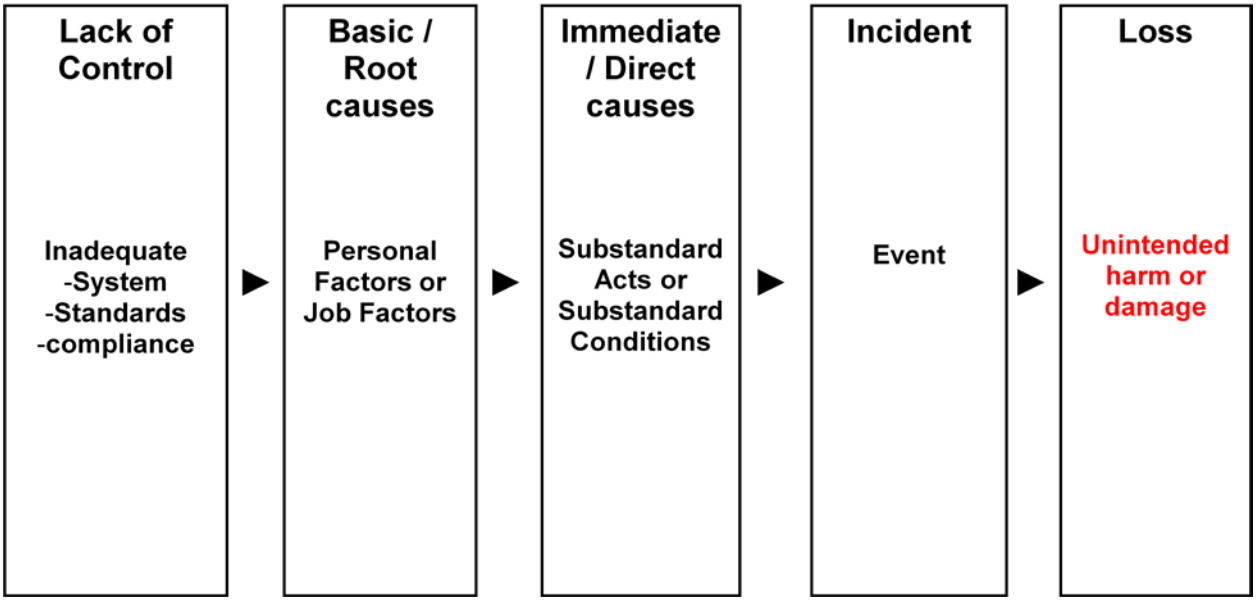


Figure 7: Domino Causation Model

4.2 Causation Theory

Management: Lack of Control: "lack of control by management" begins the process that eventually results in incidents. If management do their job, i.e. "planning, organizing, leading, and controlling," they can prevent incidents from happening at all. If management does not do their job, however, it creates the conditions for certain basic causes from which incidents can arise.

- Inadequate Systems — Management system deficiency
- Inadequate Standards — Not meeting standard or standard not adequate

Basic Causes: basic causes can be defined as belonging to two different groups: Personnel Factors and Job Factors. Personnel Factors reveal why some people "engage in substandard practices (the third domino)" (or what Heinrich called "unsafe acts"). Job Factors reveal why "substandard conditions" (what Heinrich called "unsafe conditions") exist.

- **Personnel Factors**
  Lack of understanding or ability
  Improper motivation (bad attitude)
  Illness, mental, or personal (non-work-related) problems
- **Job Factors**
  Inadequate work
  Bad design or maintenance
  Low-quality equipment
  Normal or abnormal wear and tear

Immediate Causes (Symptoms): unsafe acts and conditions are *symptoms* of **root causes** that dominoes 1 and 2 represent. In an organisational environment where management allows these factors to continue unchecked, incidents can occur.

- Substandard Acts — Something done wrong.
- Substandard Conditions — Something wrong with place, plant, equipment.

Incident (Contact): defined as any event which has the possibility of creating a loss, and a **Loss** event is an "accident." (as defined in 3.1 above). Losses cannot be predicted, either in how and when they will occur.

Each of these sub-definitions may then be further divided in to individual acts, conditions, factors, etc. See Appendix 1 for examples.

