

PETRONAS TECHNICAL STANDARDS
HEALTH, SAFETY AND ENVIRONMENT

**HAZARDS AND EFFECTS MANAGEMENT
PROCESS
(GUIDELINE)**

PTS 60.0401

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PREFACE

Petronas Technical Standards (PTS) are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice. The objective is to set the recommended standard for good technical practice applied by PETRONAS in oil and gas production facilities, oil refinery, gas processing, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

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AMENDMENT RECORD SHEET

Chap. No.	Section No.	Description	Issue No.	Date	Revision No.	Date	Approve by: (initial)
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1. **INTRODUCTION**

Hazards and Effect Management Process (HEMP) is a portfolio of tools and techniques available for the management of HSE hazards. This process is particularly important for those responsible for the management of hazards.

The objectives of this guide are to:

- provide a general overview of the Hazards and Effects Management Process
- describe the tools and techniques most commonly used in PETRONAS
- assist in the selection of the appropriate tools and techniques for Hazards and Effects Management
- provide guidance on the integrated application of the tools and techniques and
- outline how the results are to be incorporated within the HSE Management System.

This document, PTS.60.0401, describes:

- the need, within the context of an HSE Management System, to define both the techniques and tools commonly in use together with the competencies required for their effective application
- the more common terminology and concepts used in the analysis of hazards and effects and the determination of risk
- the stages of the Hazards and Effects Management Process and its role within the HSE Management System. The role of experience, codes and standards, checklists and structured techniques are discussed
- in summary the various structured review techniques available in Petronas to support the process.

1.1 **ELEMENTS OF THE HSE MANAGEMENT SYSTEM**

The HSE Management System contains the following elements:

- Leadership and Commitment
- Policy and Strategic Objectives

- Organisation, Responsibilities, Resources, Standards and Documentations
- Hazards and Effects Management Process (HEMP)
- Planning and Procedures
- Implementation and Monitoring
- Assurance
- Management Review

The Hazards and Effects Management Process (HEMP) is central to the effective implementation of the HSE Management System. The process ensures that hazards and potential effects are fully evaluated. To achieve this, a number of tools and techniques are used. These are described in this document.

1.2 TOOLS FOR THE HAZARDS AND EFFECTS MANAGEMENT PROCESS

1.2.1 Selection of tools

The objectives set out in the HSE Management Systems (HSE MS) and subsequently the HSE Case effectively become the acceptance criteria for the risk determined in the hazards and effects management process.

This document is designed to identify, specify and aid the effective selection of an integrated suite of tools and techniques. Most of these have been in use for some time. The various tools and techniques have been collated for ease of reference, to demonstrate their relationship to each other and to describe their input to the HSE MS and HSE Case. As stated above this document does not specify when to use the tools, this is done in the documents describing the business activities. A very broad framework of tools, techniques and guidelines used in hazards and effects identification and assessment during the life cycle is provided in Appendices I and II.

Codes, standards, checklists, as well as individual experience and judgement are in no way replaced by any of these techniques and continue to play a vital role.

1.2.2 **Application and competence**

Successful application of a technique is largely dependent on the experience of the personnel using it. For this reason, familiarity, competence and training are important factors to be taken into consideration when planning and resourcing projects and drafting contract specifications. The competence levels required to operate these techniques effectively may then be identified and the relevant resources secured.

The application of tools in the hazards and effects management process such as Environmental Assessment, Health Risk Assessment and QRA will continue to involve specialists but their output can now be brought together with other studies in a common HSE Management System. Specialist assistance when using other tools and techniques may also be necessary. However the successful application of any tool and technique will always be dependent on the participation of the staff involved in the activities under study. Most of the tools described require a multi-disciplinary approach.

Health, Safety and Environmental management is no different from any other aspect of Petronas business and remains a line responsibility. HSE therefore falls under the same management system. H, S and E have been considered together in this document although external reasons may exist for presenting certain studies separately. For example, when two separate authorities deal with safety and environmental regulation and require separate submissions.

2 **HAZARDS AND EFFECTS TERMINOLOGY**

This chapter provides an overview of the more common terminology and concepts used in the analysis of hazards and effects and the determination of risk.

A comprehensive list of terms and their definitions is provided in the glossary of this document.

2.1 **HAZARDS, EFFECTS AND INCIDENTS**

A hazard is defined as:

'The potential to cause harm, ill health or injury, damage to property, plant, products or the environment, production losses or increased liabilities'. This definition can be extended to include social/cultural disruption.

This represents a specific use of the word hazard, which in more common usage can mean danger, chance or risk. Risk is defined in item 2.4. It is important to recognise the adopted definition of this basic term and to be consistent when

using common techniques. Hazards should not be confused with hazardous activities e.g. drilling, lifting a load with a crane, etc.,. Examples of hazards are: hydrocarbons under pressure, objects at height, electricity. Appendix III contains a listing of generic hazards.

The terms 'chronic' and 'acute' are used to differentiate between hazards and effects associated with continuous discharges and occupational exposure (prolonged) and those relating to one off events, (health, safety and environmental incidents) which might include poisoning, oil spills, fires and explosions.

In environmental terms, 'chronic' effects are sometimes referred to as 'routine' and are defined as the result of planned emission or discharge to the environment. Such releases may include flaring of gas, or discharge to sea of produced water following repeated and prolonged exposure to relatively low levels or concentrations of a hazardous agent.

The aim is to control all health and environmental hazards and effects within defined limits. Under health, for example, controls for benzene define levels in air for long term exposure. For environment, for example, controls for flaring may include limiting the volume of gas disposed of, defining criteria for the combustion efficiency and defining environmental quality standards for combustion products. Similarly, control of noise emission will be based on noise limits, which will be set for a given location.

An effect in the context of this manual is usually an adverse effect either on the health or safety of employees or the public. An environmental effect is any direct or indirect impingement, whether adverse or beneficial, upon the environment of the activities, products and services of the company. This also includes impact on social and cultural systems.

