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Health and Safety Risk Management

This document aims to form a bridge between high level guidance and the more detailed aspects of managing health and safety risk in specific areas

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Contents

1. Introduction

1.1 Risk Management

Engineers and technicians have a vital role to play in the way that health and safety risks are managed. The guiding principles, the competence and commitment required for effective management of risk are clearly set out by the United Kingdom (UK) Engineering Council in the following documents:

- Guidance on Risk for the Engineering Profession published in 2011;
- Standard for Professional Engineering Competence (UK-SPEC) most recently reviewed in 2013.

In addition to the above the Inter-Institutional Group (IIG[1]) on Health and Safety (now known as the Joint Institution Group on Safety Risk - JIGSR) published some documents, which covered key topics in 2013 as follows:

- Risk communication and professional engineers;
- The business case for engineering in health and safety;
- Life-long learning for Health and Safety Risk Management.

All engineers should, as a first step, familiarise themselves with the content of the above Engineering Council and IIG documents and the purpose of this publication is to provide supplementary information for the members of the Institution of Engineering and Technology (IET). For ease of reference the IIG documents are reproduced in the Appendix.

This document sets out to form a bridge between the above high level guidance and the more detailed aspects of managing health and safety risks in specific areas. The IET Factfiles[2] provide further information on key issues with reference to the more comprehensive materials published by the UK Health and Safety Executive (HSE).

> *Note: Throughout this document the term 'engineer' may be used on its own for brevity. However, when this occurs, it should be interpreted as an inclusive term for all professionally registered engineers and technicians.*

1.2 The Importance of Good Risk Management

As an example, the UK has one of the best health and safety records in the world and performance has improved substantially over the last two decades. However, in 2013/14, there were still 133 workplace fatalities, an estimated 629,000 workers had an accident in the workplace and of these an estimated 148,000 led to an absence from work of over 7 days. Ill-health caused by activities in the workplace is sometimes not given as much attention as direct injury. However, what some have referred to as 'slow accidents' can also be devastating in terms of their human and societal cost. In 2013/14 in the UK, 1.2 million people who worked during the year were suffering from an illness they believed was caused or made worse by their current or past work. In 2012, over two and a half thousand people died of mesothelioma (primarily caused by exposure to asbestos during their working life) whilst several thousand others died from other occupational cancers and diseases.

This toll of suffering to individuals and their families has major economic consequences for industry and society more generally with an estimated 28.2 million days lost per year due to work-related ill health or injury.

Major industrial accidents can lead to fatalities and injuries on a large scale, can have enormous economic and reputational consequences for companies and can have major impacts on society in terms of disruption to infrastructure and environmental damage. Whilst much has been done to reduce their frequency and consequences, major man-made industrial disasters continue to occur regularly around the world.

Improvements in health and safety are usually and rightly seen by organisations as a way of minimising risks to their employees and contractors and the consequent financial consequences, including the often associated damage to plant or products. Reputational damage can also be considerable if health and safety is not managed effectively. In the UK in 2013/14, there were nearly 700 health and safety related prosecutions and nearly 14,000 formal enforcement notices were issued. Important as this is, it should also be recognised that there are often significant benefits to organisations from achieving high standards in health and safety: engineered improvements can have wider business benefits as can the encouragement of employees to work together to propose and achieve improvements. In short, 'Good health and safety is good business'.

2. Leadership skills and competence

2.1 Leadership Skills

The Engineering Council document "Guidance on Risk for the Engineering Profession" established six key principles which are quoted below together with a brief extract of the guidance:

1. **Apply professional and responsible judgement and take a leadership role**
   Engineers should demonstrate by example a commitment to safety, reliability and ethical conduct through the professional management of risk, from the inception of any project. Engineers at all levels should clearly demonstrate the standards by which they expect risks to be managed, thus setting an example to others.
2. **Adopt a systematic and holistic approach to risk identification, assessment and management**
   The factors that give rise to risk are interdependent and cannot be examined in isolation. It is vital in managing risk to be aware of this interdependency, and rather than dealing with risks one-by-one as they arise, use approaches that deal with whole systems.
3. **Comply with legislation and codes, but be prepared to seek further improvements**
   Regulations and codes are generic. They can only deal with anticipated events, and cannot predict every possible situation. Engineers should take a measured, yet challenging approach to potential risks, whether or not regulations apply.
4. **Ensure good communication with others involved**
   Shortcomings in communication are present in nearly all failures in the management of risk. Communicating effectively with customers, clients, suppliers, subcontractors and colleagues is important to ensure that risks and their implications are understood properly.
   Within an organisation, risk management should be communicated as a core value.
5. **Ensure that lasting systems for oversight and scrutiny are in place**
   Effective oversight and scrutiny processes are important safeguards in controlling risks. They should be challenging, and carried out with independence from those creating the risk or attempting to control it.
6. **Contribute to public awareness of risk**
   The perception of risk amongst the public is influenced by a range of factors, including emotional ones. Engineers have an important role in raising awareness and understanding about the real levels of risk and benefit, and helping to prevent misconceptions.

2.2 Competence

The skills sets of professional engineers and technicians are engineering discipline and country specific. However the skills required for risk assessment and management are universal as exemplified in the UK Engineering Council's standard for Professional Engineering Competence (UK-SPEC[3]). This is an important starting point in understanding the requirements for competence.

For every discipline, each professional engineer and technician must have as a core ethical principle the health and safety, and welfare, aspects of everything they do. This responsibility extends to:

- Themselves;
- Work colleagues;
- Visitors to the workplace;
- Contractors;
- The public; and
- The users of their products and services.

Society rightly places great faith in the engineering profession, trusting engineers and technicians to regulate themselves on its behalf. This trust can only be delivered through significant individual commitment that is publicly demonstrated by the attainment of the professional competence and behaviours that are described in, for example, UK-SPEC.

UK-SPEC describes the competence and commitment requirements that have to be met for registration as an Engineering Technician (EngTech), Incorporated Engineer (IEng) or Chartered Engineer (CEng). It includes examples of activities that could demonstrate achievement of the requirements, to enable individuals and employers to find out whether they or their staff can meet the registration requirements.

Engineers have a key role in ensuring that the safety and health of the workforce and the public is given prominence in all that they do, whether this is in ensuring day-to-day safety, dealing with hazards to health, or minimising the potential for major accident events affecting society. This requires understanding of, and competence in, the key issues underpinning high standards of health and safety risk management from design, through to operations and the management of projects, and in relation to the entire engineering life cycle of a process, product or project. It includes an understanding of legal requirements, good practice and the organisational and cultural issues that need to be addressed to ensure high standards.

It is vital that the capability to understand and manage health and safety risks continues to receive attention throughout an engineer's career, whether their role is primarily in an engineering capacity, or that of a manager or senior manager.

The IIG document entitled 'Life-long learning for Health and Safety Risk Management' (**see section 7.2**), contained a schedule describing, in broad terms, the continued learning that is likely to be required as part of Continuous Professional Development (CPD) in relation to health, safety and risk.

The document considers different career levels from Trainee, through Qualified Engineer/Technician, to Manager, and then Director/Partner (or equivalent). For each level, it outlines a typical level of attainment (cumulative through a career) and the typical means to attain the required level. As an example, a manager might be expected to be able to:

- Inculcate a health and safety culture;
- Ensure that team members have the opportunity to maintain competence;
- Understand the need to benchmark and review performance;
- Understand wider Occupational Health and Safety roles and responsibilities in the organisation;
- Provide a holistic approach to risk management - including health and safety;
- Implement and maintain (with support) a comprehensive health and safety management system;
- Understand the need to demonstrate commitment to good practice and continuous improvement, demonstrating this in practice by personal example;
- Encourage a questioning attitude, and
- Listen and recognise when health and safety concerns are raised and deal with them appropriately.

It is regarded as particularly important that engineers (and indeed others) who take on broader managerial and leadership responsibilities ensure that they are equipped to manage health and safety risks and not only new responsibilities such as those relating to project and people management, financial matters and other issues that might be more clearly recognised as key areas where competence may need to be further developed as their role broadens.

2.3 Safety Culture

Professional engineers and technicians are increasingly expected to take a leadership role in making decisions which contribute to the welfare, safety and health of all society.

A strong safety culture is vitally important if accidents in the workplace and major events in high hazard industries are to be minimised. It comprises the attitudes, beliefs and behaviours that are generally shared within the organisation and it is these that determine how leaders, and other members of the workforce, respond to safety issues and how they promote learning and improvement. The term ‘safety culture’ was first introduced by the International Atomic Energy Agency (IAEA) following the Chernobyl nuclear accident (reference). They attempted to understand the attributes of a strong safety culture and defined it as:

> *“That assembly of characteristics and attitudes in organisations and individuals which establishes that as an overriding priority, plant safety issues receive the attention warranted by their significance”.*

The definition of safety culture used by the Advisory Committee (to the former UK Health and Safety Commission (HSC)) on Safety of Nuclear Installations (ACSNI) was:

> *“The safety culture of an organisation is the product of the individual and group values, attitudes, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation’s health and safety programmes. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventative measures.”*

It is important to understand that safety culture is a part of the overall culture of the organisation. In a positive safety culture there is a collective commitment to excellence in health and safety and a sense of trust that this is supported throughout the organisation. In a negative safety culture the opposite is the case, with the commitment of some individuals strangled by the cynicism of others and a lack of leadership support and commitment. In such a safety culture, some or all of the following traits will be noticeable:

- Procedural violations will be widespread and 'short cuts' the norm. There will frequently be a failure to comply with the safety management system which may be regarded as 'fine words' that do not reflect reality.
- People will not feel willing or able to raise safety concerns because they feel they will not be taken seriously and issues will not be addressed satisfactorily. They may feel that raising issues is unwelcome to management.
- Management decisions will appear consistently to put production or cost ahead of safety.

From various studies it is clear that certain factors appear to characterise organisations with a positive safety culture. These factors include:

- Leaders demonstrate a strong commitment to safety through both words and actions. They are visible and supportive to the workforce in improving safety and this is reflected in their decisions and priorities. They will encourage reporting and discussion, provide time for the workforce to review and improve safety, and support safety-related decisions even where this has an impact on production or costs.
- Clear safety accountabilities will exist in line management and there is a clearly understood system for safety management which is 'owned', understood and used effectively without 'workarounds'.
- All employees are involved and supported in striving for safety improvement. Everybody in the organisation feels involved, is engaged in the promotion of improvements, and takes personal responsibility for safety and decision making reflects 'safety first'. The approach includes contractors.
- Effective communications and commonly understood and agreed goals exist. Everybody feels able to raise safety concerns and there is a sense of support and trust when 'difficult' issues are raised.
- The organisation strives to learn from its failures and those of others. It ensures that the learning is understood and embedded in the way things are done.
- A questioning attitude and a rigorous and prudent approach is exhibited and encouraged amongst everybody in the workplace.

A strong safety culture is not something which can be achieved overnight and should be seen as a long term, continuous and systematic process. Various processes may be used to evaluate the existing safety culture e.g. Health and Safety Laboratory's safety climate tool. These are usually based on questionnaires which seek to elicit the views of the workforce about issues such as those listed above. It is then important to determine priorities for change and the actions necessary to effect the change; in all cases with the involvement of the workforce. Reviews of progress can then lead to a continuous cycle to gain improvement and develop the trust and commitment of all involved.

2.4 Public understanding and communication with stakeholders

The fourth and sixth principles in the Engineering Council document 'Guidance on Risk for the Engineering Profession' emphasises the need for engineers to communicate effectively about risk matters and to contribute to public understanding of risk. This vital and sometimes neglected topic was picked up by the IIG document 'Risk Communication and Professional Engineers' and some of the issues and factors that engineers need to consider was discussed more fully.

Effective communication of risk issues by engineers is vital if health and safety outcomes are to be optimised. In order to express the issues relevant to particular risks to the wider public, engineers have to bridge a potentially wide culture gap. In many cases, engineers regard the need to address risk satisfactorily as primarily an issue of being 'objective'. However, society generally does not see the issues as simply as this. Unless engineers understand what lies behind the sometimes complex public attitudes and perceptions and take account of them, there is a danger that they will not be able to gain acceptance for important technological advances or improvements in our capability to minimise the risks to which we are exposed.

Research has suggested that achieving trust is vital and that five characteristics are required:

- competence (those communicating know what they are talking about);
- objectivity (this frequently means a view that the source of information is independent);
- consistency (a track record in dealing competently with similar matters);
- openness (a willingness to disclose information and not to appear secretive); and
- empathy (willingness to accept the validity of concerns and to listen and consult).

Concerns are usually greater and trust is more difficult to build where:

- engineers disagree or appear to disagree about the risks involved;
- exposure to the risk is involuntary (i.e. it is imposed by others) and is perceived to be out of the control of those subject to the risk;
- it is perceived as 'artificial' rather than naturally occurring;
- the risk is unfamiliar or poorly understood (e.g. it appears to be new with potentially unknown consequences);
- the consequences are dreaded, hidden, irreversible or particularly memorable
- there is doubt about the benefit from accepting the risk - particularly where benefits and risks appear to be distributed unevenly.
- the risk is catastrophic (i.e. it is likely to affect a large number of people at one time);
- similar developments have led to unpredicted or underestimated consequences, and
- those creating the risk are perceived as obtaining a particular advantage (e.g. a commercial incentive to underplay the risks) and, particularly, where the organisation or individuals involved have a history of being perceived as uncaring.

It is important that engineers have an understanding of these issues, are sensitive to public concerns and develop the competencies required to listen to stakeholder concerns and communicate in such a way as to try to relate to them and, where possible, to address them.

3. Understanding hazards and risks

3.1 The difference between a hazard and a risk

The terms 'hazard' and 'risk' are often used interchangeably in everyday use. Nevertheless, they have quite different meanings and engineers should be aware of this difference.

Put at its simplest, a hazard is something that can cause harm. There are a very wide range of hazards. Some simple examples include: chemicals that might produce adverse health effects; an object on a scaffold which might fall on somebody causing serious injury; high voltage electricity with the potential to give rise to a range of consequences including electrocution; machinery which has the potential to cause serious injury if not properly guarded or used and breathing asbestos and some other dusts which can cause cancer.

A risk is the likelihood that the hazard in question will actually cause the identified adverse effect. It therefore depends on both the likelihood of the consequence arising and a measure of the consequences or harm that has arisen, or will arise.