Therefore considering a simple example of a pedestrian walking around the corner of a building and being hit by a fork lift truck then a basic assessment could be:

Loss:	Injury to pedestrian.
Incident:	Fork lift truck hits pedestrian.
Immediate cause:	Pedestrian walking in an area where fork lift trucks are operating (ACT); inadequate warning of truck movements/signs (CONDITION).
Basic Cause:	Pedestrian had not been warned of the danger (PERSONAL); poor design of operating area, lack of marked walkways (JOB).
Lack of control:	Inadequate standards defining requirements for design of areas where pedestrians and trucks coexist ; inadequate risk assessment and training.

5 Incident investigation

5.1 Why Investigate

There are hazards in all workplaces; risk control measures are put in place to reduce the risks to an acceptable level to prevent accidents and cases of ill health. The fact that an incident has occurred suggests that the existing risk control measures were inadequate. Learning lessons from other adverse events such as near misses can also prevent costly accidents.

Employers have a responsibility to investigate adverse events for a number of reasons:

1. **Legal reasons:** to ensure the organisation is operating within the law.
2. **Information and insights gained from an investigation**
    - An understanding of how and why things went wrong.
    - An understanding of the ways people can be exposed to substances, conditions that can affect their health, or situations where harm can be caused to the environment.
    - A true snapshot of what really happens and how work is really done. (Workers may find short cuts to make their work easier or quicker and may ignore rules).
    - Identifying deficiencies in risk control management, to learn lessons for the future, transfer of experience to other parts of organisation.
3. **Benefits arising from an investigation**
    - The prevention of further similar adverse events. If there is a serious accident, the regulatory authorities will take a firm line if the organisation has ignored previous warnings.
    - The prevention of business losses due to disruption, stoppage, lost orders, damage to reputation and the costs of criminal and civil legal actions.
    - An improvement in employee morale and attitude towards health and safety. Employees will be more cooperative in implementing new safety precautions if they are involved in the investigation and they can see that problems are dealt with.
    - The development of managerial skills which can be readily applied to other areas of the organisation.
    - Demonstrate organisations concern for protecting the local environment to various stakeholders such as local inhabitants, authorities, investors.

An investigation is not an end in itself, but the first step in preventing future adverse events. A good investigation will enable general lessons to be learnt which can be applied across the organisation.

The investigation should identify why the existing risk control measures failed and what improvements or additional measures are needed. More general lessons on why the risk control measures were inadequate shall also be learned.

5.2 What to Investigate

The type and degree of any investigation will to a large extent depend on the actual severity and outcome of the incident. However, it is just as important to consider the Loss Potential associated with any incident, i.e. it is the potential severity and likelihood of the incident recurring that should determine the level of investigation, not simply the injury or ill health suffered on this occasion. For example: Is the harm likely to be serious? Is this likely to happen often?

Similarly, the causes of a near miss can have great potential for causing injury and ill health. When making decisions consider the potential for learning lessons. For example if a number of similar adverse events have occurred, it may be worth investigating, even if each single event is not worth investigating in isolation. It is best practice to investigate all adverse events which can affect the public.

While the argument for investigating accidents is fairly clear, the need to investigate near misses and undesired circumstances may not be so obvious. However, investigating near misses and undesired circumstances is as useful, and very much easier than investigating accidents. Adverse events where no one has been harmed can be investigated without having to deal with injured people, their families and a demoralised workforce, and without the threat of criminal and civil action hanging over the whole proceedings. Witnesses will be more likely to be helpful and tell the truth.

5.3 When to investigate

The table below may assist in determining the level of investigation which is appropriate for the incident/event. The first step as part of the initial incident response is to consider the worst potential consequences of the adverse event (e.g. a scaffold collapse may not have caused any injuries, but had the potential to cause major or fatal injuries).