The (undesired) release of a hazard is a hazardous event. If the hazardous event is the first event resulting from the release of a hazard then it is called a 'Top Event'. This is the undesired event at the end of the fault tree and at the beginning of an event tree (see item 2.5). In the context of environmental routine hazards, the undesired event can relate to the breaching of defined limits, such as oil in water discharged to sea or noise levels in and around locations, or in the context of health hazards, this relates to exceeding occupational exposure limits and other standards for the full range of agents hazardous to health.

An incident is an unplanned event or chain of events, which has the potential to cause injury, illness and/or damage (loss) to assets, revenue, the environment or third parties. An incident involves the release of a hazard, which includes the exceedance of defined limits.

2.2 THREATS AND BARRIERS

A threat in the context of this document is something that could potentially cause the release of a hazard i.e. an incident. Examples are corrosion, fatigue damage, poor visibility, overpressure, lack of knowledge/competence, etc.

To prevent a threat or combination of threats ultimately resulting in the release of a hazard, some kind of counter measures are necessary. These measures are called barriers. In the case of corrosion as a threat, for example, appropriate barriers could be a corrosion-resistant coating, inspection programmes or corrosion allowances. For overpressure one barrier would be a pressure relief system. Environmental barriers could include operational controls, e.g. traffic restrictions for noise, or hardware controls, e.g. provision of water treatment equipment. Health barriers include, for example local exhaust ventilation (LEV) and PPE.

Barriers may be physical (shields, isolation, separation, protective devices) or non-physical (procedures, alarm systems, training, drills).

2.3 CONSEQUENCES, MITIGATION AND RECOVERY PREPAREDNESS MEASURES

Should the barriers fail to prevent or avoid the release of a hazard then some kind of counter measures are required to limit the consequences of the hazardous event or effect. The purpose of these countermeasures is the mitigation of consequences and to aid in reinstatement. One example of mitigation is a fixed fire protection system, another would be the evacuation of personnel from the area. Those measures aimed at reinstating or returning the situation to normal operating conditions are also called recovery preparedness measures. All such measures ranging from the first steps in mitigation through to reinstatement of the operation are termed recovery preparedness measures.

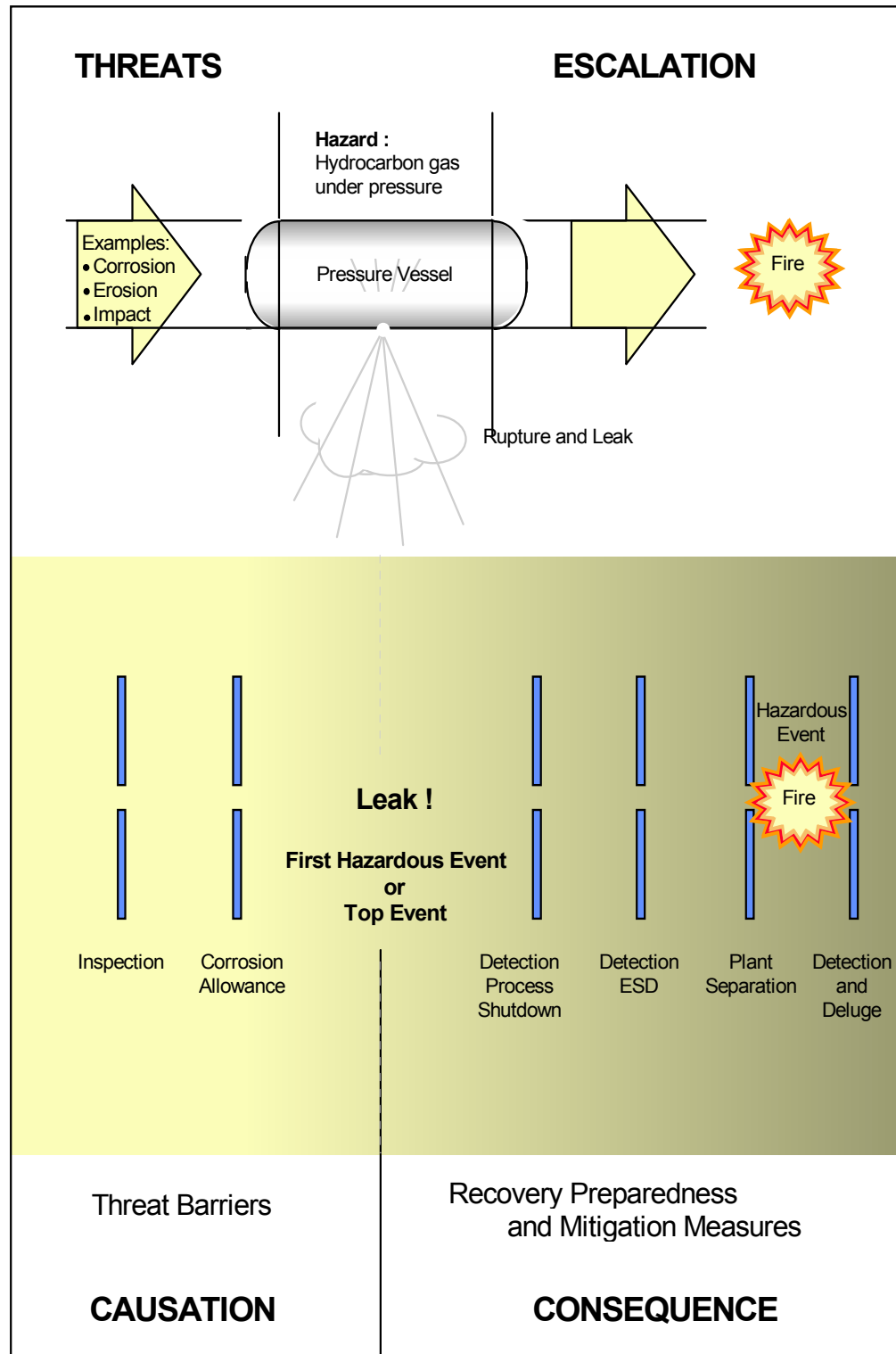


Figure 2.1 Terminology: Acute or incidental release (safety example)