Risk can be stated in a variety of ways. For example in the UK:

- The risk of a worker being killed at work is less than one in 200,000 per annum; and
- Around 12,000 deaths each year from occupational lung disease and cancer are estimated to have been caused by past exposure, primarily to chemicals and dusts, at work.

It is also very important to consider the 'context' of a risk. For example, the risk associated with an industrial hazard might be regarded by an individual differently to that associated with a leisure activity even if the consequences and chance of occurrence were the same.

To help further explain the difference between a 'hazard' and a 'risk', consider a can of solvent safely stored on a shelf. It will present a hazard if it is toxic or flammable, but whilst safely on the shelf will present very little risk (low risk) of injury to a person in the room arising from poisoning or being burnt.

When the can of solvent is taken down and used, the risk of injury or death will increase (medium risk) because harmful vapour may be released and there is a danger of spillage and of it igniting.

Things get worse if the can of solvent is spilt. The risk arising from the hazard has therefore increased (high risk) as a result of the way that it has been used (or misused).

The risks are related to a particular defined outcome such as injury from inhaling the solvent or being burnt if ignition occurs. The magnitude of the risk is affected by factors other than the state of the solvent - for example, whether there is a source of ignition or whether breathing apparatus is being worn.

3.2 Comparing risks - looking at the statistics

Making comparisons between various health and safety related risks is not as straightforward as it might appear at first sight and there is a need to make sure that a comparison is like with like.

Firstly, the reliability of the actual statistics can be variable. For example, there may be a legal requirement to report serious injuries arising in the workplace, but not only may the criteria for reporting be different in different parts of the world but the extent to which the requirement is actually observed may well vary from country to country, or from industry to industry within a country. Smaller organisations such as tradesmen or farmers, for example, may report fewer accidents per person exposed than many larger companies, simply because they are less aware of their responsibilities or as a result of differences in culture and practice.

Secondly, it is vital to consider the statistical basis of the figures. If there are relatively few deaths or injuries over a defined time period, this may mask potentially wide variations because the statistical power may be low. Averaging over longer time periods may increase the numbers, but mask other important effects such as changes in performance or reporting levels over time.

In addition to these, there is other, perhaps less obvious issues that may need to be considered before making comparisons between countries or industry sectors. Suppose, for example, that a comparison were made between the risks of fatalities as a result of working in mining, with those of being a nuclear worker exposed to low levels of radioactivity, or with the risk of death from various forms of transportation. A number of other important factors would need to be considered.

In the mining industry, there is a need to establish whether the statistics relate to those working underground and exposed to the wide range of hazards in these activities, or whether they also include those carrying out jobs (e.g. office jobs) where the risks would be much lower. There may also be a need to be clear whether statistics take account of the health risks arising from exposure to hazards such as coal dust. Because ventilation standards may have changed significantly over time, it may also be important to take this into account as well as the fact that there is a long latency period between exposure to the hazard and death.

In the nuclear sector, similar issues of definitions of populations affected and long latency effects will be relevant. Here data may also be based on projections of the risks arising from exposure to radiation in normal operation or as a result of accidents.

The ill-health effects of exposure to very low amounts of radiation are based on properly cautious assumptions - so may lead to overestimates. For example, it is assumed that radiation exposure leads to a risk of cancer even at very low levels as a cautious assumption made to ensure that people are adequately protected.

It is also important to distinguish between actual reported numbers and projections. Estimates of the numbers of deaths to workers and the public from accidental releases of radiation are often based on engineering analysis using techniques known as quantitative or probabilistic risk assessment in order to estimate the size and probability of a release. They are also used in other high hazard, complex industries to estimate the risk of accidents. They systematically sum the probability of engineering systems failing to provide the protection that they were designed to give and successive ‘lines of defence’ breaking down. The data on which these estimates are made often rely on a degree of expert engineering judgement.

In transportation there will be other complications in analysing the statistics and comparing them. Sometimes the data will be based on distance travelled or it may, for example, be based on the number of journeys undertaken. By analogy with the choice of populations referred to above in the context of the mining or nuclear industries, it is important to define whether accidents include only specific activities such as commercial flights or passenger train journeys. There are also important issues relating to how we view the risks. Driving, despite the higher fatality rate on almost any measure, is often regarded as a voluntary activity with at least some of the risks within our own control. People may thus be more averse to the risk than if it is externally imposed and thus perceived to be outside their control.

Some of the other factors which shape people's attitudes towards risk were set out in the IIG document 'Risk Communication and Professional Engineers'[4]. This is an important issue for engineers to understand.

Thus when presented with comparative statistics, it is important to think critically about the assumptions that have been made for each. They may not be comparing the same things.

3.3 Tolerability of risk

When the level of risk associated with an activity or occupation has been established taking account, if necessary, of some of the 'pitfalls' in risk estimation outlined in the previous section, it is often necessary to make decisions about what is acceptable and unacceptable in terms of the risks to the individual and society.

An approach for helping to determine the acceptability of risk is the 'Tolerability of Risk' framework as illustrated in **Diagram 1** below. This was developed by the Nuclear Installations Inspectorate[5] (now the Office for Nuclear Regulation) in the context of nuclear power stations in the UK and then generalised by the HSE[6]. It provides a conceptual framework distinguishing between risks which might be regarded as broadly acceptable through to those which are likely to be unacceptable except in exceptional circumstances.

The triangle represents increasing levels of 'risk' for a particular activity, moving from the bottom of the triangle (as drawn below) towards the top.

The gradation of colour in the figure illustrates the fact it is difficult to impose 'hard' boundaries between the three regions. The factors and processes that ultimately decide whether a risk is unacceptable, tolerable or broadly acceptable are dynamic in nature and are sometimes governed by the particular circumstances, time and environment in which the activity giving rise to the risk takes place. For example, standards change, public expectations change with time, what is unacceptable in one society may be tolerable in another, and what is tolerable may differ in peace or war.'

It is thus difficult to assign hard and fast numerical boundaries between the three regions. It has been suggested that in a UK context[7] that an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions.

The boundary between the unacceptable and tolerable regions is more difficult to determine. This is because risks may be unacceptable to an exposed individual or because of the repercussions of an activity or event on wider society (referred to as societal risk). Nevertheless, in the context of the tolerability of risk from nuclear power stations in the UK, it has been suggested that an individual risk of death of one in a thousand per annum should represent the dividing line between what could be just tolerable for any substantial category of workers for any large part of a working life, and what is unacceptable for any but exceptional groups. For members of the public who have a risk imposed on them 'in the wider interest of society' this limit is judged to be an order of magnitude lower - at about one in ten thousand per annum per annum.

3.4 Judging Reasonable Practicability - 'How Safe is Safe Enough?'

The concept of 'reasonable practicability' underpins much of the regulation of health and safety in the UK. The principle may find relevance elsewhere. It is a vital part of the UK Health and Safety at Work etc. Act 1974, and many of the regulations that stem from it. Reasonable practicability is often encountered in the form of the acronyms 'SFAIRP' (So Far As is Reasonably Practicable - the legal term in the Act) and more frequently as 'ALARP' (As Low As is Reasonably Practicable). The terms are regarded as synonymous.

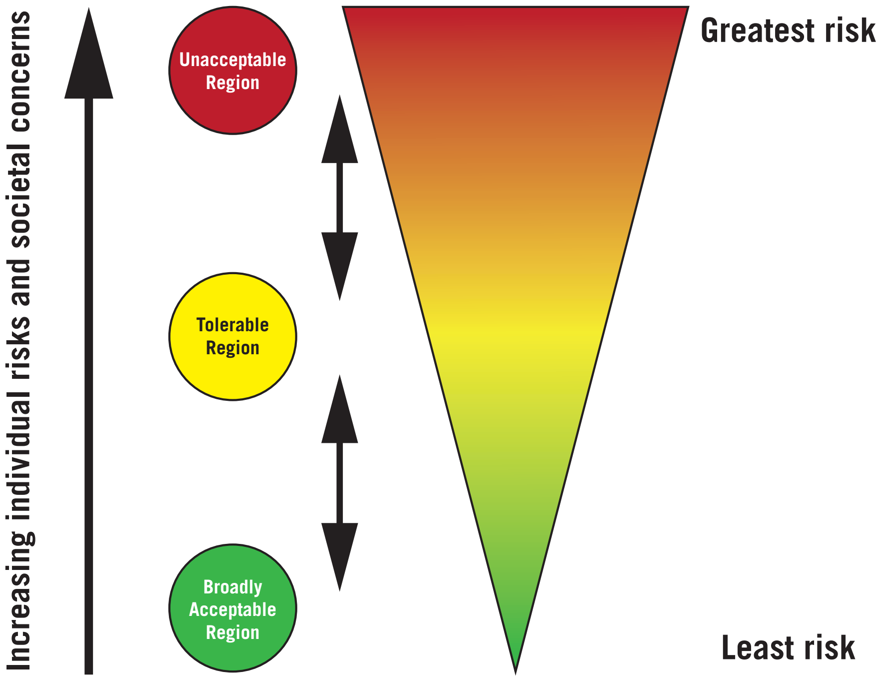

Diagram 1. Framework for Tolerability of Risk

	The top zone represents the unacceptable region. For practical purposes, a particular risk falling into that region is regarded as unacceptable whatever the level of benefits associated with the activity.
	The middle zone is known as the tolerable region. Here, the need is to establish that all reasonably practicable steps have been taken to reduce risks is particularly important. How this is judged is discussed in section 3.5. Risks here are typical of those risks from activities that people are prepared to tolerate in order to secure benefits. In this region, regulators will require risks to be further reduced if it is reasonably practicable to do so.
	The bottom zone represents the broadly acceptable region. Risks falling into this region are generally regarded as acceptable if adequately controlled. Regulators would not usually require further action to reduce risks unless reasonably practicable measures are available. However, it should be noted that there is a legal requirement to ensure that all reasonably practicable steps have been taken to reduce risk, irrespective of the level of risk. The levels of risk characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives.

The definition set out by the UK Court of Appeal (in its judgement in Edwards v National Coal Board [1949][8] is:

> *'Reasonably practicable' is a narrower term than 'physically possible' a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them - the risk being insignificant in relation to the sacrifice - the defendants discharge the onus on them.'*

Making sure a risk has been reduced ALARP thus involves weighing the risk against the sacrifice needed to further reduce it and the duty-holder (any person with a duty under health and safety legislation) must be able to show that not making an improvement would be grossly disproportionate to the benefits of risk reduction that would be achieved. The value of 'gross disproportionate' to be used is not defined but will be determined on a case by case basis dependent on the level of risk and its context.

In many countries requirements are 'absolute' or 'prescriptive' (as are some requirements in UK law) and 'reasonable practicability' is not generally part of the legal requirements which form the basis for their regulatory system. The ALARP approach has considerable merits as it allows a more flexible approach and encourages improvements where these are warranted. On the other hand, it requires judgement on the part of both duty holders and regulators.

There are two primary ways by which ALARP may be judged. The first of these, which is particularly important as the basis of decision making in less complex undertakings but is also important in high hazard industries, requires comparison with relevant good practice. For example in the UK this is defined by the HSE as 'those standards for controlling risk that HSE has judged and recognised as satisfying the [UK] law, when applied to a particular relevant case, in an appropriate manner'. This is determined by consensus and will often be based on regulatory guidance and industry or international codes of practice. Formal regulatory guidance, such as HSE Advisory Codes of Practice (ACOPS)[9] have special legal status in that if a duty holder conforms with them, the duty holder will be deemed to have done all that is reasonably practicable.

In some circumstances, such as developments in high hazard industries, or where a new technological development is being proposed which could have significant consequences, the decision about whether ALARP has been achieved may involve numerical analysis, in addition to comparison with good practice. An approach that has been widely used involves Cost Benefit Analysis (CBA). In this case, both the risk reduction (benefit) and the sacrifice (cost) are converted into a monetary value so that they can be compared. What exactly is included and, in particular, the statistical 'Value to be ascribed to Preventing a Fatality (VPF)' or serious injury is not straightforward and can be controversial and difficult to determine. More recently, a new approach (the J-Value technique)[10] has been developed based on established economic theory which requires no specific assumptions to be made about the value to be attached to saving a human life and also allows loss of life expectancy to be included in the analysis. This can be important, for example, in comparing immediate risks with longer term potential effects (such as exposure to a carcinogen[11]).

It is very important, whatever the approach used, that a suitable 'balance' is achieved in reducing the risks to which we are exposed. There is evidence that some past risk decisions have concentrated resources on reducing particular risks whilst in other cases the resources allocated have been much less[12]. Such decisions clearly need to reflect socio-political concerns, but it is also important that they are made on an informed basis so that resources can be applied where they are most effective.

4. Safety management

Those responsible for workplace health and safety should be able to demonstrate that they have done all that is reasonably practicable to reduce risks.

It is sometimes said that occupational health has been the ‘poor relation’ in considering health and safety and therefore it is vital that whilst efforts continue to reduce the toll of workplace deaths and injuries from accidents, significant and increased attention must also be given to the impact of ill-health.

Here, some of the steps that can be taken in practice to assess and reduce risks are discussed.

The control measures necessary will vary in their number and complexity, and the rigour of their methods to ensure compliance. It is important that the measures taken should be ‘fit for purpose’ and ‘proportional’. Thus a small undertaking and/or those with low risks such as an office environment will not need to go as far as a potentially higher risk organisation such as a factory. An explanation of the key steps for such lower risk situations is given in an HSE publication ‘Health and Safety Made Simple’[13]. At the other end of the spectrum, the potentially highest risk undertakings, such as some chemical plants and all nuclear installations, may have special requirements and be subject to special ‘permission’ or licensing regimes that impose specific duties on them, such as the production and approval of safety cases.

A safety management system consists of the arrangements and processes used by an organisation to manage health and safety. Its objective is to provide the necessary framework around which good performance can be established and maintained. To be effective, it needs to be supported by a strong safety culture.

A comprehensive approach to developing a safety management system particularly in the context of an organisation which has to control significant risks is set out in an HSE publication ‘Managing for Health and Safety’, often referred to as HSG 65[14].

The key elements of the recommended approach are:

- **Plan:**
  - Determine policy
  - Plan for implementation
- **Do:**
  - Profile health and safety risks
  - Organise for health and safety
  - Implement the plan
- **Check:**
  - Measure performance
  - Investigate accidents and incidents
- **Act:**
  - Review performance
  - Learn lessons
  - Adjust and adapt

This is shown conceptually in **Diagram 2**.