Likelihood of recurrence	Potential worst consequence of adverse event			
	Minor	Serious	Major	Fatal
Certain				
Likely				
Possible				
Unlikely				
Rare				

Risk		Minimal		Low		Medium		High
Investigation level		Minimal level		Low level		Medium level		High level

- In a minimal level investigation, the relevant supervisor may look into the circumstances of the event and try to learn any lessons which will prevent future occurrences.
- A low level investigation may involve a short investigation by the relevant supervisor or line manager into the circumstances and immediate, underlying and root causes of the adverse event, to try to prevent a recurrence and to learn any general lessons.
- A medium level investigation may involve a more detailed investigation by the relevant supervisor or line manager, the health and safety adviser and employee representatives and may look for the immediate, underlying and root causes.
- A high level investigation may involve a team-based investigation, involving supervisors or line managers, health and safety advisers and employee representatives. It may be carried out under

the supervision of senior management or directors and will look for the immediate, underlying, and root causes.

5.4 Who should investigate?

For an investigation to be worthwhile, it is essential that the management and the workforce are fully involved. Depending on the level of the investigation and the size of the business, supervisors, line managers, health and safety professionals, union safety representatives, employee representatives and senior management/directors may all be involved (see section 5.3).

A joint approach should ensure that a wide range of practical knowledge and experience can be brought to bear and employees and their representatives can feel empowered and supportive of any remedial measures that are necessary. A joint approach also reinforces the message that the investigation is for the benefit of everyone.

In addition to detailed knowledge of the work activities involved, those involved in the investigation process should be familiar with health and safety good practice, standards and legal requirements. The investigation team shall include people who have the necessary skills and in particular for larger investigations of more serious accidents, investigative skills (e.g. information gathering, interviewing, evaluating and analysing). Those carrying out investigations shall be given sufficient time and resources to enable them to carry out the investigation efficiently.

It is essential that the person leading the investigation should have the authority to implement immediate preventive actions and where necessary to form a team having the required expertise to carry out the investigation. The role and commitment of the supervisor is crucial since he/she represents the first level of management and probably has the best understanding of the local working conditions.

5.5 Initial action – gathering information

There are a lot of things that have to be done when an accident occurs. The success of an investigation comes in the first few moments. A supervisor's initial action varies for every accident. The person on the scene must be the judge of what is critical however it is important to capture information as soon as possible. These steps are guidelines to apply as appropriate:

- Take control at the scene – supervisors need to take charge, directing and approving everything that is done.
- Ensure first aid is provided and call for emergency services.
- Control potential secondary events – these events such as explosions and fire are usually more serious. Positive actions need to be taken quickly after careful consideration of the consequences.
- If necessary, stop all work and prevent unauthorised access.
- Identify sources of evidence at the scene.
- Preserve evidence from alteration or removal.
- Notify appropriate management in the organisation.
- Notify regulatory bodies and insurance companies if appropriate.

5.6 Investigation

It is vital that as much information, facts and evidence is identified and preserved as soon as possible. If necessary, the whole area should be cordoned off to stop anyone disturbing or destroying the evidence. Some evidence will need to be left in place until all the facts have been gathered, other evidence can be moved as soon as photographs have been taken, sketches drawn, equipment examined and records checked (training, maintenance logs/needs, schedules, job procedures and practices etc.). Digital cameras are particularly useful, since pictures may be taken quickly, studied on the spot and sent to other relevant people in the organisation, thereby facilitating an understanding of the accident.

Interviews shall be performed as soon as possible, starting with people involved and witnesses in order to get a description of the event. This should continue with line management and staff in order to get an overview of the procedures, instructions and permits, organisational relations and lines of communication, and workplace contributing factors. It is essential to create an understanding that the aim of interviews is to collect facts in order to learn from the incident and NOT to place blame. Re-enactments can be useful but should be used carefully by the investigators.

From all the information collected, it is important to identify and select all the significant and relevant facts that may have contributed to the incident and not just to rely on the obvious ones which appear at first sight. It is important to understand 'the big picture' i.e. an orientation to the people, equipment, materials and environment involved in the accident.

In summary the essential elements of collecting the facts for the accident are as follows.

- Identifying sources of evidence at scene;
- Preserving evidence;
- Getting the big picture;
- Making sketches, maps, photographs, videos of the scene;
- Conducting interviews and examinations and material failure analysis;
- Checking records;
- Avoiding early judgements.

5.7 Analysing, evaluating and organising information

Numerous accident and root-cause analysis systems have been introduced in recent years.