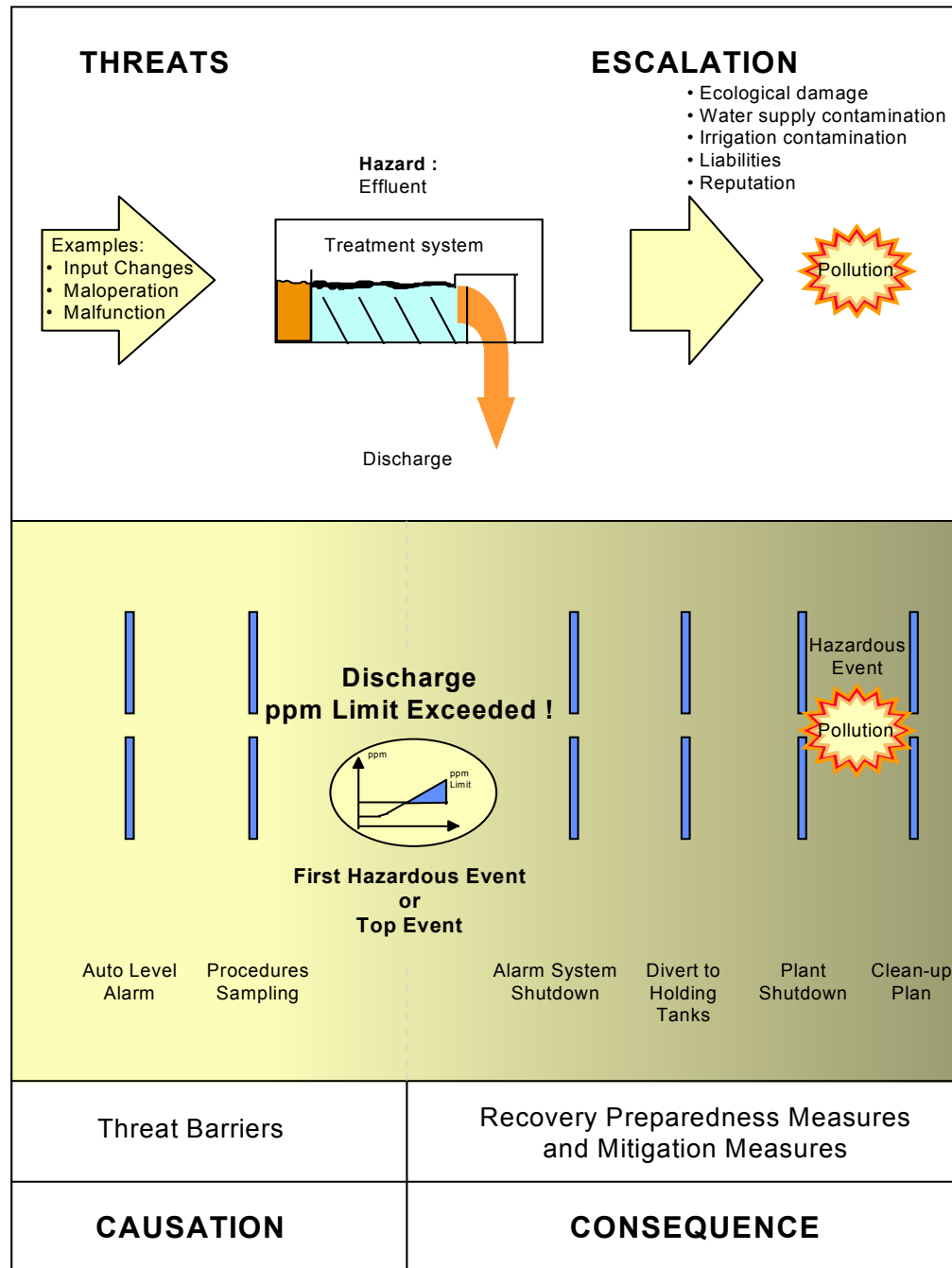


Figure 2.2 Terminology: Chronic or routine release (environment example)