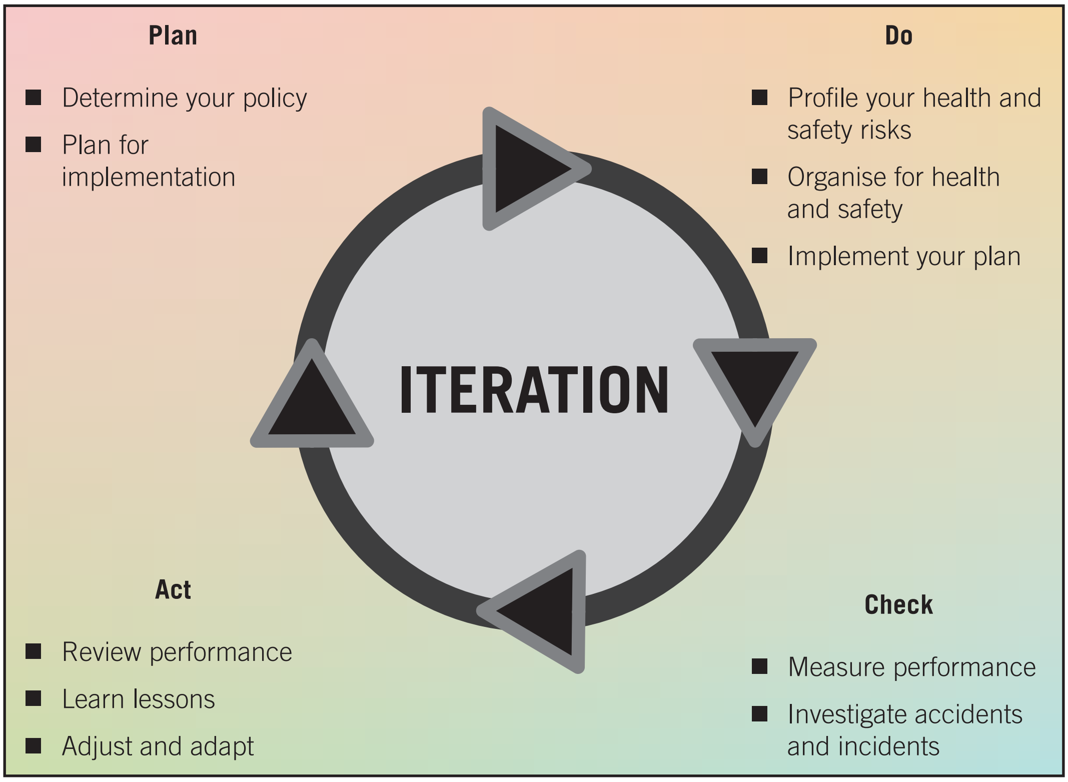

Diagram 2. Health and Safety and Risk Control Systems

The approach thus has five key elements:

- A clear statement of health and safety policy. This should specify the top-level goals of the organisation and set the corporate requirements for health and safety in a way which is unambiguous. It should also commit to provide the necessary resources to ensure that the goals can be achieved.
- The structure and organisation by which the policy is to be achieved. This will be concerned with establishing management control, securing co-operation, ensuring effective communication and specifying levels of competence.
- The planned and systematic approach to implementing policy. The approach should be an integral part of the organisation's general management systems. It will have the objective of assessing risks, assigning priorities for the reduction of risk and establishing standards to enable this to be achieved.
- The measurement of performance against the standards which have been set. This will provide a measure of achievement and reveal when and where action is required to achieve further improvements[15].
- The arrangements for audit and review of all the elements of the system. This process of self-regulation will ensure that lessons are systematically learnt and will enable performance to be compared with internal and external standards in order to promote continuous improvement.

The same basic steps used to reduce the risks of accidents can be applied to ill-health.

The risks to health in the workplace can be broadly categorised under three headings:

- exposure to hazardous substances,
- exposure to a range of physical hazards, and
- impact of how an organisation operates.

The following sections discuss some of these requirements in greater depth.

4.1 Profile your health and safety risks

Any workplace, in any country, has potential risks that must be controlled to prevent injury or loss.

Various types of risks arise from a variety of hazards that cause significant numbers of incidents. These may vary from country to country dependent upon working local practices and the culture. We consider in this section of the document a range of hazards which are frequently encountered in workplaces, their impact and some of the specific control measures that can be used to control risks. This is not a complete list and the reader is referred to the HSE website[16] for more details. In some cases, the subjects are also dealt with more fully in IET Factfiles and Briefings and these are referred to where appropriate.

It is very important not only to consider risk of immediate injury but also of adverse health outcomes.

4.1.1 Working with electricity

- Engineers and technicians designing, installing, commissioning, maintaining, operating and decommissioning electrical plant need to be competent for the energy levels involved.
- This is to enable individuals and their organisations to have a sufficient level of knowledge and understanding to manage the risks associated with and electrical system.
- Consideration must be given to the safety of all people who might have authorised, or unauthorised, access to the electrical plant or system.
- Relevant training and experience must be provided for those required to work with the electrical plant.
- Some workers involved in non-electrical trades may be exposed to electrical risks and should be aware of those risks and the appropriate measure to take to ensure safe operation and maintenance.
- Workers must be familiar with the risks arising from the tasks they undertake and the environments in which they work.
- Workers must be given sufficient information to complete their work safely.
- There should be an adequate instruction for the required work.
- Adequate supervision and support must be provided.
- Workers should know their limitations for their work
- Workers should challenge if they are instructed to exceed their limitations.
- Warning notices must be provided in zones of greater risk.
- Suitable barriers and shrouds must be provided to control the electrical risks in zones of greater risk.

- Employees must co-operate with their employer to enable safe working.
- Employers should ensure that they have safe working practices and that those practices are followed.
- All equipment not hard wired as part of an electrical installation i.e. portable equipment e.g. a hand held drill plugged into an electrical socket, must be subject to formal and regular checking for being safe to use.
- For more information see IET Briefing HSB 34a[17], b[18], c[19].

The IET published a Code of Practice for Electrical Safety Management in 2012 which contains a structured approach with key principles for effectively managing electrical safety[20].

In addition to working with electricity there are other risks for people in the working environment. These risks can cause immediate injury or have longer term effects on health. Sometimes workers neglect to think about these risks when they are focussed on their tasks. Some common examples are given below, but there are potentially many others.

4.1.2 Slips and trips

- The most common cause of major injuries at work; averaging a third of all reported major injuries in the UK[21].
- Major slips result in broken bones and can also be precursors to more serious events such as a fall from height.
- Cost to UK industry: 1,332,000 working days lost.
- The risk of slips and trips must be controlled to try and avoid people being harmed (employees, visitors, members of public, patients etc.).
- Employees must use any safety equipment provided and must not cause danger to themselves or others.
- Manufactures and suppliers have a duty of care to ensure that their products are safe, and have instructions for use.

4.1.3 Working at height

- Falls from height (in the UK) are the single largest cause of fatal accidents and major injuries in the workplace[22].
- In 2012/13 falls from height accounted for:
    - 46 UK work related fatalities;
    - 2,835 major injuries; and
    - A further 2,832 injuries that caused the person to be off 3 days or more
- Every employer should ensure that work at height is properly planned, appropriately supervised and carried out in a manner which is safe and that when work is carried out at height, suitable and sufficient measures are taken to prevent employees falling a distance liable to cause injury. Both of these requirements are subject to the test of reasonable practicability.
- The person who organises, plans and supervises work at height, or work equipment for use in such work, must be competent to do so.

4.1.4 Confined Spaces

- Every year people die as a result of work in confined spaces.
- If work in confined spaces cannot be avoided, it must be well-managed and the risks must be controlled to ensure safety.
- A confined space can be any wholly or partially enclosed area where there could be a risk of death or serious injury or ill-health from a hazardous substance, lack of oxygen or such other 'specified' risks such as drowning or very high or low temperatures.
- Many hazardous substances are heavier or lighter than air, so they may gather in low or high points of a confined space.
- Tanks, process vessels and sewers are obvious confined spaces; less likely to spot, but equally dangerous, are open-topped chambers, vats, furnaces, ducts and unventilated rooms.
- Sometimes work may create a confined space, such as during construction of a plant or building.
- The key is to know where they are, to list them, affix warning notices, and establish a 'permit to work' is required for entry.

4.1.5 Asbestos exposure

- With up to a 25 year latency period, deaths from asbestos occur as a result of earlier exposures.
- A comprehensive survey should be conducted by a competent person to identify, assess the condition and document the presence and location of all Asbestos Containing Materials (ACMs).
- Potentially affected workers should receive training in the precautions they must take.
- Asbestos removal work should only be performed by a licensed contractor.
- Cutting and drilling of asbestos containing materials should be subject to a risk assessment and only be undertaken by authorised competent persons in a controlled manner.
- Asbestos Containing Material should be identified, labelled and managed safely in place by trained employees or contractors.
- The organisation should assess regularly the condition of ACMs to ensure that the materials remain in a good condition.

4.1.6 Noise induced hearing loss

- Noise-induced hearing loss is a common problem and a common reason for industrial injury benefit payments and personal injury claims.
- A survey of ambient noise levels (noise surveys) should be regularly conducted in all areas where noise levels are significant.
- An assessment of personal noise exposure should be conducted for all individuals, or groups of individuals, likely to be exposed to noise in order to identify those at risk.
- The results of noise surveys and personal noise exposure assessments should be documented and the records retained.
- Noise surveys and personal noise exposure assessments should be updated if there is any reason to suspect that the assessments are no longer valid.
- For higher noise levels all reasonably practicable options for reducing them and/or exposure times should be investigated and implemented.

- If personal noise exposure cannot be reduced then the wearing of suitable hearing protection should be enforced.
- Areas designated as 'Mandatory Hearing Protection Zones' should be marked with appropriate signs.
- Information and training should be provided to ensure that individuals understand the risks associated with exposure to excessive noise and the correct use of control measures provided for their protection.
- Audiometric testing should be carried out on all workers whose personal noise exposure equals or exceeds the levels laid down by the organisation. Action to be taken when the results of audiometric tests show evidence of noise induced hearing loss.
- Personal noise exposure should be considered in the design and specification of new installations, when equipment is added to existing facilities or when equipment is modified. Priority should be given to reducing noise levels in the work place or minimising the time individuals spend in noisy areas. Hearing protection should only be used as secondary protection or as a last resort.

4.2 Carry out a risk assessment

Risk assessment considers what might cause harm to workers or other people affected by the work activities.

The risk assessment should not create vast amounts of unnecessary paperwork; it should identify any significant risks.

One well regarded method of producing a risk assessment involves five steps:

- Identify the hazards.
- Decide on who might be harmed and how.
- Evaluate the risks arising from the hazard.
- Record findings.
- Review the assessment.

4.2.1 Identify the hazards

The first step is to observe what actually happens in the workplace and then identify the hazards by considering what could happen. Attention should be directed to hazards that can result in serious harm or affect a number of people. Employees or their representatives may be aware of hazards, which may not be immediately obvious to the assessor, and they should be asked for their views. Regulations specific to certain industries may be helpful in identifying hazards.

4.2.2 Identify who can be harmed by hazards

All employees and groups of employees should be taken into consideration by the assessment, including people who may not be present in the work area all of the time, such as cleaners, visitors, contractors, maintenance personnel, etc. Members of the public should be included if there is a chance they may be injured in workplace activities. Workers who may be particularly at risk should also be identified, such as newcomers to the company, young, inexperienced people, and disabled staff.

4.2.3 Evaluate the risks

The intention here is to assess the chance that harm from a particular hazard may happen, taking into account the precautions already in place. The risk may vary from very low with no need to consider any precautions. One example of a high risk would be hand feeding a power press where substantial precautions are required. In the UK this is governed by 'The Provision and Use of Work Equipment Regulations 1998 (PUWER 98)'[23]. In this example, the hazard is closing tools, which may trap the operator's hands. The risk is high, because of the frequency of access (say 400 times per hour) and the potential for severe injury i.e. amputation of fingers or hands.

If the evaluation reveals that existing precautions are inadequate it is necessary to consider whether the hazard can be eliminated. If this is not possible, a decision needs to be taken on how the risks can be controlled so that the possibility of harm being done to people is minimised. The process should start by checking that all statutory obligations are met - for instance that guards are fitted to machines to prevent access to dangerous moving parts of machinery. It is then necessary to check that the published guidance (standards) on industry practice is being followed - membership of a relevant trade association normally gives access to this type of information. Finally, all reasonably practicable precautions should be implemented to keep the workplace safe.

4.2.4 Record significant findings

Significant findings of the assessment should be recorded. Details on how the assessment was made are unnecessary, provided it can be shown that a proper assessment was carried out, all the significant hazards and groups of people identified as being affected by these hazards were taken into account and any residual risk was low. In simple terms, it is necessary to demonstrate that a proper check was made and that any precautions are reasonable.

Records should be kept for future reference as they may help to demonstrate that legal obligations have been met.

4.2.5 Review the assessment and revise if necessary

New processes or procedures introduced into the workplace may lead to new hazards and significant changes in workplace activities need to be included in a revised assessment. In any case, a review of all assessments should be carried out at regular intervals to keep them up to date with current practice.

Good organisational arrangements and excellent systems of work will go a long way towards minimising health and safety risks in the workplace. It is now becoming widely appreciated that to be successful and to maintain and improve on that success, organisations have to work to develop a good safety culture.

4.3 Measuring performance

Measurement of performance must form part of a health and safety management system. There are two components to effective monitoring:

- **Active Monitoring** (before things go wrong): Regular reporting and inspection to ensure standards are being implemented and objectives are being met.
- **Reactive Monitoring** (after things go wrong): Regular reporting and investigation of injuries, cases of illness, property damage and near misses, i.e., identifying why performance was substandard.

Many organisations rely too heavily on reactive 'lagging indicators' but a consequence of this approach is that improvements or changes are only determined after something has gone wrong.

Switching the emphasis in favour of active monitoring with leading indicators to confirm that risk controls are operating effectively is an important step forward in the management of risks.

Priority should be given where risks are greatest and information referred to the leaders with authority to take remedial action, such as organisational and policy changes.

An important outcome of monitoring performance is that the organisation should strive to achieve a learning culture in order to enable and share good practice and to minimise shortfalls in performance. This requires staff to be encouraged and given the time to report problems or failures in an open way within a 'just' culture so they are not blamed for failures which are openly reported to improve performance. When issues are reported they should then be investigated to the extent warranted by their significance and feedback given and the opportunity taken to use the resulting learning as widely and effectively as possible.