Following an accident, the immediate causes are normally relatively easy to identify. They are the circumstances which immediately precede the accident and are often referred to as unsafe acts or unsafe conditions. As indicated in section 4.2 a more systematic approach is to divide the cause analysis into:

Immediate causes:

- Acts
- Conditions

Basic causes:

- Personal factors
- Job factors

Root causes:

- Control and management elements

It is more common to refer to immediate causes as substandard acts or substandard conditions; the aim of the investigation being to restore standards of safe working practice and standards of safe working conditions. Immediate causes are the symptoms of the problem and tackling these alone will not prevent the problem re-occurring.

The root causes, which lie beneath the symptoms, are the reasons why persons have used substandard acts and why substandard conditions existed, e.g. inadequate systems, standards or compliance.

There are a number of methods used for accident analysis and investigation each having varying degrees of complexity.

5.8 Fault Tree

One method consists of conducting an analysis using the "fault tree method". In this, a sequence of events is plotted starting with the accident and working to the root causes. Next, a cause and effect

diagram is drawn to establish means of eliminating the causes. The goal of the study is generate an action plan to eliminate as many of the identified root causes as possible.

Example

In an oxygen filling plant, Mr Lemaire starts to fill cylinders with oxygen. He notices a leak on the oxygen valve downstream of the pump and atmospheric exchanger. Whilst trying to shut off the valve, he falls over, hitting a profiled section with a sharp edge on the pump frame and cutting his right leg badly.

A superficial analysis produces the following deductions and measures:

- the accident is put down to lack of care on the part of Mr. Lemaire;
- the valve is replaced with a new one.

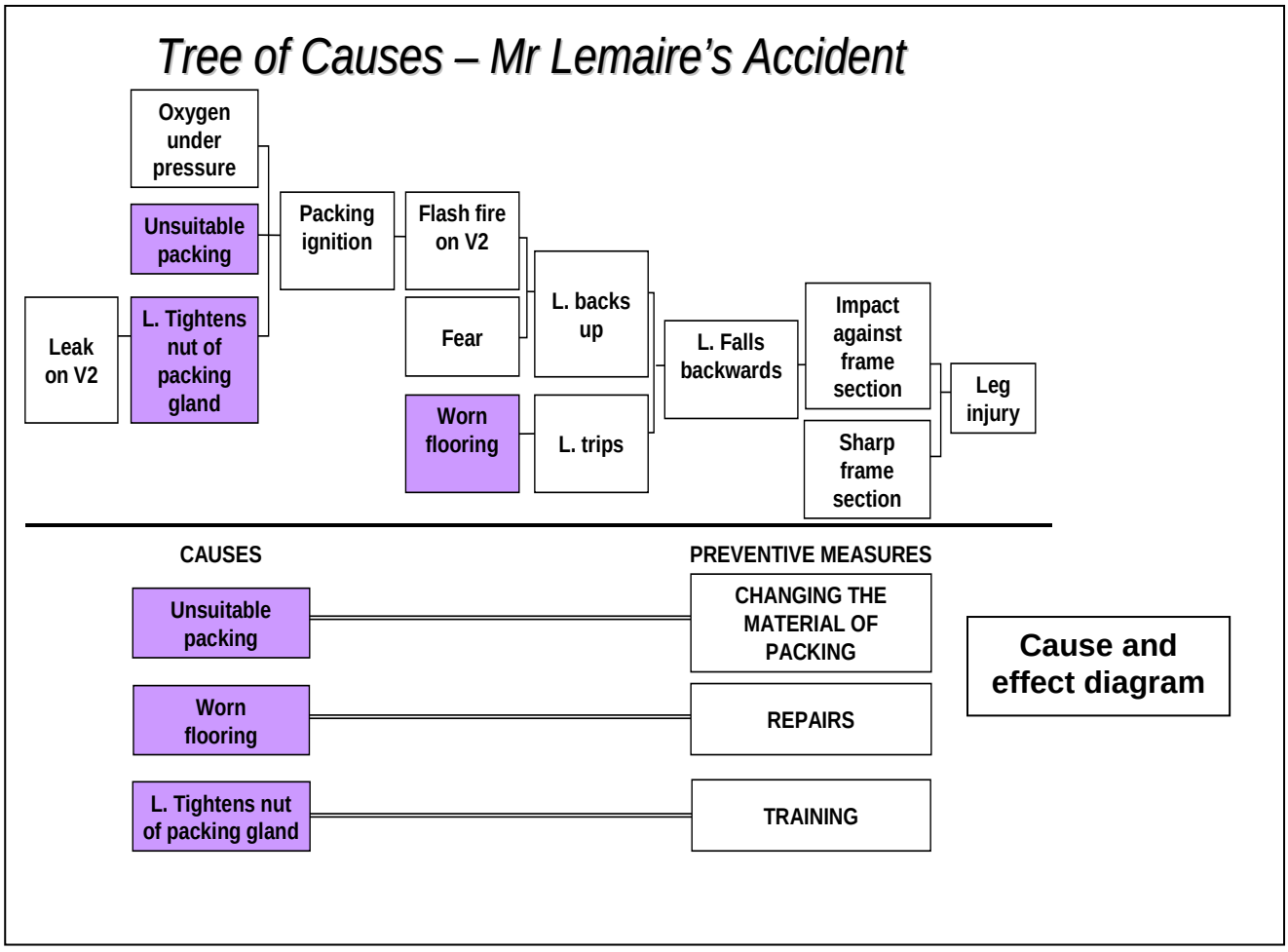
A thorough examination and use of the fault tree technique lead to completely different conclusions.