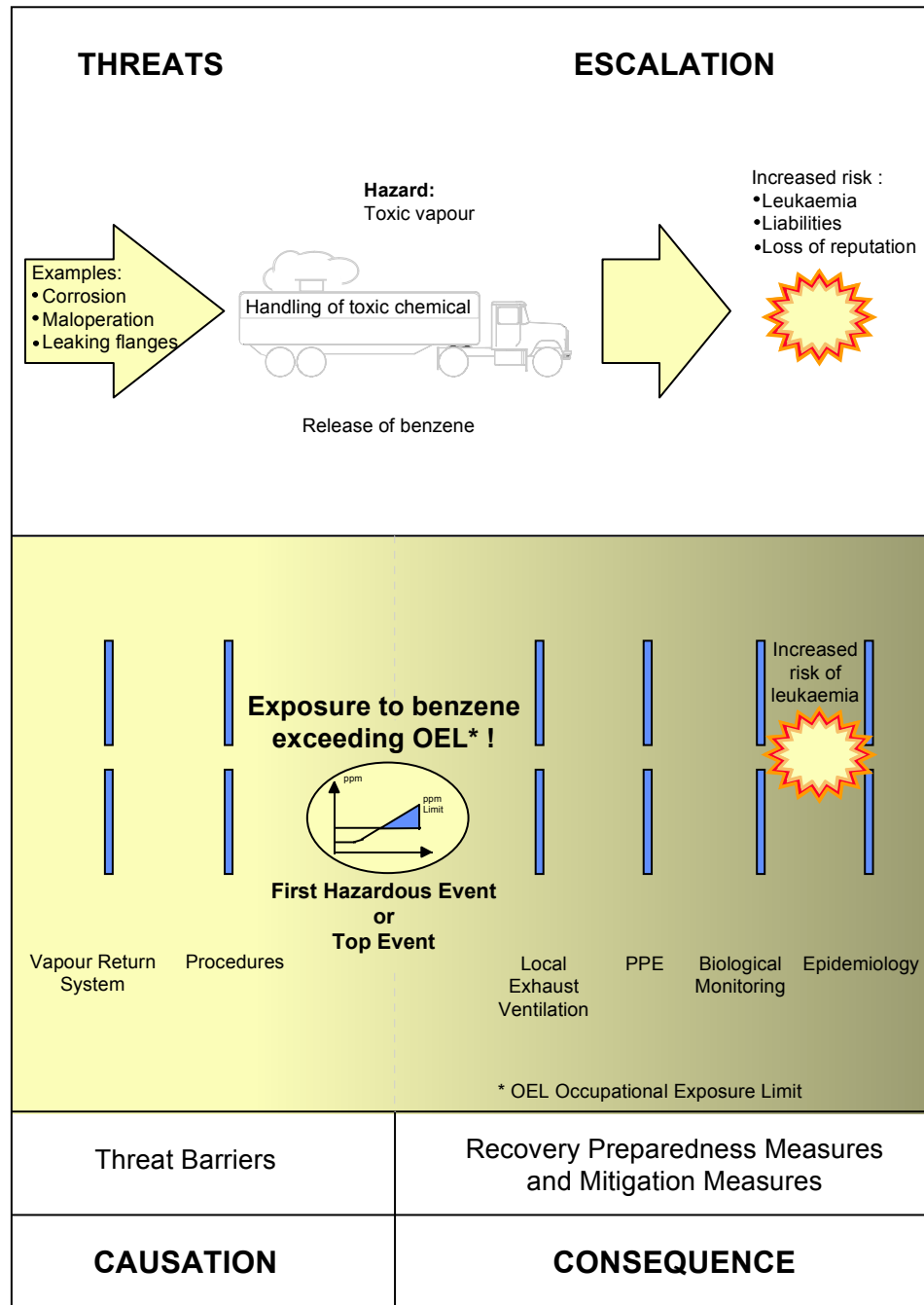


Figure 2.3 Terminology: Chronic or routine release (health example)

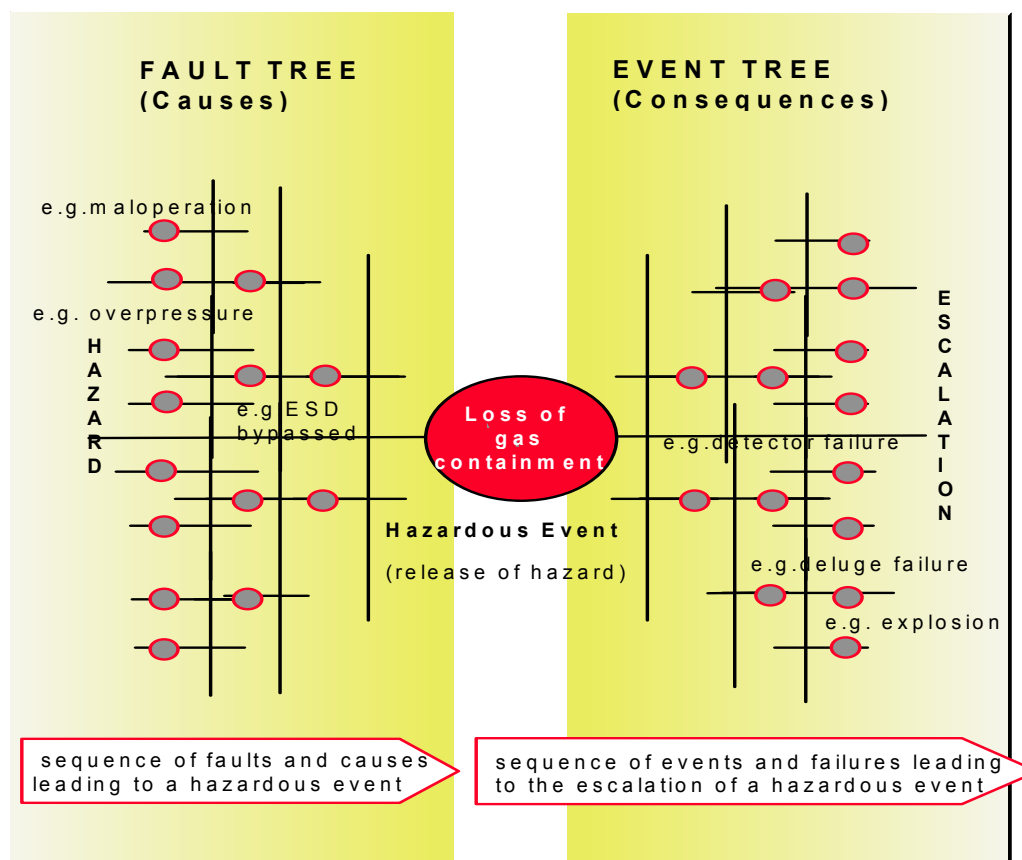


Figure 2.4 Cause consequence diagram (bow tie)

2.4 RISK

'Risk' combines the chance that a specified undesired event will occur and the severity of the consequences of the event or otherwise is the product of the probability of occurrence and the severity of the consequences. To determine the 'risk' of a specific 'hazardous event' taking place therefore requires information on the likelihood of the event taking place and the severity of the adverse consequences that could be expected to follow from it.

The terms 'probability', 'likelihood', 'frequency' and 'chance' are often used interchangeably however in the HEMP terminology, the following apply and should be consistently used:

- likelihood and chance both indicate the possibility of something happening

- frequency is a rate, e.g. number of incidents per hour
- probability is a ratio. It indicates the number of chances of something happening to the total number of chances.

2.5 FAULT AND EVENT TREES

A common way of understanding the possible threats or causes that could lead to the unplanned release of a hazard is to present them diagrammatically using a fault tree. In a similar way after the release of a hazard an event tree may be used to determine and display the potential outcomes or consequences.

Fault Tree Analysis is used to show the sequence of possible threats or causes that could lead to the release of a hazard. The fault tree leads to a single point where the undesired event has taken place or where the hazard has been released. This is known as the Top Event and represents the transition from the Fault Tree (threats/causes) to the Event Tree (consequence).

The Event Tree is made up of nodes which correspond to the different stages in an escalating incident sequence. The lines which lead out of each node correspond to the paths of success or failure in mitigation of the incident.

The whole sequence showing the progression from any cause, (Fault Tree) through the Top Event to the full range of consequences (Event Tree), for a single hazard can be represented in a single diagram (often called a 'bow tie') as shown in Figure 2.4. In a quantitative assessment such as QRA, a number of hazards will be considered together, however in qualitative assessment it is normal to consider one hazard or one bow tie.