Audits, by staff or outsiders, complement monitoring activities by looking to see if health and safety policy, organisation and systems are actually achieving the right results. They should be concerned with the reliability and effectiveness of health and safety policy and pay particular attention to:

- The degree of compliance with health and safety performance standards including good engineering practice and legislation;
- Areas where standards are absent or inadequate; and
- Achievement of stated objectives within given time-scales.

It is important that audits look not only at the presence or absence of procedures but also at how these are being used (i.e. compliance) and to understand where procedures are not followed, why this is occurring.

It is also important that some 'audits' are carried out by independent parts of the organisation rather those with line responsibility. This process of 'oversight' allows performance to be assessed against higher level organisational requirements and to compare the performance of different parts of the organisation.

4.4 Review performance

Management Review of performance should be undertaken by senior leadership to evaluate on a regular basis whether management systems and controls are performing as intended and producing the desired results as efficiently as possible. Continuous improvement is using the results of that review to identify and implement a series of actions that will improve safety performance.

On a regular and routine basis the review should check learning from:

- Incidents and near misses
- Lagging and leading safety performance indicators
- Audits
- Changes to legislation and evaluation of compliance
- External lessons learnt

Shortfalls in performance and opportunities for improvement should be identified.

5. Process safety and avoiding major accidents

Many of the issues described above are in relation to the health and safety of the workforce in their day-to-day operations. This is variously referred to as ‘workplace’, ‘occupational’, ‘personal’ or ‘industrial’ safety. Another term - ‘Process safety’ - is often used to refer to minimising the risk of major events in more complex, high hazard industries such as chemical, nuclear and some other industrial plants where there is a risk of catastrophic failure which can impact on people at the plant and have safety and environmental consequences beyond the site boundary. The principles to be applied to achieve safety are similar between ‘workplace’ and ‘process’ safety but there are important differences. It is important to realise that a good workplace safety record does not necessarily mean that good process safety performance is achieved[24].

Process safety needs special attention – failures arise from the complex interaction of engineered systems, people and processes. It highlights the need to consider deeper technical and organisational issues. In workplace safety on the other hand, failures often arise from a simple sequence of events and causes are thus easier to evaluate and to address.

We might thus broadly define process safety as:

> *“The safety of any process, project or facility which involves for its successful operation or implementation, the understanding and management of the complex interactions between engineered safety provisions, organisational procedures, and the performance of people.”*

5.1 Process safety - engineering techniques to minimise the risk of major events

Engineers working to minimise the risks of process safety failures have available a wide range of techniques to assess and mitigate the engineering risks. The simplest concept is ‘defence in depth’. To compensate for potential human and mechanical failures, successive ‘barriers’ are established so that if one line of defence fails, there is another which can continue to maintain the safety of the plant. In addition, these take account of the need not only for redundancy (for example, more than one system available to achieve the same safety objective), but also ‘diversity’ (systems which rely on different processes and/or means of operation). For example, if there was an unplanned loss of off-site power, a well-designed system would not only have back-up supplies, but these would be supplied from different types of source (such as diesel generators, batteries etc.), and these would not be subject to simultaneous failure due to a single event e.g. a flood or earthquake. This latter concept is known as ‘the single failure criterion’.

Going beyond these relatively simple concepts, ‘engineered defence in depth’ can employ a range of other techniques to achieve a required level of safety. For example, in the chemical industry there is wide use of ‘Hazard and Operability Studies’ (HAZOPs). These comprise structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may lead to unacceptable risks. It is carried out by a suitably experienced multi-disciplinary team and aims to identify potential hazards and operability problems. Structure and completeness are given by using guideword prompts as part of a systematic process.

Other approaches to ensuring acceptable levels of safety involve ‘event trees’ and ‘fault trees’. Event trees are logical evaluative processes which work by tracing forward in time (or forwards through a causal chain) to model the risks in a design or process. In contrast, a fault tree analysis (FTA) evaluates risk by tracing backwards in time, or backwards through a causal chain. The analysis takes as its starting point a particular hazards or failure (e.g. loss of offsite power), and systematically identifies potential failure modes. Finally, these logical and systematic processes can be developed into a 'Probabilistic Safety Analysis' (PSA), sometimes also referred to as a 'Quantitative Risk Assessment' (QRA). In this case, numerical reliabilities are attached to each node in the 'tree' so that an estimate can be obtained of the likelihood of a particular failure mode leading to a defined consequence e.g. a major release of radioactivity or chemical release.

The summation of these can be used to compare risks with safety criteria or objectives and, in particular, to evaluate where process safety systems may need to be strengthened.

5.2 Functional Safety and Safety Instrumented Systems

Complex industrial and chemical plant requires active systems to prevent plant hazards occurring and/or mitigate the consequences of hazards which do occur. In the process industries these are termed "safety instrumented systems" (SIS) since they use instruments to monitor the state of the plant and react automatically to any hazardous conditions before these can lead to accidents, usually via physical actuators but sometimes via information provided to human operators. The term "functional safety" relates to the property of an active system of being safe by virtue of the actions which it performs rather than its physical construction or composition. Examples of SIS in the chemical industry are protection systems which shut down a plant in response to abnormal plant conditions, or fire and gas detection systems. The level detection and alarm system fitted to the Buncefield[25] storage tank is an example of an SIS which failed to perform its designated safety function when the demand arose.

The basic safety management process with respect to functional safety and SIS is very similar to that outlined in section 4: identify the hazards which the plant or other business system could potentially create during its operation (or maintenance), specify the safety functions necessary to control the risk from these hazards, and implement the safety functions in the SIS. Differences arise in the nature of the hazards, which are generally those which could lead to major accidents with consequences to both workers and the public, and the complexity of the required solutions.

Nowadays most SIS (and the equivalent types of system in other industries such as railway signalling and control, automotive and aviation) are computer based and rely on software to achieve their safety functions, although such systems can be augmented by electronic, electrical, electro-mechanical or hydraulic systems to provide some degree of risk reduction as additional barriers. In addition to determining the safety functions which the SIS must perform, the reliability of the SIS must be specified, to ensure that the residual level of risk is reduced to a level which is tolerable and ALARP, taking into account the likelihood of each hazardous plant condition arising in the first place. Failures of an SIS are classified as random failures (of hardware) or systematic (errors in the specification or design of the system such that it will fail whenever a particular set of conditions occur). Random hardware failures can be controlled by techniques such as redundancy and diversity as discussed in **section 5.1**. Software is only subject to systematic failures, but the complexity of software means that it is difficult to ensure that all systematic defects ("bugs") have been eliminated. The relevant international standards, in particular IEC 6151143 and IEC 6150844, define four Safety Integrity Levels (SILs) ranging from 1 to 4, with 1 being the lowest and 4 the highest. The SIL is determined by the degree of risk reduction or control which the SIS must provide, and in turn specifies the nature and extent of the techniques and measures which should be used to prevent defects remaining in the design, for both hardware and software. A SIL 2 system, for example, is one which must achieve a probability of failure on demand of 1 in 1000, or for continuous operation a failure rate of 1 dangerous failure in 100 years. These are very demanding targets and require the greatest care in specification, design, construction, installation and operation of the SIS.

The following guidance points should be noted:

- Engineers responsible for the overall plant must work closely with SIS engineers to establish and maintain correct safety functional and integrity requirements.
- The SIS and the plant must be subject to safety performance monitoring to record demands and failures, and the SIS modified as required.
- Rigorous change management must be applied to the specification and implementation of the SIS as discussed in **section 5.3**.
- Engineers involved in the development of SIS must have the specialist competencies necessary including hardware and software as required.
- The safety culture must include the SIS. Engineers and managers responsible for plant operation must respect the operating and maintenance provisions required for the continued safe operation of the SIS.

In connection with the last bullet, it is often required to carry out proof testing at specified intervals to ensure that the integrity of the SIS will not degrade over time, as happened with Buncefield. Testing often impacts on production schedules and targets and in this respect a good safety culture with respect to major hazards is extremely important.

5.3 Understanding disasters

Despite the use of these analytical techniques major events (disasters or near hits) still occur in engineering processes and it is important to try to understand why. In the last few decades a number of major events have occurred which have been the subject of major and detailed inquiries, and from which much learning has emerged - not only about the engineering failures involved, but also about the organisational and cultural shortcomings that were important precursors to the events. They include examples spanning a range of engineering disciplines, for example:

- The Paks, Tokaimura and Fukushima nuclear events,
- The Columbia Space Shuttle disaster,
- Rail accidents at Southall, Hatfield and Potters Bar in the UK, and many others worldwide,
- The Longford, Texas City, Buncefield and Deepwater Horizon petrochemical plant events,
- The Nimrod aircraft crash in Afghanistan, and
- Numerous civil engineering disasters - including the Port of Ramsgate Walkway collapse and the Heathrow tunnel collapse in the UK.

Research has attempted to understand the underlying failure mechanisms underpinning events such as these, which in many cases have led to loss of life and injury to workers, the public, as well as in several cases enormous financial and reputational damage to the organisations involved, and significant societal disruption.

Many of the issues are particularly well set out in the Charles Haddon-Cave QC's report into the loss of RAF Nimrod XV230 "A Failure of Leadership, Culture and Priorities"[26] and the official investigation Report of Columbia Accident Investigation Board, Chapter 5[27].

'Organisational accidents' is a term used to describe such accidents by Professor James Reason who has written extensively on the subject. He points out that in breaching barriers and safeguards, three types of factor are often involved - human, technical and organisational. The breaches are also frequently affected by the balance between production and protection and this is usually dynamic over the life of an organisation. The defences providing protection are sometimes relatively strong (e.g. at start-up or following a near-miss or other warning), but can also be weakened. One example of such weakening occurs where there is a concentration on production leading to a reduction in safety margins – particularly after an event-free period.

The idea is developed into Professor Reason's now well-known 'Swiss Cheese' model where safety systems are represented by successive layers of Swiss cheese, this is shown conceptually in **Diagram 3**. Normally the trajectory towards loss is interrupted by one of the layers. The idea, however, is that the holes in each layer represent flaws in the various layers of the safety system. This should be seen as a dynamic system with each defensive layer shifting according to local conditions. Defences can be removed in some circumstances (e.g. during maintenance). Furthermore the 'holes' in the defences will also be dynamic. For example, they will shrink and expand in response to conditions or operator actions.

Holes in the defences are very often caused by people working within complex systems and thus generally go beyond the scope of the individual. Professor Reason refers to these as latent conditions. They may arise from poor design, weak supervision, undetected defects, poor maintenance, unworkable procedures, inadequate training, poor equipment etc. These may be present for years before they combine with local circumstances or active failures such that the 'holes line-up' and provide a direct path 'from hazard to loss'. Professor Reason also makes the important point that latent conditions are present in all systems and are 'an inevitable part of organisational life'. They can arise both 'locally' and from strategic decisions made at high-levels in the organisation and beyond. These can shape the corporate culture, creating a build-up of latent conditions.

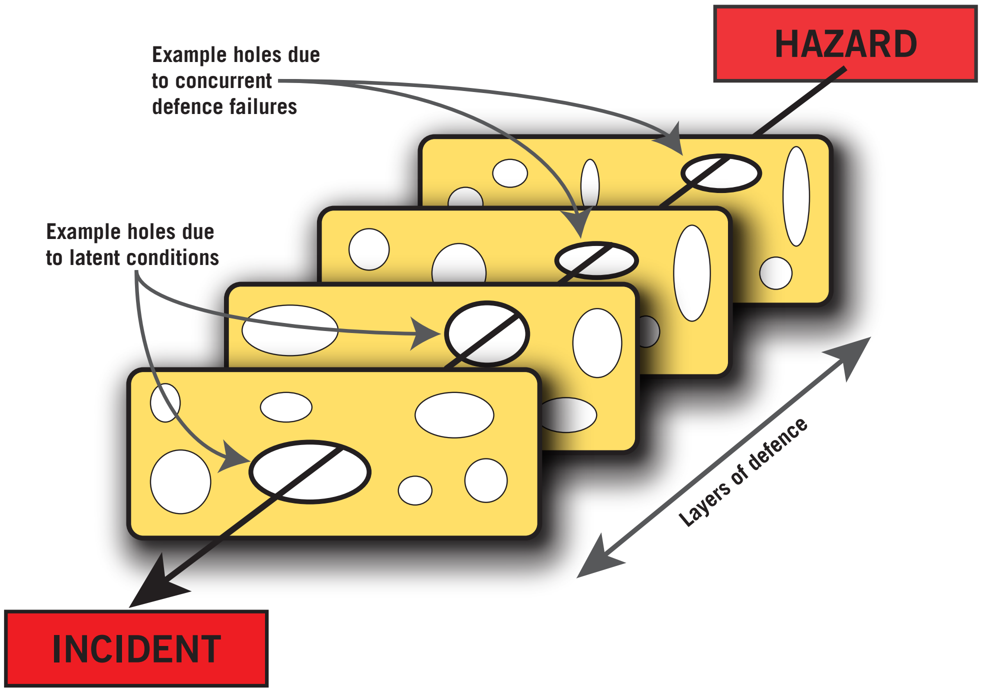

Diagram 3. The Swiss Cheese Model as envisaged by Professor James Reason

Because of the multiplicity of defences and 'mobility' of the holes, windows of opportunity for the 'line up' referred to above are usually rare. They are often triggered by an active failure, for example, the decision at Chernobyl deliberately to remove defences in order to accomplish a task. Professor Reason represents the development of an organisational accident in terms of three levels:

- the person (unsafe acts),
- the workplace (error-provoking conditions), and
- organisational factors.

Investigations must recognise these factors and should not stop at the local/unsafe act (e.g. breach of a procedure) or failures in competence but should seek to address the deeper organisational and cultural causes which led to these.

The 'Swiss Cheese' model is a useful conceptual tool. In using it, however, it is important to recognise the need to see clearly the 'dynamic' element of it and the 'coupling' that exists between layers of defences. In discussing ways that such complex, organisational accidents can be minimised, Professor Reason discusses several events - from aviation accidents to the collapse of Barings Bank - and draws out common features. He was able to demonstrate how pre-existing (and often long standing) latent conditions contributed to the breakdown of system defences. In each case, the essential process of checking and reviewing defences also broke down. Another common factor in some of the events was that 'the people involved had forgotten to be afraid'. As Professor Reason put it, "chronic unease is the price of safety".