In actual fact, Mr Lemaire began tightening the oxygen valve when a flash fire occurred. He took fright, and moved backwards with a start, tripped on the damaged floor. This is how he came to hit the pump frame. Furthermore, it was established that the material comprising the valve packing was incompatible with oxygen.

In the end, the following preventive measures were taken:

- the valve trim was replaced (with a new packing made of a suitable material),
- the floor was repaired,
- operators were given training (never tighten pressurised parts).

The fault tree revealed by studying the accident is shown below.



5.9 Systematic cause analysis

Systematic cause analysis is very simply using the basic headings indicated in section 4.2 and under each heading, for example “immediate causes, unsafe acts”, considering the characteristics of the incident related to a predefined list as indicated in Appendix 1. The incident would then be considered against “immediate causes, unsafe conditions”. Under each heading it is often the case that there are several potential unsafe acts and conditions.

Therefore considering again the example in 5.7.1 it is possible to identify:

Unsafe Act:	- Work on running equipment
	- Work / task carried out wrongly
Unsafe Condition:	- Defective equipment/systems/materials
	- Fire or explosion hazards
	- Slippery or rough surfaces
	- Tight/narrow workspace (possibly)

The next step would be to consider each of the “immediate causes” identified in relation to the list of basic factors as indicated in Appendix 1, for example:

Unsafe Act:	>Work on running equipment	> Personal Factors	- inadequate work standards
			- insufficient training
		> Job factors	- experience (possibly)
			- lack of awareness
			- lack of knowledge

This process is then repeated for other unsafe acts and conditions.

Once all potential basic cause factors have been identified (often items tend to repeat themselves) then each basic cause is mapped against a control element, sometimes called “area for corrective action”, e.g. employee training, evaluation of loss prevention work (risk assessment) or engineering controls.

This method will still yield the answers as indicated in 5.7.1. However in addition it also provides a more in depth analysis of the incident and very much brings the focus of corrective and preventive action back to assessing the fundamental management processes that define the equipment used or the level of training.

5.10 Developing corrective actions

Adequate corrective actions to minimise or eliminate a problem can only come from a sound investigation, which has truly solved the problem. Otherwise, the problem will occur again and again but with different symptoms.

An action plan must be prepared with timing objectives and names of people (or department) in charge of the actions. Following up the action plan up to its completion is essential.

5.11 Report

An investigation report should be written in a timely manner. It communicates facts about the incident/accident. **It should identify corrective actions**. Most organisations have a standard investigation report form. Using a standard form has several benefits.

1. It raises all the questions that should be answered; i.e. what was the event? What happened? What were the causes? etc.
2. It provides consistency in data reported. It prompts sharing of information with others. It allows analysis for trends and that helps safety management.
3. It provides follow-up corrective actions.

5.12 Communication

One of the most valuable actions is to circulate information within and outside organisation in an efficient way. The use of photographs is advised since it draws the attention and sensitivity of people and helps them to remember.