For qualitative and quantitative risk assessment the same process is used (ie bow tie) but in QRA, risks are quantified initially per Top Event then summated for a number of scenarios and hazards.

2.6 LIKELIHOOD AND CONSEQUENCE (OR EFFECT)

The Likelihood of a Top Event occurring may be determined by quantitative evaluation of the possible threats or from historical data bases.

Lack of good data may limit the development of a fault tree however in some circumstances the historical frequency of the top event may provide an adequate time.

Consequence analysis can be applied to assess HSE aspects for a range of scenarios and typically involves the use of predictive models. Examples include the use of:

- physical effects models for predicting the behaviour and loading from potential hydrocarbon releases (dispersion, fire, radiation, explosion and smoke) in terms of flammable limits, heat radiation, explosion overpressure, etc.
- physical consequence models for predicting the consequence of the effects of hydrocarbon release events (structural damage, vessel integrity loss, etc.)
- air and water dispersion models for predicting the behaviour of discharges to the atmosphere or water bodies respectively

3 HAZARDS AND EFFECTS MANAGEMENT PROCESS (HEMP)

3.1 THE STEPS IN THE PROCESS

The Hazards and Effects Management Process (HEMP) was originally developed to provide a structured approach to the analysis of safety hazards throughout the life cycle of an installation. The environmental and health risk assessment processes fulfil a comparable function with respect to environmental and health hazards at all stages of the life cycle. These assessments are based on the same concept and have been brought together as HEMP. The process is applicable to all business processes in the life cycle of an operation from inception to abandonment. The tools and techniques available are applied in a logical and rigorous way, setting acceptance criteria and screening against them as the process proceeds. The arrangements identified as necessary to manage assessed threats and potential consequences and effects are then incorporated in the design phase or for existing operations it is necessary to verify that what is in place is suitable and sufficient. If not, then remedial action is taken and all necessary procedures are incorporated into the HSE Management System.

The principles of 'identify', 'assess', 'control' and 'recover' are the basis of HEMP, with the individual stages summarised in the following steps:

1. Identify Hazards and Potential Effects
2. Evaluate Risks
3. Record Hazards and Effects
4. Compare with Objectives and Performance Criteria

5. Establish Risk Reduction Measures.

Step 1 : Identify hazards and potential effects

Systematically identify the hazards, the threats and potential hazardous events and effects which may affect, or arise from, a company's operation throughout the total life cycle of the operation.

Step 2 : Evaluate risks

Systematically evaluate (assess) the risks from the identified hazards against accepted screening criteria, taking into account the likelihood of occurrence and the severity of any consequences to employees, assets, the environment and the public. This includes the risks associated with deviation from limits set for environmental and occupational health hazards.

Step 3 : Record hazards and effects

Record all those hazards and effects identified as significant in relation to the screening criteria in one of the following documents:

- HSE MS Activities Catalogue
- HSE Activity Specification Sheets
- Hazards and Effects Register
- HSE Critical Operating Procedures
- Manual of Permitted Operations.

These documents will then be included in Parts 3 and 5 of the HSE MS and HSE Case.

Step 4 : Compare with objectives and performance criteria

Compare the evaluated risks against the detailed HSE objectives and targets for the project or installation. For all cases these targets must be maintained and be consistent with the Company Policy, and Strategic Objectives. Performance standards at all levels must meet the criteria set in the HSE Case which in turn must comply with the Company's HSE Management System.

Step 5 : Establish risk reduction measures

Select, evaluate and implement appropriate measures to reduce or eliminate risks. Risk reduction measures include those to prevent or control incidence i.e. reducing the probability of occurrence and to mitigate effects i.e. reducing the consequences. Mitigation measures include steps to prevent escalation of developing abnormal situations and to lessen adverse effects on Health, Safety and the Environment. Risk reduction measures also include recovery preparedness measures, which address emergency procedures as well as restoration and compensation procedures to recover.

Revisit Step 3 to record fully the activity/task requirements.

3.2 IMPLEMENTATION OF HEMP

The Hazards and Effects Management Process can be implemented at any point in the life cycle of a facility or operation as:

- When planning the development of new facilities, reviewing existing facilities, or planning for the abandonment and decommissioning of existing facilities, the focus is on the identification and assessment of hazards and effects that may be avoided, reduced or eliminated.
- In the operational and maintenance phase, the focus is on control of hazards and effects by procedures and the development and implementation of effective recovery preparedness measures.
- In the abandonment and decommissioning stages the focus is directed towards safe clean up and rehabilitation.

People involved in operational activities however should always be alert to identify new hazards particularly in non routine operations.

3.2.1 Assets: planning and review

In a new development, the HEMP will normally be iterative, beginning on a wide basis with little detail and then progressing through the development cycle as more detail becomes available.

In the review of an existing development a similar iterative approach may be adopted starting with a wide approach on general issues then converging on areas of specific concern and more detailed assessments.

This management process is applied to all hazards and potential effects. Those engaged in design and planning activities who utilises tools, such as HAZOP, Health Risk Assessment or Environmental Assessment are already familiar with this approach.

Appendices I and II give an indication of when the tools and techniques are used during the life cycle of a development and in the development of an HSE Case for an asset.

The output from the various tools and techniques used in the HEMP in the planning and review stages of a new development is used primarily to refine the design by identifying the hazards and threats, removing them if possible and making the design as inherently safe to operate as practicable. The output therefore primarily concerns the hardware although the design planning phase can profoundly affect all subsequent stages of the development.

3.2.2 **Activities: planning and review**

This relates to the preparation for practical physical activities involved in the implementation of plans. This preparation should involve those carrying out or supervising the activity. The techniques for the identification and assessment of hazards used in the planning and review stages are also applicable but in the operational phase tend to be more focused on procedural aspects rather than hardware design.

In the implementation or operations phase, planning activities such as the systematic preparation of Permits to Work and Job Hazard Analysis address all the steps of the HEMP.