Organisations often seek to strengthen their defences against adverse events by adding procedures - often as a result of the findings from event or near-miss investigations. Professor Reason points out that this can be dangerous, since as procedures are added or modified, the scope of allowable actions shrinks and violations increase in order to get the job done.

More recently, the approach to reducing vulnerability to major events has been the subject of considerable research. Sociologist Charles Perrow argued[28] that some technical undertakings are complex and so closely coupled, that accidents are largely inevitable. 'Normal accidents' arise from systems with a high degree of complexity and very strong coupling. Many manufacturing processes, according to Perrow, may be tightly coupled, but have relatively low complexity (in the way he defines this). Thus failures at one point in the system have relatively few unintended consequences for the rest of the system. In industries such as railways and aviation, there is complexity, but physical separation of the units (aircraft, trains etc.). This means that learning can be built into other elements of the system (for example, by grounding and modifying a type of aircraft). Perrow argued that the most difficult arrangements to control are advanced chemical and nuclear installations. Here, complexity is high and the degree of coupling means that 'errors' cannot necessarily be contained.

The requirement for a flexible, adaptive organisation was seen as a key component in what have been termed 'High Reliability Organisations' (HROs). Social psychologist Karl Weick and his co-workers (Kathleen Sutcliffe and David Obstfeld) suggested[29] that HROs have 'collective mindfulness' of danger. This goes beyond individual mindfulness and must start at the organisational level. It is argued that HROs organise themselves in such a way that they are better able to notice the unexpected in the making and halt its development. This emphasises the danger of over-reliance on processes or values.

The issue of accident modelling has been addressed by a number of authors. Recent work has concentrated less on accident models which consider a chain or sequence of events and more on a system view. Approaches to this are discussed in a recent book by Professor Nancy Leveson (2012)[30].

In discussing the components of an effective safety culture Professor James Reason makes points relevant both to this section and to the concept of safety culture in **section 2.3**. A strong safety culture and thereby a greater resilience to organizational accidents, is not just about procedural compliance. Professor Reason suggests that there are several identifiable further components. First there is a requirement for a 'reporting culture' where reporting of errors and near misses are encouraged as a matter of organizational practice within a 'just' culture where 'blame' is reserved for wilfulness or recklessness. This then needs to be a component of a learning culture where the reporting is used to generate improvement and where it actually makes a difference. Finally, he points out that organisations must be 'flexible', with decision making processes varying depending on urgency and expertise.

A recent study at Bristol University[31] involving a detailed study of the collective findings of reports from twelve major events, across a variety of industry sectors, identified a range of common organisational and cultural precursors to the events.

These were grouped under eight generic headings:

1. Leadership issues
2. Operational attitudes and behaviours (operational 'culture')
3. The impact of the business environment (often commercial and budgetary pressures)
4. Oversight and scrutiny
5. Competence (at all levels)
6. Risk assessment and risk management (also at all levels)
7. Organisational learning
8. Communication issues

Leadership commitment and visibility/ engagement were seen to be a particularly important issue as it has a strong impact on others.

From these, sets of 'Expectations' were then developed as statements of good practice drawn from the reports into the events, which if recognised and implemented, should enable organisations to build stronger defences against the occurrence of future events. These are being developed into probing question sets which are designed to test whether such defences are actually present as an input to tools to measure resilience to these types of precursor. One feature of the findings was that there were considerable similarities between the precursors although they occurred in different industries and some related to operational failures whilst others related to 'projects'. This provides encouragement that if resilience can be built against such precursors, this can be widely applied.

5.4 Managing Change

The need to manage change has been known for a long time. The Flixborough accident in 1974 illustrated the possible consequence when engineering changes are not properly designed and implemented. Since then it has been considered a basic requirement for any industry working with major hazards to have a management system that covers proposed changes to plant, equipment, process or the organisation (people). The change management system should include as a minimum:

- Change control, making sure things are not changed without going through the management system:
- Evaluation, considering the need or opportunity and selecting the appropriate solution;
- Assessment and authorisation, reviewing the planned change to make sure it is likely to be safe and effective;

- Implementation, making sure the change is introduced in a controlled and safe way;
- Review, checking after the change has been introduced that it has been effective and achieved its objectives;
- Reversal - if a change is temporary or considered to be unsuccessful, it may be necessary to have a process to remove it and return the system to its previous state;
- Audit - making sure the system is functioning correctly and effectively.

One of the recurring themes in incidents is that workers do not recognise they are introducing a change or feel it is so small that it does not need to go through the management system. Sometimes a series of these seemingly small incremental changes can lead unintentionally to a cumulative change that is significantly different from the original intent. Training is clearly important to make sure that workers understand that any change has the potential to compromise safety. It is also important that systems are not too burdensome, so that workers are not inclined to bypass the system if they perceive the effort involved is disproportionate to the possible risk.

5.5 Human factors

The UK's HSE state that human failures are responsible for up to 80% of all types of accident and figure in almost every major accident and therefore it is important to reduce those failures as much as possible.

Well trained workers can help to minimise the likelihood and consequences of an accident. At the same time, however, workers not effectively trained in the operation, maintenance, or emergency response of plant equipment, processes, or physical hazards can make errors that directly cause the major accident or significantly exacerbate a developing situation.

The UK's HSE believe that the following subjects need particular attention:

- Competence
- Humans and Risk (integration of human factors into risk assessments and accident investigation)
- Written procedures
- Emergency Response
- Maintenance
- Safety culture
- Safety-critical communications
- Alarm handling and control room design
- Fatigue
- Organisational change and transition management
- Human Factors and the Major Accident Prevention Policy

The UK's HSE also publishes the following checklist:

- Choose the most skilled people to do the work, either your own people or contractors.
- Give people interesting and varied work without overloading them.
- Arrange for work to be done in teams if that's the best approach.

- Takes care that the working environment is not too hot or cold or uncomfortable.
- Keep noise levels down to help communications and concentration.
- Provide good lighting.
- Arrange reasonable working hours, meal and rest breaks.
- Make sure that there's enough room to work and that it is not cramped or confined.
- Issue written instructions and other essential paperwork that works well.
- Avoid overloading people with too much information and ensure that it is not contradictory.
- Provide the proper tools and equipment to do the work.
- Do not apply unreasonable time pressure.
- Minimise interruptions to jobs and do not change priorities if possible.
- Make sure that, if a job is handed over to another shift, key information is handed over with it.
- Provide good supervision of important tasks or of less experienced teams.
- Have practiced and realistic emergency plans in place in case there's a problem.
- Encourage a good working culture and good relationships between people.
- Do not keep changing the organisation, individual responsibilities or lines of management.

Some examples of major accidents where human factors were not adequately considered are:

- The car ferry the Herald of Free Enterprise sank because vital information (the fact the main loading door was not closed) was not available to the Captain.
- The Ladbroke Grove rail crash, 1999 where the stop signal (amongst other contributory factors) was difficult to see in some lighting conditions.
- The Andria Doria sank after a collision at sea because the Captain got confused by the type of radar in use.

Engineers should understand the human factor issues so that they are taken into account in the design of new products, systems and installations and understand where there are deficiencies in operating systems that could cause anything from ill-health to the operator through, potentially, to major accidents.

6. Conclusions

This document has set out to 'form a bridge' between the various high level requirements and guidance produced by bodies such as the Engineering Council and the more detailed aspects of managing health and safety risks in specific areas. Key issues are summarised in UK HSE publications, IET Briefings and documents produced by other professional bodies, including JIGSR, IOSH and SaRS which have as their prime purpose achieving improvement in health and safety risk management.

The document has attempted therefore to provide a picture of the framework which underpins the subject with some specific examples, thus giving engineers and managers the opportunity to see how the various concepts and approaches to health and safety risk management form an integrated whole. In doing so, it has also attempted to provide an overview of some key areas of health and safety such as management processes for the identification and control of risks, the different focus required to minimise vulnerability to major events in high hazard industries such as 'process safety' and vital underlying concepts such as safety culture. It has stressed the sometimes unrecognised business benefits of high standards in health and safety and the importance of engineering in achieving this. In addition, the opportunity has been taken to introduce and discuss some areas of specific concern of which we need to retain a high level of awareness. These include: the sometimes neglected subject of occupational health; the need to deal with risks holistically taking into account ergonomics and human factors from design right through the engineering life cycle of a plant, project or product; the need to recognise and achieve lifelong learning relevant to the subject, and the importance of risk communication by engineers which recognises and addresses the concerns of stakeholders.

In conclusion it is recommended that all engineers should give personal attention to the following five steps:

1. **When in a leadership role at any level in an organisation, show commitment to health and safety and demonstrate this by personal action and example;**
2. **Maintain lifelong competence and understanding of the key issues - from legal requirements and good practice, through to the communication and interpersonal skills which will enable this competence to influence others and be put into practice;**
3. **Maintain alertness to the risks in the workplace or in the project which are present or are likely to emerge, maintaining a questioning attitude and constructive challenge and responding to it and encouraging and giving an opportunity to others to do so;**
4. **Ensure that identified risks are reported, effectively addressed in a holistic way and that the opportunity to learn from failures and deficiencies is taken and learning is shared with others. It is vital that we never 'turn a blind eye' or encourage others to do so when health and safety related issues are encountered;**
5. **Take the opportunity (and encourage where possible others) to promote and be involved in activities which aim to make improvements to health and safety including engineering, organisational and cultural improvements.**

7. APPENDIX – IIG Papers (now the Joint Institution Group on Safety Risk - JIGSR)

7.1 Risk Communication and Professional Engineers

Background and Objectives

This paper arose from discussions at a Workshop between members of the Inter-Institutional Group on Health and Safety (IIG) and the HSE in November 2011. The IIG subsequently set up a working group to produce the paper (with HSE input). It was agreed that it would have the following objectives:

a. identify the key issues for professional engineers in risk communication in the context of health and safety risk management;

b. summarise recent developments in the area being carried out by professional and government bodies;

c. identify where further action might be appropriate; and

d. make recommendations on what more might be done to promote appropriate action to improve risk communication.

Introduction

Public understanding of risk and effective communication of risk issues by experts and policy makers is vital if health and safety outcomes are to be optimised. Public underestimation of risk can lead to failure to take appropriate precautions to ensure protection against harm in a variety of important ways; whilst overestimation of risks can lead to opposition to potentially important technological developments and can also lead to public demands for inappropriate legislation and regulation. It is entirely appropriate that there should be public debate about requirements for health and safety provisions and about technological developments with health and safety implications, and that public perception and socio-political issues should be an important consideration in decision making. To inform this debate, it is vital that engineers and others responsible for communicating risk issues do so in ways which are accurate, trustworthy, credible, proportionate, and which recognise valid concerns.

In order to express the issues relevant to particular risks to the wider public, engineers have to bridge a potentially wide culture gap. In many cases, engineers regard the need to address risk satisfactorily as primarily an issue of meeting 'objective' criteria often expressed in statistical terms. This process of risk assessment and optimisation provides an important basis in trying to ensure that scarce resources are employed cost effectively in minimising the risks to which individuals and society are exposed and it is important that this 'objective' element in risk management is not neglected. However, society generally does not see the issues as simply as this. Unless engineers understand what lies behind the sometimes complex public attitudes and perceptions and take account of them, they will be unable to communicate effectively with the wider public about the issues involved in identifying, assessing and managing risks. As a result there is a danger that they will not be able to gain acceptance for important technological advances or improvements in our capability to minimise the risks to which we are exposed.

This paper examines what is being done to ensure that the subject is understood by the key stakeholders and that appropriate action is being taken to develop thinking on this issue and to improve mutual understanding. Whilst the primary focus of the paper is on health and safety risks (in line with the objectives of the IIG), it is necessary to see these in the context of wider issues of risk communication and management, and how risk is regulated. Health and safety risk management issues constitute a very important part of the range of risks which have to be addressed by professional engineers and they also constitute an important element in the ethical requirements placed upon them. In developing the skills to handle risks relating to health and safety effectively, engineers develop competencies which will have direct application to the handling of the broader spectrum of risks which they have to manage.

Key Issues

This document does not provide an exhaustive review of the extensive research that has been carried out on risk communication. However, a short bibliography of research is included in Annexe 2. This not only deals with research into aspects of risk communication addressed in this paper, but also with associated issues such as how perceptions of risk are formed, social amplification of risk, the response of different 'personality types' to risk and the development of effective processes to involve stakeholders and to generate trust and improved understanding.

A key issue identified in the research carried out on the subject relates to the issue of trust. Where the public or those affected perceive something to be of high risk, trust in those responsible for introducing the risk and those controlling it, can help to mitigate concerns. Conversely, a lack of trust can lead people to oppose a development even where scientific evidence indicates that the risks are relatively low.

- Research has suggested that to achieve trust, five characteristics are required:
- competence (those communicating know what they are talking about);
- objectivity (this frequently means a view that the source of information is independent);
- consistency (a track record in dealing competently with similar matters);
- openness (a willingness to disclose information and not to appear secretive); and
- empathy (willingness to accept the validity of concerns and to listen and consult).

Concerns are usually greater and trust is more difficult to build where:

- experts disagree or appear to disagree about the risks involved;
- exposure to the risk is involuntary (i.e. it is imposed by others) and is perceived to be out of the control of those subject to the risk;
- it is perceived as 'artificial' rather than naturally occurring;
- the risk is unfamiliar or poorly understood (e.g. it appears to be new with potentially unknown consequences);
- the consequences are dreaded, hidden, irreversible or particularly memorable (e.g. it could lead to cancer, or genetic effects, or it is perceived to be associated with a technology that has had a major and memorable impact on society such as nuclear weapons);
- there is doubt about the benefit from accepting the risk - particularly where benefits and risks appear to be distributed unevenly. For example, ethical concerns arise where there is perceived to be a greater impact on a vulnerable group (e.g. children, future generations or the elderly);
- the risk is catastrophic (i.e. it is likely to affect a large number of people at one time);
- similar developments have led to unpredicted or underestimated consequences (e.g. consequences of concern have arisen from technology which is perceived to be similar); and

- those creating the risk are perceived as obtaining a particular advantage (e.g. a commercial incentive to underplay the risks) and, particularly, where the organisation or individuals involved have a history of being perceived as uncaring.

In a recent paper to the Institution of Mechanical Engineers, the Chair of the HSE, Judith Hackitt CBE, emphasised the importance of building public confidence and made the point that this will not come from telling people that 'we know best'. What will help to deliver it is:

- acknowledging justifiable fear or apprehension of the new and unknown;
- explaining innovations in terms of benefits and risks;
- being honest about what can be done to reduce but not eliminate risk; and
- constantly reminding people that inaction is itself, not risk free.