Communication actions might be:

Immediate	-	Safety alerts, training, etc.
Short term	-	Newsletters, Group meetings, etc.
Long term	-	Changes in Company Standard or Procedures
	-	Retraining programme

6 Summary: – steps in incident/accident investigation and reporting

- Identify what happened and how the incident/ accident could occur.
- Investigate, analyse, report and record accidents and/or near misses utilising the root cause analysis method and other techniques such as brain storming etc.
- Identify all factors contributing to the occurrence (actions, conditions, circumstances etc,.) and management actions/practices necessary to prevent/control future repetition.
- Determine potential areas where current management practices may need further evaluation or action.
- Develop, initiate action plans and strategies to correct deficiencies.
- Capture and track all actions; ensure they are clearly identified and implemented.
- Manage and control, by means of a system providing for a definite assignment of accountabilities (and completion target dates) that each preventive/corrective action step is implemented.
- Communicate information within and outside organisation.

An internal system should exist and establish that all deficiencies are promptly detected in any other location, plant and activities and that, as mentioned above, suitable preventive / corrective action plans with accountabilities and target dates are enforced to eliminate the identified deficiencies.

7 References:

Heinrich HW (1931). *Industrial accident prevention: a scientific approach*.

APPENDIX 1 – Causation factors

IMMEDIATE CAUSES:

ACTS	CONDITIONS
• Erroneous unloading • Horseplay/careless act • Improper lifting • Improper loading • Improper placement • Improper use of equipment • Improper work position • Inadequate communication • Inadequate implementation of protective measures • Inadequate use of PPE • Inattentive • Indiscreet/lack of concentration • Improper lifting/position for task • Insufficient control of equipment • Insufficient control/follow-up • Machinery and/or equipment incorrectly used • Neglected to tidy up • Operating equipment without authority • Other • Put safety system or equipment out of function • Removal of safety devices • Safety devices put out of function • Signs or barricading not respected • Under influence of alcohol/drug • Use of defective equipment • Used wrong or defective equipment • Work on running equipment • Work/ task carried out wrongly • Wrong working position	• Bad housekeeping/untidy work space • Chemical Exposure • Dangerous or unhealthy working environment • Defective equipment • Defective equipment/systems/materials • Defective tool/equipment • Ergonomics • Extreme weather condition • Falling object • Fire or explosion hazards • Fire/danger of explosion • High noise level • Inadequate communication/warning system • Inadequate preparing/performance • Inadequate protective equipment • Inadequate tool • Incident or proposal omitted • Insufficient or excessive illumination • Insufficient preparedness • Insufficient safety devices • Insufficient ventilation • Lack of planning • Light/sight • Misplaced or loose objects • Other conditions • Parallel Activities • Platform Movement • Poor psycho-social working environment • Psycho-social Condition • Slippery or rough surface • Temperature extremes • Tight/narrow work space

BASIC CAUSES:

PERSONAL FACTORS	JOB FACTORS
• Abuse • Design/construction • Inadequate leadership or guidance • Inadequate maintenance • Inadequate purchase • Inappropriate design/construction • Inappropriate tools or equipment • Inappropriate work standards • Incorrect/Inadequate performance • Insufficient communication • Insufficient infrastructure • Insufficient training • Lack of procedures • Other job factors • Unsatisfactory control • Wear and tear	• Experience • Inadequate mental/psychological capability • Inadequate physiological capability • Lack of awareness • Lack of knowledge • Lack of respect for instruction/laws • Lack of skill • Mental/psychological stress • Motivation • Other personal factors • Physical stress • Poor motivation

LACK OF CONTROL:

CONTROL ELEMENTS
For all of the causes identified below, considerations include: A: Inadequate requirements/guidelines B: Requirements/guidelines not appropriate C: Requirements/guidelines not followed Control elements • Accident/incident analysis • Accident/incident reporting and investigation • Analysis of critical tasks and procedures • Appointment and placement • Emergency preparedness • Employee training • Engineering controls • Evaluation of loss prevention work • Group communication • Health care, occupational health or work environment • Inspection and maintenance • Leadership and administration • Management training • Motivation initiatives • Observation of workmanship • Personal communication • Personal protective equipment • Purchasing controls • Safety rules and work permits