The PTS' on the basic Permit-to-Work System, 60.2001, and Job Hazard Analysis, 60.2005, can be used for a team review of the procedure for a repeated activity or as a one-off review of a new activity.

PTS 60.2115 'General Workplace Practices' contains activity specification sheets and hazard register sheets for typical HSE activities and hazards encountered in the workplace.

The Manual of Permitted Operation (MOPO) describes conditions where specific activities cannot be carried out at the same time and is described in PTS.60.0303 - Documenting an HSE Management System and HSE Case.

Waste management procedures, described in the PTS 60.3005 - Waste Management Guide, provide information for the inclusion of waste management activities.

The output from the various tools and techniques in the HEMP for operational-type activities will be used in the development and review of working procedures and form part of the HSE Case for the operation of the facility. For a significant or new activity, such as a major construction project, a seismic or drilling campaign or abandonment, the output from the various tools will be included in an HSE Case.

For a smaller work scope usually confined to one contract, the HSE Case is sometimes called an HSE Plan or where the work or operational task is one of many to be undertaken, terms like 'Work Procedure' or 'Work Statement' are sometimes used. All these descriptions only reflect the scale of the operation.

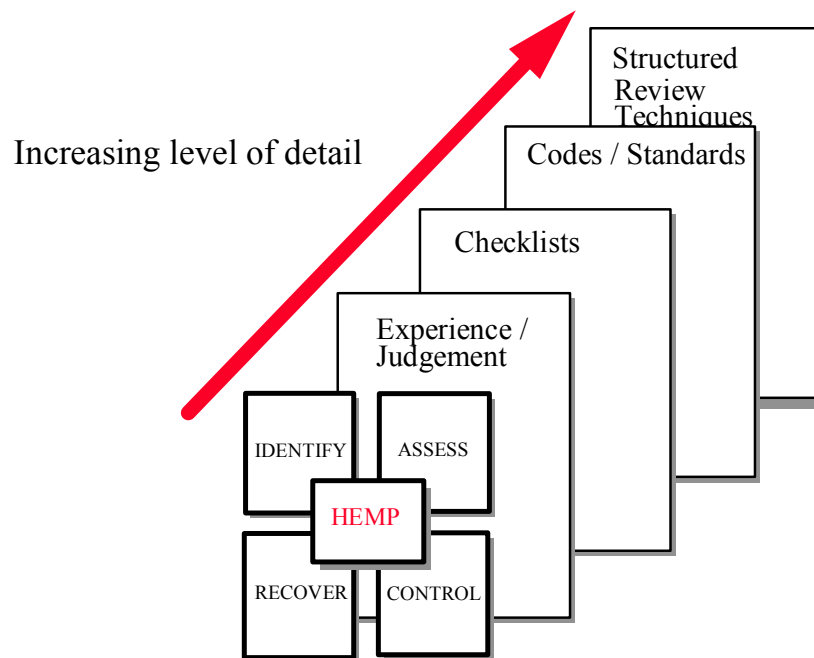
The most important point is that in their preparation the steps of the Hazards and Effects Management Process must be followed. That is hazards and potential effects must be identified and assessed and Control and Recovery Preparedness measures must be developed and in place ahead of time.

3.3 APPROACHES TO THE HAZARDS AND EFFECTS MANAGEMENT PROCESS

Hazards can be identified and assessed in a number of ways. The hazard identification and assessment process is based on the following:

- experience / judgement
- checklists
- codes and standards
- structural review techniques

Figure 3.1 APPROACHES TO THE HAZARDS AND EFFECTS MANAGEMENT PROCESS



3.3.1 Experience / judgement

The knowledge of experienced staff provides a sound basis for hazard identification and assessment. One can draw on experience gained from different aspects of the PETRONAS' business in different locations. Practical

staff experience gained in the field and feedback from incidents, accidents and near misses is invaluable.

3.3.2 Checklists

These are a useful way of ensuring that known hazards and threats have all been identified and assessed. The use of checklists, however, must not be allowed to limit the scope of review. They are normally drawn up from standards and operational experience and focus on areas where the potential for mistakes is high or where problems have occurred in the past. Hazard Registers taken from the life cycle of previous developments are particularly useful as a basis for checklists. They should be maintained throughout the life of the development and include both the operational and abandonment phases (Ref. 1).

Table VI.1 is a checklist called the Hazard Hierarchy, which includes health, safety and environmental hazards previously identified by OPU/JVs. The checklist approach is used in several techniques such as HAZID, HAZOP and FIREPRAN, etc.,

3.3.3 Codes and Standards

These reflect collective knowledge and experience, accumulated on the basis of national or international operations. They generally focus on hazard assessment and control, since the hazard is inherent and recognisable. Codes and standards usually contain information on hazards applicable to a particular type of operation. The designer of a pressure vessel relief system, for example, can use a PTS or ISO Standard to find detailed guidance on the relief cases that should be considered. In some cases compliance with prescriptive standards alone will reduce risk to 'as low as reasonably practicable'. Similarly, the acceptability or otherwise of emissions or discharges to the environment or release of agents harmful to health can be assessed by reference to environmental quality standards and occupational health exposure limits. For environmental and occupational health, the process begins with an inventory of emissions and effects agents hazardous to health respectively.

Codes and standards can therefore provide guidance on all four steps of identify, assess, control and recovery.

Where new or non-standard designs are concerned, especially ones containing configurations with multiple interfaces, it is unlikely that all the possible interactions can be identified using codes and standards alone. In more complex facilities such as offshore process facilities, other hazard management tools will be required.

3.3.4 Structured review techniques

The following chapters of this document describe the Structured Review Techniques and Procedures in current use. Some of these techniques were initially developed for use in safety management others have been specifically developed for environmental and occupational health management often using similar principles as for safety management. One example is HAZID (Hazard Identification) and another is HAZOP (Hazard and Operability Study). With interpretation, these techniques are also capable of addressing emissions, discharges, waste generation and occupational exposure to hazardous substances, etc. Many of the techniques described also contain screening and acceptance criteria for Controls.