Developments of Relevance to the Discussion

Issues arising from understanding and communicating about risk, particularly in the context of safety, have been the subject of debate among engineers and scientists for many years. For example, The Royal Society initiated major discussions in the 1980s and 1990s which were instrumental in beginning the process of broadening the purely scientific interpretation of risk among the scientific and engineering communities to take account of the views of social scientists (3.4). The need for wider considerations to be explicitly considered in decision making was heightened by major public inquiries such as that for Sizewell B, where quantitative risk assessment began to be considered in the context of societal considerations and led the Nuclear Installations Inspectorate (NII)/HSE, together with the nuclear industry, to set out criteria which attempted to frame risks in a wider 'socio-political' context in such publications as 'The Tolerability of Risk of Nuclear Power' and subsequently, in a broader context, 'Reducing Risk, Protecting People'.

The topic of risk communication has recently received much attention from government departments, regulatory bodies and from the professional engineering and safety community. This section introduces several of the major studies and reports of relevance to this paper and summarises some of the key conclusions and recommendations. For convenience, the discussion is broken into two parts - developments relating to the engineering profession (4.1), and consideration of handling risk-related issues in a wider context within government (4.2). The latter is important because it can both determine the response to technological developments and will impact on their development and use through regulation. Both are important issues for the engineering profession.

In reviewing and discussing developments, material has been selected with the purpose of contributing to the objectives set out in Section 1above.

Developments in the Engineering Profession

Royal Academy of Engineering Report on 'The Societal Aspects of Risk'

The Royal Academy of Engineering has facilitated a continuing debate among professional engineers on risk-related issues informed by input from social science research. Publications from this 'risk project' included the proceedings of a debate entitled 'Trust me, I'm an engineer' and a particularly relevant report on 'The Societal Aspects of Risk'.

The latter report made the point that one of the reasons that the subject of risk is so complicated and important is that it brings together technical issues with social ones and that both of these must be addressed. It summarised the role of experts, drawing out many of the issues identified in Section 3, above, as being of importance in achieving public trust in communications on risk. Following a discussion of key issues, illustrated by examples of success and failure, it concluded that: "....The conventional separation between the technical (the province of engineers) and the social (the province of managers, politicians and the public) cannot survive scrutiny. Engineering decisions are inevitably shot through with social considerations, just as many apparently political decisions depend on technical judgements. Indeed it is often hard to tell just where the 'technical' ends and the 'social' begins". Given this, it concluded that "Engineers need to be as adept at functioning in a wider political environment as they are in a technical one". It recommended that the following guidelines should be considered in all engineering activities:

- at an early stage, identify the interest groups that might have a stake in the project;
- define the boundaries of the system under consideration and ensure that decisions about the appropriate boundaries are understood and accepted by interest groups;
- aim to quantify the risks with as much precision as is relevant and achievable;
- do not attribute a greater degree of precision to risk assessments than deserved;
- recognise the social, political and economic implications in any risk assessment and acknowledge them publicly;
- stimulate public debate on the perceived risks and benefits; and
- establish a consultation and feedback process about risks with stakeholders, including the public and local community.

Engineering Council 'Guidance on Risk for the Engineering Profession'

This important document published in March 2011 sets out the key principles underpinning the role of professional engineers and technicians in dealing with risk, and their responsibilities to society. It highlights eight important outcomes arising from the effective management of risk and in a short pamphlet (and associated 'wallet card'), lists six principles (each with associated practical advice on how these might be achieved) to guide and motivate professional engineers and technicians in identifying, managing and communicating about risk. The Guidance points out that the control of risk will depend both upon the support of those inside the organisation and the agreement of those outside, and that the engineer will thus need to pay attention to human and cultural perspectives as well as purely technical aspects. The six principles are:

a. apply professional and responsible judgement and take a leadership role;
b. adopt a systematic and holistic approach to risk identification, assessment and management;
c. comply with legislation and codes, but be prepared to seek further improvements;
d. ensure good communication with others involved;
e. ensure that lasting systems for oversight and scrutiny are in place; and
f. contribute to public awareness of risk.

The fourth and sixth principles are particularly relevant to the current discussion. It is emphasised that within an organisation, risk management should be communicated as a core value and that there is a requirement for strong, honest and effective two-way communication; where appropriate, the establishment of a consultation and feedback process about risks with all stakeholders; a clear expression of the balance of risk and benefit; and, the encouragement of 'open reporting' within a culture of learning and questioning. In raising awareness and understanding about the real levels of risk and benefit and in helping to prevent misperceptions, it is suggested that engineers should be prepared to engage in public debate on perceived risks and benefits, ensure that risk and its management (along with the interdependency of risk factors) is brought out in discussion with the public, and that concepts of 'risk and reward' are communicated. They should recognise the social, political and economic implications and acknowledge them publicly, explain quantitative aspects of risk clearly and with the use of supporting evidence, be honest about uncertainties, and challenge misrepresentations.

Other Recent Developments

The Institution of Occupational Safety and Health (IOSH) has championed 'creating a risk intelligent society'. The proposed approach is explained in IOSH evidence to the Löfstedt Review. The IOSH initiative aims, among other things, to work towards health and safety issues being part of national, vocational and professional education and training. This will help people to develop risk management skills which will be valuable in all aspects of life, inform decision-making and improve the quality of people's lives. It will also help business, because having a 'risk intelligent' workforce will help protect and grow their skill base, encourage sensible and safe behaviours, prevent accidents and ill-health, and cut down absences and losses. Furthermore, IOSH point out that it will ultimately benefit society, as better risk management will help reduce the massive costs, both human and financial, from health and safety failures.

In response to a consultation on science in a review of the National Curriculum being carried out by the Department for Education, the Royal Society for the Prevention of Accidents (RoSPA) has made suggestions as to how understanding in schools about health and safety and risk issues might be strengthened. RoSPA pointed out that in the context of risk being poorly understood and applied by the lay public (including teachers), and in the need to prepare pupils for adult life, '....The science curriculum is an ideal context in which to teach the concept of risk, the language of risk and the process of risk assessment'.

Several professional bodies have carried out work more recently to try to make risk management and communication a higher priority through raising awareness and providing training materials. The IIG, with HSE/HSL support, developed during 2006-2008 an outline of core material ('a common vocabulary') for undergraduate engineers and produced a sample CD showing how health and safety and related risk issues might be taught on a common basis to all engineers in an interesting and engaging way using e-learning techniques. The feedback from this pilot, following wide consultation, was very positive and in 2010, IOSH commissioned a report to examine how this material could be used more broadly and what steps needed to be taken to move it forward. Recently, the HSE have provided initial funding for the project to be taken to its next phase, led by the Health and Safety Laboratory (HSL). Representatives from the IIG/professional bodies, industry and academe are offering input and advice on how this can be best achieved. In addition to teaching basic concepts to undergraduate engineers, underpinned by the Engineering Council Guidance discussed above, the teaching material could potentially provide input to the creation of a better understanding of health and safety risk issues more widely - such as in schools, further education and industry.

More recently, the Hazards Forum in collaboration with the Engineering Council, the Royal Academy of Engineering, and industry sponsors, has initiated a programme of discussion meetings on risk communication for engineers. Accounts of these meetings will be published in Hazards Forum Newsletters.

Developments in Government

Since the late 1990s, there has been a growing appreciation that handling risk effectively - both in terms of opportunity and threat - is increasingly central to government in its role as a regulator, steward and manager of risks at the strategic, programme and project/operational levels. In particular, that the accelerating pace of change in science and technology and greater societal connectedness are creating new responsibilities and demands on government. This section provides a summary 'time-line' of the key developments and initiatives. It shows that a very large number of initiatives have taken place in recent years within government to provide guidance on risk- related issues and emphasises the importance and topicality of the subject as a concern of government. Recently, health and safety regulation has received particularly intense and repeated scrutiny, with a large number of actions being taken by the HSE to address concerns - many of which appear to stem less from the nature of regulation than public (and media) perceptions of risks and the application of regulations in a risk averse context. Some of the items in the 'time-line' relate more generally to the management of risk and its regulation and go beyond risk communication in a safety context. However, they draw out points which have relevance to this discussion. Others are specific to health and safety and relate to attempts to address potential concerns and, where appropriate, to simplify regulation.

The key developments are:

1996 *- Establishment of the UK Interdepartmental Liaison Group on Risk Assessment (ILGRA) as an informal committee of senior policy makers on risk issues to help ensure coherence and consistency in governmental risk assessments and to advance good practice. It established a sub-group on risk communication. ILGRA ended its work in 2002.*

1997 *- Formation of the Better Regulation Task Force. In 1998, it published 'Principles of Good Regulation'. This contained five tests of whether regulations are fit for purpose which are now widely recognised and used: proportionality, accountability, consistency, transparency and targeting.*

2002 *- The Cabinet Office published its Report entitled 'Risk: Improving Government's Capability to Handle Risk and Uncertainty'. This recommended a comprehensive programme of change to improve risk management across government.*

2005 *- The Better Regulation Executive (BRE) was set up within the Department for Business, Innovation and Skills to co-ordinate the government's approach to regulatory reform.*

2006 *- Establishment of the Better Regulation Commission (BRC) - a non-departmental public body under the oversight of the Department for Business, Enterprise and Regulatory Reform. The BRC was set up to provide independent oversight of the BRE and provide a strategic focus on risk-based regulation.*

2008 *- The BRC was replaced by the Risk and Regulation Advisory Council (RRAC), an independent advisory panel with a mandate to focus on risk-based management of regulation.*

2009 *- A summary was published of the RRAC's work entitled 'Response with Responsibility – Policy-making for Public Risk in the 21st Century' .*

2009 *- The Regulatory Policy Committee was established to provide independent scrutiny of proposed regulatory measures put forward by government and to challenge where proposals are not supported by robust evidence and analysis.*

June 2010 *- Lord Young's Review of health and safety legislation and the compensation culture was initiated, with publication in October 2010 of the Report: 'Common Sense, Common Safety' .*

April 2011 *- The 'Red Tape Challenge' was established. This cross-Whitehall programme seeks to put a 'spotlight' on different areas of regulation by inviting comments on a website. The intention is thus to provide a clearer picture of which regulations should stay, which should go and which should change. The presumption is that all burdensome regulations will go unless government departments can justify why they are needed. Health and Safety legislation had its 'spotlight' period in July 2011 and underwent a 'Star Chamber' process in 2012. Comments were taken into account by the Löfstedt Review.*

May 2011 *- The Löfstedt Review was established. This was set up to look into the scope for reducing the burden of health and safety legislation on business while maintaining the progress that had been made on health and safety outcomes. Professor Löfstedt's final Report - 'Reclaiming Health and Safety for all' and the government response was published in November 2011.*

January 2012 *- Independent Regulatory Challenge Panels were initiated to deal with disputes over specific advice given by HSE or local authority regulators to duty holders where there is no existing appeals mechanism.*

April 2012 *- The HSE 'Myth Busters Challenge Panel' began work to look into complaints regarding the advice given by non-regulators such as public bodies, insurance companies, health and safety consultants and employers, and to provide an assessment as to whether a sensible and proportionate decision has been made.*

September 2012 *- An informal working group on risk-based policy making was set up within the European Parliament to influence legislation.*

Three of these developments are of particular relevance to the subject of this report:

Cabinet Office Report 'Risk: Improving Government's Capability to Handle Risk and Uncertainty'

This Report emphasised the importance of ensuring that governmental decisions include consideration of risks; that tools and methods of risk management are established and applied; that responsibility for handling risk is kept with those who can best manage them; and that those involved in decision making have the skills to give due weight to risk issues and have recourse to professional expertise. In discussing the handling and communication of risks to the public, the issue of trust was again emphasised with six points being stressed:

a. clarity about objectives and values;

b. openness and transparency around decisions;

c. decisions to be clearly grounded in evidence;

d. public values and concerns to be clearly taken into account in making decisions;

e. provision of sufficient information for individuals to make balanced judgements; and

f. mistakes to be quickly acknowledged and acted upon.

These points were embedded in five principles for managing risks to the public:

1. openness and transparency
2. engagement
3. proportionality and precaution

4. evidence
5. responsibility

The Report concluded with a set of recommendations on how government might improve its handling of risk more generally.

The Risk and Regulation Advisory Council

The RRAC produced a number of reports, guides and tools to help policy-makers and the public tackle public risk before its ‘Offensive against the poor handing of public risk’ ended in 2009. Three of these are of particular relevance:

‘A Practical Guide to Public Risk Communication’ (21) again recognised the importance of developing trust - as exemplified by the Bovine Spongiform Encephalopathy (BSE) and Mumps Measles Rubella (MMR) vaccine controversies which occurred around the time of its publication. The document provides a short, practical guide to help government get its risk messages across effectively, based on five elements:

- assembling the evidence - demonstrating a credible basis for the position;
- acknowledgement of public perspectives - considering how those affected understand the risk;
- analysis of options - considering the broad range of options and their trade-offs;
- authority in charge - defining the nature of involvement; and
- interacting with the audience - identifying the audiences and the appropriate methods for communicating with them.

For each of these, the document provides a series of ‘prompts’ that might enable policy makers to consider whether they had considered each of these issues in sufficient depth.

It was suggested that the guide should be used in conjunction with a further RRAC document - ‘A Worrier’s Guide to Risk’. This sets out questions that recipients of risk communication messages can ask to help them understand and assess how the messages relate to their own circumstances.

At the end of the RRAC ‘offensive’, ‘Response with Responsibility - Policy-making for Public Risk in the 21st Century’ was published in May 2009. This summarised the results of the RRAC’s work and made recommendations. The report concluded that there were five trends that contribute to breakdowns in the appropriateness and effectiveness of policy making and which require strong leadership from government to counter and achieve robust and appropriate policies. These were:

- risk ‘actors’ who shape perceptions and responses to public risk - here, a small subset were seen as active ‘risk-mongers’ who wilfully distort perceptions and can endanger the policy making process;
- streams of data, information and opinion which can distort perceptions of risk and scare people away from managing risks themselves;
- intolerance of failure which leads to more red tape and restrictions on people’s behaviour;
- pressure on government to act hastily; and
- the risk of removing responsibility from individuals - with the potential consequence of reducing community resilience.

The Council developed an approach which it believed would help government and the public to deal with these issues. This involves taking a step back from the immediate concern, recognising the wide range of groups that can combine to influence responses to a risk, and incorporating them actively into the policy-making process. In particular, the Council placed an emphasis on three key disciplines:

- understanding the risk in context - how perceptions of the risk have been shaped, including using a process developed for mapping the landscape around the risk;
- engaging with a broad community - using the map of the risk landscape to develop a common understanding of the issues and to explore together how the issues can be tackled; and
- effective communication - quickly restoring focus to the underlying nature of any given risk and provoking public debate about interventions and trade-offs.

The Council recommended that government should establish an independent Public Risk Commission, which among other things, should communicate with and challenge risk actors and risk-mongers when there is evidence of unhelpful behaviour, and champion as an independent voice, the need for individuals, businesses and organisations to take back responsibility for the management of risks that they can understand and control. This, it was concluded, would provide a foundation for different policy solutions and more societal resilience.

Whilst welcoming the work of the RRAC, the recommendation to create a Public Risk Commission was not taken up; the view being taken that the proposed functions could be carried out by existing institutions, including the newly established Regulatory Policy Committee.

The Löfstedt Review

In addition to reviewing current health and safety regulations and guidance, the Löfstedt Review made important observations and recommendations regarding improving the understanding of risk. The HSE's 'Principles of Sensible Risk Management', together with the 'Myth of the Month' series were welcomed as attempts to dispel health and safety myths in response to media stories. Löfstedt also mentioned the importance of 'Reducing Risks, Protecting People' in providing an overview of risk and risk management and welcomed the work of IOSH (see above) in attempting to create a 'risk intelligent society' and its website for schools and colleges. It also recognised the contribution of the HSE's risk education programme, RoSPA's safety information programme, and the British Safety Council's qualifications for school children. It again emphasised that consideration of risk requires an inclusion of the 'social context' and a recognition that the public, stakeholders and regulators perceive risks differently and that risk communication techniques need to recognise that traditional practices are no longer effective in 'post trust' environments. It therefore concluded that there needs to be a wider debate within society about risk.

In particular, the Report concluded that there needs to be a shared understanding of risk and how it should be regulated, and that a mechanism is needed to bring together Parliament, policy makers, academics and the public to achieve this. It concluded that this should be broader than just occupational health and safety and encompass other areas such as public health and environmental issues. Professor Löfstedt therefore made two specific recommendations in this context:

- 'The House of Lords be invited to set up a Select Committee on Risk or establish a sub-committee of the Science and Technology Committee to examine this issue and consider how to engage society in a discussion about risk', and
- 'That the Government asks the Chief Scientific Advisor to convene an expert group aimed at addressing this challenge. The outcomes need to be disseminated widely across Parliament, policy makers, academics and the public.'

It is clear from the wide range of initiatives launched by Government in this area, that the subject is regarded as important in policy formation and in ensuring that the UK is competitive and takes advantage of technological developments. It is also clear from the above summary, that many ideas have been generated which may have a significant impact on the engineering profession. The next section of the paper discusses some of the actions that might be taken by the profession to move these forward and to engage in the continuing debate.

Summary of the Key Issues Emerging from the Discussions

There are several issues emerging from this paper which professional engineers and their professional bodies may wish to consider further and act upon:

1. Providing scientific and technical data is necessary but not sufficient if risks are to be successfully managed. It is important that benefits and dis-benefits are objectively and transparently assessed in order to ensure that resources are used as effectively as possible in minimising risks, but it is also vital that 'socio-political' concerns are addressed and transparently weighed in decision making. A suitable balance has to be struck between understanding and using engineering, scientific and economic analysis and taking proper account of societal perceptions and concerns.
2. There is a need to examine what the barriers are for engineers and engineering organisations to communicate more effectively about risks and how these can be overcome. For example, do they recognise and accept the importance of managing and communicating about risk; are they aware of the guidance and tools which exist and the conclusions of research from the social sciences; and are they sufficiently encouraged and supported to communicate about risk and challenge 'bad science'?
3. Engineers and scientists may need help to become more aware that if they do not pay attention to - and develop expertise in - building trust and meeting the needs of stakeholders, they are unlikely to be successful in gaining acceptance for developments and, indeed, trust in the profession may be degraded. It is therefore vital that the current thinking and recommended good practices, many of which have been summarised in the discussion above, become better embedded in the training and continued professional development of engineers at all levels. This does not imply that all engineers should engage in risk communication as some may not find it easy to engage with the subjective judgement involved. However, it is important that the need is understood by both individual engineers and the organisations in which they practice, and that those with the necessary skills are encouraged to participate in wider stakeholder communication where this is judged necessary and appropriate.
4. The public are faced with increasing challenges in judging the relative importance of the risks they face. Their understanding is not always helped by poor communication and potential bias from those creating the risk, from pressure groups with a particular 'angle' on an issue, and by some parts of the media, which may on occasions exaggerate risks or scare people in order to provide 'a story'. It is thus important that a more 'risk intelligent' society is created and that sources of information are developed which are seen by those with interest and/or concerns about issues to be sources of objective and trusted information. This also reflects the conclusions of the Löfstedt Report that there needs to be a wider debate in society about risk.

As will be seen from the discussion above, there have been a very wide range of government and regulatory initiatives, reflecting the importance of better risk management and communication and ensuring that it is translated into fit-for-purpose, better understood, and proportionate regulation. Engineers are at the fore-front of addressing many of these issues and in shaping perceptions in business and among the public. It is thus important that they play a pivotal role in shaping the on-going debate.

Recommendations

In response to these issues, three broad recommendations are made:

It is apparent from the review of initiatives such as the Engineering Council Guidance on Risk and the work of bodies such as the Royal Academy of Engineering and the Risk and Regulation Advisory Council, that there already exists much material which should enable engineers and safety professionals better to understand and take appropriate action to improve risk communication in the context of health and safety (and more widely). They will frequently be best able to make judgements based on technical and economic considerations about the cost effectiveness of reducing health and safety risks and will understand the uncertainties and potential systems-related 'knock-on' effects of decisions.

In listening to and taking account of broader stakeholder concerns and perceptions, it is important that decisions continue to take account of these technical conclusions and that an appropriate balance is struck.

It is suggested that guidance be developed which takes account of the issues summarised in Section 3, above, and many of the good practices which have been identified in Section 4, and in other published work. This would draw together the principles and tools which are available and put them in the context of real examples of the types of decisions which engineers might be expected to influence - particularly in a health and safety context, but also more widely - thus providing a 'compendium' of good practice. This could include examples of how technical/economic judgements can be developed, the need to take a 'systems' approach considering the full life cycle of an engineering undertaking taking account of issues such as the design process and ergonomics, but most importantly in the context of this paper, how broader societal concerns might be transparently presented and communicated to facilitate an improved decision making process, and when it is appropriate for this to take place.

Recommendation 1: A group representing professional bodies is established to provide good practice guidelines to engineers and safety professionals to improve awareness, facilitate improved analysis of the issues and improve communication. This could draw on existing material whilst promoting the development of any further tools which may be required. It could include advice on the circumstances in which wider communication about risks might be appropriate.

The need to provide new and engaging teaching materials to provide a basic understanding of the principles of risk management (and in particular health and safety risk) to undergraduate engineers has been identified as important by the professional bodies and the HSE, and progress is being made in developing these. Issues relating to understanding risk and putting it into context, together with risk communication, have been identified as a component of this. The Engineering Council Guidance (9) is an important new development and it is suggested that this should provide the basis for underpinning and encouraging take-up of the new material as it is developed.

In a further report, sponsored by IOSH, which reviewed the earlier work in this area, it was concluded that some of the basic messages about health and safety risks contained in the proposed material and presented in a thought provoking and engaging way, could also potentially be used in further education, in schools and for improved training in industry. The development of teaching materials for schools has been the subject of initiatives by several of the bodies involved in trying to improve understanding of health and safety risks. If developing a more risk intelligent society is to be achieved, it is suggested that the various initiatives and existing materials (including the current HSE/HSL and IIG initiative) should be drawn together as far as is possible, to provide a coherent approach with the aim of developing a broad portfolio of *engaging material, which can be used not only in the context of the teaching of undergraduate engineers, but more widely.*

Recommendation 2: Initiatives to develop innovative and engaging teaching material (such as the HSE/IIG work to teach risk concepts to undergraduate engineers in a health and safety context) should continue to be endorsed and supported by the professional bodies and used, where appropriate, in ensuring that such issues receive due attention in accreditation. As a broader objective, support should be given to drawing together current developments and sharing of good practice to provide a portfolio of materials which can be presented to a wider audience in education, industry and potentially more broadly as an input to developing a more risk intelligent society.

It is important that 'third parties', who are likely to be trusted by a broad range of stakeholders, act to provide clear advice on risks based on the scientific/engineering evidence, looking at issues in a 'systems' context and providing balanced judgements which take account of the important issues drawn out in this paper. Engineering and safety professionals have a critical role in this and professional bodies might consider how they could play a stronger role - building, where possible, on existing work including that of the Royal Academy of Engineering, Engineering Council and other engineering- and science- related bodies concerned with communication and public understanding of risk.

This relates strongly to the need to challenge lack of objectivity/bias in claims which under- or over-estimate risk. It should be recognised, however, that effective and constructive 'challenge' sometimes has to take place in an environment which deters individuals from raising issues, and this is professionally difficult for them. It is suggested that consideration be given to how further support can be given where required.

The recommendations of the RRAC and the Löfstedt Report about wider consideration of risk issues and how society might be encouraged better to engage with the issues should be addressed and it is important that the engineering institutions and other bodies ensure that the engineering profession is fully engaged in this - demonstrating and emphasising the important role that engineers are able to play and working more closely with government to facilitate this.

Recommendation 3: The professional bodies, both individually and collectively, should further consider how they can play a role in the wider debate on risk issues which has been proposed in the Löfstedt Report and elsewhere. In particular, they may wish to consider whether the engineering and safety community can be more effective in challenging claims which are at odds with the evidence and, where appropriate, in supporting those in the engineering community who attempt to challenge such claims.

7.2 The Business Case for Engineering in Health and Safety

Executive summary

This paper highlights the essential and growing role of engineering in supporting risk management and economic sustainability, listing some key steps for engineers, managers and government to consider. The business case for health and safety engineering solutions is outlined, providing real-life examples of many engineering-related successes and failures. This is supported by an explanation of how and why the case needs to be made more strongly.

A holistic, joined-up approach to the future challenges and opportunities is key to the UK's economic and social development and prosperity. It is, therefore, vital that the business and wider societal case for achieving improvements in health and safety and the invaluable role that the early adoption of engineering solutions can play are more widely appreciated. This will help inform better choices; counter negative misperceptions about the 'burden' of health and safety, all too prevalent in our modern media; and foster greater 'risk intelligence'.

Making the case for 'socially responsible business' will help to: encourage more investment and action to prevent injury and illness (through design and engineering solutions); increase resilience to disasters and their potential impact on infrastructure (through better materials and assembly and continuity planning); manage health problems at work (through ergonomics and work adaptation); and improve people's health and wellbeing (by accommodating physical activity and providing conducive working environments).

A greater understanding of health, safety and risk management is needed at the conception stage of engineering and construction projects and in all workplace settings where problems can potentially be 'engineered-out'. Retrofitting in such situations, even if feasible, can be costly and less effective than putting in the right design at the start. Effective collaboration between engineers, health and safety professionals and workers themselves can lead to more effective risk control and prevent money being wasted on ineffective measures. Successes need to be evaluated and failures thoroughly investigated, so that lessons can be learned and shared.

Many of the costs, human and financial, that are associated with failure to capitalise on engineering can be 'hidden' - while many of the benefits can be long-term, societal and not attributed or recognised properly, if at all. So to be persuasive, it is necessary to address both of these problem areas, by building an accessible and authoritative evidence-base and improving communication and influence.

Some key steps for engineers
■ Use a multidisciplinary approach and work closely with health and safety professionals, risk managers, HR personnel and others, taking a 'whole lifecycle' or 'systems' approach
■ Research the health and safety risk implications of the project being proposed, tendered for or worked on
■ Actively seek to eliminate hazards and reduce the risks through engineering solutions and design, using guides such as 'Healthy by Design'
■ Prepare and present an economic case to complement the legal and moral one, using for example, the IOSH 'Li£e Saving' resources
■ Evaluate interventions to help increase the evidence-base and share lessons with fellow engineers and other stakeholders, as appropriate, following professional guidance.

Some key steps for managers
■ Foster a multidisciplinary approach to avoid money being wasted on ineffective measures and consider the lifecycle costs (from design to disposal) of projects when assessing the value of engineering-related proposals
■ Encourage the use of evidence-based practice and the evaluation of engineering interventions at work
■ Embed 'risk intelligence' in procurement standards and apply the hierarchy of risk controls
■ Seek examples of good engineering practice and consider the wider organisational and cultural benefits from improved health and safety.

Some key steps for government
■ Ensure all publicly-funded projects use suitable engineering solutions and design to reduce occupational health and safety risks and the societal costs of failure
■ Promote the business case for the early adoption of good engineering and health and safety risk management as vital components of a growing and sustainable economy
■ Actively involve engineers, health and safety professionals and others in developing and implementing the national industrial strategy and in fully assessing the risks and benefits
■ Promote wider understanding of good health and safety risk management, the benefits of a holistic approach, and the need for more 'risk intelligence' within the education process.

Introduction

This paper highlights the essential and growing role of engineering in supporting risk management and economic sustainability, listing some key steps for engineers, managers and government to consider (see above). The business case for health and safety engineering solutions is outlined, providing real-life examples of many engineering-related successes and failures. This is supported by an explanation of how and why the case needs to be made more strongly.

The impact of failures in health and safety across all sectors in the UK are very considerable in both human and financial terms. HSE estimates4 that work-related injuries and ill health in Britain cost society £13.4 billion in 2010-11, excluding occupational cancer and property damage from accidents at work costs. It is likely that these additional costs would be of a similar order of magnitude.

In 2011-12 there were 172 people killed at work, an estimated 212,000 serious injuries and 1.1 million workers suffered an illness they put down to work. There were an additional estimated 12,000 deaths due to work-related illness from avoidable past exposures to hazardous substances. In total, 27 million working days were lost to work-related injury and ill health.

Nationally, the cost of general ill health for Britain's working age population has been put at a staggering £100 billion. Dame Carol Black also noted that every year around 300,000 people fall out of work onto health-related state benefits and of the 27.5 million people in employment, 26% had a health condition or disability.