4 STRUCTURED REVIEW TECHNIQUES

Structured review techniques are available for all phases of the 'identify, assess, control and recover' process. The recommended techniques are presented in this chapter under the same headings as used in Chapter 3, i.e.:

- Identify Hazards and Potential Effects
- Evaluate Risks
- Record Hazards and Effects
- Compare with Objectives and Performance Criteria
- Establish Risk Reduction Measures.

4.1 IDENTIFY HAZARDS AND POTENTIAL EFFECTS

The selection of the appropriate techniques depends upon the information available and the phase of the project or maturity of the operation.

For Petronas facilities, a generic Hazards and Effects Hierarchy has been generated and is included in Appendix III. This provides a structured listing of hazards and effects and attributes which can be used as a completeness check during hazard identification. The hierarchy provides the basis for a computerised approach to the systematic identification and assessment of hazards and their effects.

Table 4.1 Techniques for planning and review of assets

Technique	DESCRIPTION	Reference
HAZID (Hazard	A structured brainstorming technique that is	PTS 60.2004

Identification)	particularly useful in the early stages of a development, either as a stand alone exercise or as part of a more general review. The 'prompt' or 'checklist' approach guides the less experienced and prompts the experienced. Success when using the technique depends upon a properly constructed team being well managed and having the opportunity to think beyond the checklist and identify the unusual. The same technique can be applied for health hazards associated with the living environment (e.g. tropical diseases) and lifestyle (e.g. substance abuse).	
Health Risk Assessment	Is used for identifying and assessing occupational health hazards and the controls needed to manage them effectively. Chemical, physical, biological, ergonomic as well as psychological aspects of the occupational environment are included.	PTS.60.1400
Chemical Health Hazards	Supplements the general guide on Health Risk Assessment by providing specific additional advice on assessing risk to health arising from chemical agents in the work place.	PTS.60.1400
Human Factors	Encompasses a number of techniques directed at the assessment of the human element of the management of hazardous events from design through to emergency response.	PTS.60.0103
Environmental Aspect Impact Assessment Guide(EAIA)	Includes development of an environmental profile which provides information necessary to: Build an environmental description of the area or location and its environment before development Assess the beneficial and/or adverse effects of the development Identify mitigation measures Prepare a plan to enable measures to be implemented. Also applicable to ongoing activities	PTS. 60.3202
Monitoring Soil and Groundwater Quality	Provides guidance on assessing soil and groundwater quality at Petronas locations from initial desk studies to more detailed site investigations.	PTS.60.3303
Social Impact Assessment	Describes the component parts of a social impact assessment including relationship to	

	the natural environment, cultural and historical attitudes and sensitivities, population characteristics and political social institutions. Means to involve the wider public are seen as critical.	
HAZOP (Hazard and Operability Study)	One of the most widely accepted and powerful of the hazard identification and assessment tools available for reviewing the design of process facilities. It is carried out in varying degrees of detail throughout a project after design checks have been completed. HAZOP is not a design tool but a supplementary team checking exercise, which also includes the operational aspect of a design. It is unusual to make other than a subjective assessment of the consequences of a particular failure scenario during a HAZOP. The HAZOP technique has been extensively applied with success by others to areas like maintenance, drilling, etc.	PTS 60.2209
FIREPRAN	To identify deficiencies and opportunities for improvement in order to meet objectives with respect to fire and explosion management. FIREPRAN is not suited to complex, compact integrated facilities..	PTS.60.2302
SAFOP (Electrical Safety and Operability Study)	Comprises three components: SAFAN - (Safety Analysis) identification of hazards to personnel in the vicinity of electrical systems SYSOP – (System Operability) critical assessment of electrical network and plant design OPTAN – (Operational Task Analysis) analysis of operator actions to determine areas of potential operator error.	

There are few if any tools and techniques, which are limited solely to the identification of Hazards and Potential Effects. Most include assessment as well as identification. Indeed techniques, such as Health Risk Assessment and Environmental Assessment include all four elements, identify, assess, control and recover.

Inherent in some techniques, such as HAZOP, is a qualitative assessment of risk based on judgement of threats, such as hardware failure, control system failure, human error, corrosion, extreme conditions, etc.

Table 4.2 Techniques primarily for activity planning and review

Technique	DESCRIPTION	Reference
Job Hazard Analysis	Identification of potential problems within a job task that could lead to hazardous situations. Elimination or reduction of the hazard by development of safe working procedures.	PTS.60.2201
Tripod-BETA	To facilitate accident or incident investigation and analysis by providing the means to assemble and manipulate investigation information into a logical structure consistent with the Tripod accident causation model and the hazards and effects model of HSE MS.	PTS.60.0504
Tripod-DELTA	The proactive identification of potential latent failures that could lead to hazardous situations and the development of remedial actions to be taken to reduce or eliminate such hazards.	PTS.60.0503

4.2 EVALUATE RISKS

Once hazards and threats have been identified, their causes, consequences and probability can be estimated and the risk determined. Risk assessment may be on a qualitative or quantitative basis both involving the same steps. Qualitative methods may be adequate for risk assessments of simple facilities or operations where the exposure of the workforce, public, environment or the asset is low. Inherent in many of the techniques mentioned in item 4.1 is a subjective evaluation of risk. HAZOP and FIREPRAN, for example, require the team to select the critical items for further study. To do this there must be a risk assessment, which is based primarily on experience or judgement. The qualitative or banded assessment of probability and consequence from such an analysis can be plotted on the Risk Matrix described in PTS.60.0101 Group HSE Management System Manual and repeated in item 4.2.4. In FIREPRAN, HAZOP and Health Risk Assessment, this Risk Matrix is used to assist in decisions regarding risk. In the context of this manual evaluate and assess have the same meaning.

4.2.1 Scenario development (causes)

The first step in the risk evaluation is to examine the ways in which events may take place to cause a hazardous event. Causation scenarios may be developed in simple narrative or use multiple branch fault trees or utilise complex computerised modelling techniques. The method is entirely dependent on the area being assessed.

4.2.2 **Probability**

The probability of a hazardous event occurring may be determined by evaluation of the associated possible threats and circumstances or from historical databases. Once established, the probability of occurrence of each event can be included in a fault tree.

Historical records provide failure data for various types of event in the fault tree and event tree including the Top Event. Alternatively, probability can be generated in a qualitative way by the relative classification of probability into those shown on the Risk Matrix in item 4.2.4.

4.2.3 **Consequence analysis**

Consequence analysis can be applied to assess HSE aspects for a range of consequence scenarios and involves the use of predictive models. Consequence scenarios may be developed in simple narrative or use multiple branch event trees or utilise complex computerised modelling techniques.

Examples include the use of physical effects models for assessing the integrity of structures, for predicting the behaviour of emissions to the atmosphere and discharge to water and predicting heat loading and explosion overpressure. Models should only be used when they are validated in a particular application and their predictive capability is generally accepted. Successful application requires that they be used by personnel with adequate training and experience. The results from Physical Effects Modelling usually provide input to other HSE analyses such as ESSA, FEA and Layout Studies.

In performing consequence analyses it should be recognised that the majority of models provide only a good approximation of what might happen. It is a mistake to base design calculations wholly on model results. The designed system should be capable of withstanding the range of possible anticipated loadings.

Table 4.3 Techniques for consequence analysis

Technique	DESCRIPTION	Reference
Physical Effects Modelling	This encompasses a number of techniques available for modelling the effects of hazardous releases such as explosions, gas dispersion and fire	PTS.60.2211
Layout Methodology	Offshore Layout Methodology - A simplified design tool for identifying separation requirements when laying out	<i>No reference</i>

	an offshore complex Onshore Layout Methodology as above for onshore facilities	
FEA	Fire and Explosion Analysis is a collective term for the process, which identifies and evaluates all fire and explosion hazardous events as a basis for risk reduction and for preparing performance criteria for essential safety systems and the arrangements required for escape, evacuation and rescue (EER).	<i>No reference</i>
ESSA	Emergency System Survivability Analysis. This is part of the FEA and determines the ability of the emergency systems to withstand severe accident conditions. ESSA is part of the FEA process and provides information, which is subsequently used in TR/EERA.	<i>No reference</i>
TR/EERA	Temporary Refuge Escape, Evacuation and Rescue Analysis of escape to Temporary Refuge (TR), the provisions within the TR system, and the Evacuation, Escape and Rescue provisions. The analysis considers the major scenarios previously identified and compares these against respective acceptance standards highlighting critical elements and revealing any shortfalls.	<i>Shell DEP 37.17.10.11</i>
Environmental Dispersion Models	Used to predict the behaviour of contaminants following discharge. Results are used to evaluate the significance of emissions and discharges. A wide range of models are available and vary in complexity and sophistication.	Monitoring air quality and Atmospheric Emissions PTS.60.3302 Monitoring water quality PTS.60.3301
Risk Assessment Models for Contaminated Soil	These have been developed to evaluate the significance of soil contaminants to human and environmental health.	Env. quality standards - soil and groundwater: PTS.60.3013 Monitoring Soil and Groundwater Quality PTS.60.3303
Groundwater	These have been developed to predict the	A range of

Models	behaviour of contaminants in groundwater and focus on the movements of the contaminants.	models available
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These techniques are summarised in Appendix IV.

4.2.4 **Determination of risk**

Having determined the probability of the different scenarios occurring to cause a 'hazardous event' and having determined the consequences arising from that event, it is possible to represent the risk graphically using the Risk Matrix described in PTS.60.0101 Group HSE Management System Manual and repeated below:

Table 4.4 Risk matrix

Consequence				Increasing Probability				
				A	B	C	D	E
People	Assets	Environment	Reputation	Never heard of in industry	Heard of incident in industry	Incident has occurred in our company	Happens several times per year in co.	Happens several times per year in location.
No injury	No damage	No effect	No impact					
Slight injury	Slight damage	Slight effect	Slight impact					
Minor injury	Minor damage	Minor effect	Limited impact					
Major injury	Localised damage	Localised effect	Considerable impact					
Single fatality	Major damage	Major effect	Major national					
Multiple fatalities	Extensive damage	Massive effect	Major international					

The matrix need not remain as a static display of risk and measures to be taken. Over the years tolerance to risk will change therefore the shading in the diagram will change.

The above matrix gives an indication of risk tolerability but this should relate to the operation under consideration. An example of how the matrix can be further defined for a particular operation is included in Appendix V.

4.2.5 Quantitative Risk Assessment (QRA)

QRA is a potentially powerful technique which is described fully in PTS.60.2210. Appendix VI contains specific examples and guidance of when Quantitative Risk Assessment is used to its best advantage. Guidelines are available for undertaking quantitative risk assessment for specific applications including risers and pipelines.

These are:

Table 4.5 QRA Techniques for specific applications

Technique	DESCRIPTION	Reference
ASPIN	Pipeline failure risk analysis technique and data base. An easy to use quantitative failure risk assessment tool to compare different options and conditions during pipeline design and operation and to assist in optimising and planning inspection and maintenance efforts. Simplified version.	<i>no reference</i>
RISER	Risk Evaluation of Risers. Assessment of risks of pipeline riser on or near platforms with comparative risk analysis to assess the benefits of subsea valve installation on pipelines.	<i>no reference</i>

These quantitative risk assessments should only be used by personnel with adequate training and experience. It is most important that those familiar with the operation, the facility or the design are involved in the study particularly with respect to the input, assumptions and conclusions drawn to ensure that the model reflects reality.

Assumptions must reflect actual practice including inspection and maintenance frequencies and techniques, frequency of drills and operating procedures, etc.

QRA provides a structured approach to assessing risk and expresses this numerically. The main function of QRA is to identify high risk areas and assist in the comparison of design options and the selection of operations philosophies with a view to establishing effective and efficient risk management.

QRA assists in the determination of 'how safe is safe enough' by helping to analyse options to establish whether or not ALARP (As Low As Reasonably Practicable) has been achieved.

Engineers and decision makers sometimes like to use quantitative risk assessment to make a decision for them. For this purpose they would like to see well defined acceptance criteria for risk and a calculation resulting in one number to tell them whether their design is 'right' or 'wrong'. However, risk figures, which are based on probabilities, should be used with caution and comparison against absolute numerical risk criteria avoided where possible. This is important for a number of reasons.