All of this has a significant impact on individuals and their families, business, government and society as a whole. So the true potential of engineering for prevention and mitigation must be fully exploited to reduce suffering and loss, while at the same time supporting innovation and growth. Taking a holistic view, it is possible to plan early for emerging issues and opportunities. This means considering loss reduction and the benefits of health and safety management over the engineering lifecycle - from better design, through operations and beyond.

Emerging issues that need to be considered include the impact of living longer - a growing ageing population will suffer age and lifestyle-related health conditions, as well as more years of exposure to work-related health hazards. Then there are developing economies and markets, which will become future customers and suppliers; and emerging technologies, the risk profile of which is, as yet, unknown. Additionally, UK industry is starting to experience the negative effects of ageing infrastructure and climate change.

Engineering supports innovation and provides many of the solutions for keeping work safe, healthy, profitable and sustainable. So, complementing the legal and moral imperatives, there needs to be greater appreciation of the business case for the early adoption of engineering solutions in occupational safety and health and their potential societal, micro and macro-economic benefits.

Within organisations, engineering controls can reduce health hazard exposures, as well as addressing safety concerns and avoiding catastrophes (such as major fires; chemical explosions; radioactive, gas and fume releases; structural collapse; and major rail, shipping and aircraft accidents). While within economies, engineering solutions can help avoid the cost of national and international disasters, as well as preventing future disease, injury and death - keeping people, businesses and the economy healthy, productive and sustainable.

The importance of avoiding disasters has been highlighted many times, including by incidents such as Buncefield, Deepwater Horizon, and Fukushima. The National Security Strategy classifies major industrial accidents as a Tier 1 risk to the UK alongside international terrorism, military crises and hostile cyber-attacks. And the need to avoid the terrible legacy of 'slowly unfolding disasters' is clearly demonstrated through the unremitting toll of asbestos-related deaths witnessed across the decades.

This appalling catalogue of preventable loss stands in stark contrast to the major benefits that have accrued from the many successful engineering interventions such as the Thames Barrier. Effectively deployed more than 100 times over the last 25 years, it has helped protect an estimated 1.25 million people, £80 billion worth of property and infrastructure, much of the London tube network and many historic buildings, power supplies, hospitals and schools.

All those involved in taking budget-related decisions (e.g. governments, councils, employers) and those who may subsequently be affected by them (e.g. consumers, workers, facility users) need sufficient information and ability to evaluate the costs and benefits of any proposals. Reliable risk assessment and 'risk intelligence' are key to facilitating proportionate and workable solutions that are safe, healthy and practical and also, to debunking myths. Embedding sensible risk management throughout the education and training system will help achieve this.

Key points: a holistic, joined-up approach to the future challenges and opportunities is key to the UK's economic and social development and prosperity. It is, therefore, vital that the business and wider societal case for achieving improvements in health and safety and the invaluable role that the early adoption of engineering solutions can play are more widely appreciated. This will help inform better choices; counter negative misperceptions about the 'burden' of health and safety, all too prevalent in our modern media; and foster greater 'risk intelligence'.

Why make the business case?

Making the business case for suitable engineering solutions to improve health and safety performance, means that the many benefits will be clearly explained and understood by business and government. As a result, positive decisions and behaviours will be reinforced and encouraged and public awareness of the benefits of improved health and safety will be raised, helping counter some of the myths.

Vital though it is, reducing deaths, injuries and ill health, is only part of the story. ‘Good work’ is generally good for health and wellbeing and positive feelings about work have been linked to higher productivity, profitability and customer and worker loyalty. For work to be considered ‘good work’, among other things, it should be safe, supportive and accommodate people’s needs. It is important that more engineers, employers, managers, investors and government officials recognise this and understand what ‘good work’ is and how it affects products, services and the bottom line. To do this, professionals in the field need to gather, analyse and present risk management data, showing the many ways in which engineering can improve health and safety, and in turn, benefit business and society.

Strong leadership, worker involvement, health and safety competence and adequate enforcement are all important for effective health and safety management and positive culture. And within this, making the ‘business case’ for engineering intervention in health and safety issues is crucial because, as well as supporting the legal and moral imperatives, it helps justify its appropriate use and prioritisation. If the case is not made, engineering interventions for reducing or managing risk may either not be considered at all or may wrongly be seen as just adding cost without adding business benefit. Helping policy-makers and budget-holders see the ‘bigger picture’ and to appreciate the financial savings and opportunities for growth from improved design, quality assurance, project delivery and productivity can assist their decision-making and focus.

Increasingly, employers are looking to do more with less as they struggle to cope with reduced budgets and squeezed margins. But, unfortunately, many do not track the losses arising from poor health and safety management; so that the potential savings from prevention are not readily apparent. It is important that more organisations monitor the cost of poor health and safety management, so that they can appreciate its scale and the extent of their uninsured losses. Even for organisations where no serious incident has occurred, the cost of accidents can be significant. A study found that for one organisation this amounted to 37% of profits; in another, 8.5% of tender price; and a third, 5% of running costs. It also suggested that the ratio of insured to uninsured cost could be £1 to £8-36. The IOSH website provides free tools and case studies to help employers track their costs.

Many organisations, particularly those that rely heavily on their reputations in order to trade, will want to demonstrate good corporate social responsibility and to reflect this in their operations and public reports. The costs of engineering solutions are well known, so it makes good sense to balance these against a full inventory of the benefits. Not only in the short-term, but also in the long-term; and not only to the individual employer and their supply chain, but also, more holistically, to society as a whole.

As the UK and Europe focus on improving economic growth and seek to reduce the perceived regulatory burden, the strong rationale and evidence for engineering solutions in health and safety needs to be heard. The case should be made to all stakeholders and integrated into the education and training of engineers and managers and also into relevant vocational qualifications and apprenticeships. The development of new and ‘green’ technologies provide ideal opportunities to get sensible health and safety management, and sound engineering, embedded at the start of all industrial initiatives, just as happened for safety design in the Olympic park in London and can also apply to smaller projects.

The failure statistics above, including the 1.1 million workers with illness they put down to work and the 12,000 deaths a year due to work-related illness, highlight the need to ensure health issues are managed with the same preventative focus as safety. Language is important. For instance, health failures leading to long-latency conditions, such as occupational cancers and hearing loss, can be termed ‘slow accidents’. This helps to highlight that though less dramatic, immediate and visible than safety failures, they are equally devastating. The key message is that health affects work and work affects health.

Looking forward into this decade and beyond; our ageing population, the increasing prevalence of obesity and unhealthy lifestyles, combined with increasing work intensification, remote working and globalisation will all require engineering and built-environment solutions to facilitate healthier working. Better prevention of harm and practical support for those with health conditions are vital for maintaining an inclusive and diverse workforce of 'all the talents' and a strong and vibrant economy. And engineering should also be embedded as part of emergency and contingency planning, to help minimise damage and optimise recovery in crisis situations.

The government is promoting major infrastructure development plans (such as for high speed rail, increased airport capacity, energy production and distribution and the Commonwealth Games build), together with national house-building and home improvement programmes. There are also initiatives related to new scientific developments and future energy production, including green technologies, novel gas production and nuclear power. Prompt and decisive action is needed to make sure that the benefits of good health and safety are considered at the early planning and design stage and become firmly embedded in the national 'industrial strategy'.

Key points: making the case for 'socially responsible business' will help to: encourage more investment and action to prevent injury and illness (through design and engineering solutions); increase resilience to disasters and their potential impact on infrastructure (through better materials and assembly and continuity planning); manage health problems at work (through ergonomics and work adaptation); and improve people's health and wellbeing (by accommodating physical activity and providing conducive working environments).

How engineers can make a difference

Having explored the reasons to promote the economic argument for engineering interventions, there is also a need to highlight how and when they work and the scale and range of the positive effects. From original concept through to design, plan, execution and disposal, engineering can help prevent future suffering and costs and improve outcomes, growth and sustainability.

Within the 'risk control hierarchy', engineering solutions feature higher than individual protection, because they can combat the risk at source, benefit more workers at once and are not dependent on workers wanting to use them. Resorting to the use of personal protective equipment as a first option, rather than improving design, is poor practice. It is also less efficient, potentially leading to more hazard exposure and illness; requiring more training, monitoring, signage, supervision, equipment and maintenance, with all the associated costs.

Engineers, as individuals or members of multidisciplinary teams, can provide invaluable professional insights into the effectiveness of engineering interventions. Where they collaborate with health and safety professionals and workers themselves to ensure that engineering solutions are relevant to the tasks performed and are properly installed, engineers can ensure that risk is properly controlled and money is not wasted on ineffective measures. They can also contribute useful information for investigations into accident causation and data to support project designs and plans. Additionally, they can identify situations, not apparent to others, where good engineering can help to manage risk.

The obligation on engineers to address health and safety risk issues is set out in various documents, including the Engineering Council Guidance on Risk and the Royal Academy of Engineering / Engineering Council's Guidance on Ethics. At all stages of their careers, engineers have a key role in the management of health and safety risks, through planning and design, project supervision and management and corporate decision-making. Their willingness and ability to take a holistic approach to risk, throughout the project lifecycle, can make a vital difference. It can reduce the human toll and the costs involved in the three broad areas discussed above: day-to-day safety for workers and the public; the often neglected area of occupational health; and minimising disasters and major incidents (see Appendix). Training and ongoing professional development should cover not only good engineering risk management principles and application, but also evaluation techniques.

There are many success stories and examples of engineering design improving quality, project delivery and health and safety. In a study into the commercial case for applying the Construction (Design and Management) Regulations, it was concluded that "...professional added value design in its widest sense as part of the delivery of successful projects is inextricably linked to professional health and safety management." From an estimated £80 million saved on the Heathrow Terminal 5 project, by ensuring safe and efficient supply flow; through to £1 million saved on the Royal Bank of Scotland new office build, using value-engineering.24 And, though perhaps now taken for granted, introducing electrically-interlocked doors on trains has impressively saved around 200 lives over 10 years. While more recently, the Olympic-build of the high-profile 'Velodrome' deployed effective design to shave six months off the length of the project, as well as reducing the need to work at height, lowering the safety risk.

Early involvement of relevant professionals in the design-stage is essential (e.g. health and safety practitioners, safety engineers, health professionals, ergonomists and occupational hygienists). In a study into 'Improving inherent safety' in the offshore oil and gas installations (i.e. careful attention to the fundamental design and layout), interviewees felt that this design approach was worth pursuing, offering capital or operating cost savings, as well as better safety. The report concluded that project managers should consider allocating more time at the concept design stage and it should be recognised that the most critical part of any project can be at the very start when all the major decisions are taken. A point clearly reiterated by those researching the provision of occupational health/hygiene services at the Olympic Park and Athletes Village. They concluded that earlier engagement with design teams and further training on occupational health awareness for designers, architects and CDM Co-ordinators would have been necessary to effectively 'design-out' health risks.

It is not only large firms and major projects that make savings - smaller ones do too. One medium-sized engineering firm introduced a health and safety and quality improvement to its metal preparation process and discovered that it increased productivity by tenfold. And through investing in innovative design - a church installed a new lighting system so that fittings could be lowered for maintenance. This avoided the cost and risks of repeated work at height and has a projected return on investment after 12 years and decades of lower maintenance costs. Two case studies also explored the business benefits of good health and safety management for small and medium-sized enterprises. They highlighted the tangible and intangible benefits of engineering-related interventions, including improved reputation and morale and lower accident rates and insurance premiums.

While on the other hand, poorly designed or installed interventions are both ineffective and wasteful. For example, one small alarm manufacturer invested in an extractor system that was incorrectly designed and installed and proved inadequate for controlling workers' exposure to solder fumes. As such, it was a waste of money. But through collaboration with health and safety professionals and the workers themselves, an improved and cost-effective hood design was introduced, which controlled worker exposure and made workstations more productive.

And it is very important to learn from mistakes. There have been many major disasters costing hundreds of lives and many millions of pounds, which better design and engineering practice could have mitigated or even prevented altogether. Examples in the UK include events from a wide range of engineering-related operations and projects, such as the Port Ramsgate elevated walkway collapse; Hatfield railway accident; the THORP nuclear fuel re-processing facility loss of containment; and the Buncefield oil storage depot explosion. All of these involved issues of design failure and/or failures in good engineering practice, together with significant organisational and cultural failures. These events, together with other examples of successes and failures, are summarised in the Annexes.

Looking more locally and at specific situations that employers seek to tackle, such as preventing asthma or fatal accidents, the need for good engineering is clear to see. Well-designed and properly used containment, automation or local exhaust ventilation can be effective in reducing airborne contaminants; while, conversely, inadequate control can leave workers at risk. The engineering control cost is off-set by improved attendance and productivity and less need for personal protective equipment. It can be dwarfed in comparison to the societal cost of asthma cases, 4% of which are met by employers, 49% by affected workers and the remainder by taxpayers. This further demonstrates the need to look at the 'big picture' (and take a 'systems approach') in assessing costs and benefits. Another practical example is action taken due to design problems related to semi-automatic quick hitches, used by employers' for excavator attachments and which have been implicated in a number of deaths. Better guidance, training, supervision and checking have been promoted and international standards work is addressing the root cause of the problem.

[For more practical guidance on how to design-in health and safety and design-out problems, see 'Healthy by Design'. To view a video-clip showing a 'design-stage risk assessment' initiative, please see http://youtu.be/Px3vTt8--vk

Key points: a greater understanding of health, safety and risk management is needed at the conception stage of engineering and construction projects and in all workplace settings where problems can potentially be 'engineered-out'. Retrofitting in such situations, even if feasible, can be costly and less effective than putting in the right design at the start. Effective collaboration between engineers, health and safety professionals and workers themselves can lead to more effective risk control and prevent money being wasted on ineffective measures. Successes need to be evaluated and failures thoroughly investigated, so that lessons can be learned and shared.

Making the business case

Well-presented supporting data will help decision- and policy-makers to understand and support the case for engineering solutions for health and safety issues. This information can assist managers to secure the necessary budget, resources and commitment for specific interventions.

Problems and their solutions should be as 'fully costed' as is feasible and proportionate. To win the support of decision-makers, proposals need to be communicated in a coherent and persuasive way. Interventions should be evaluated from a technical, legal, social, financial and reputational perspective, using 'before and after' data, and appropriate consideration of stakeholder views. The analysis should take account of any confounding factors, data sensitivities and, where possible, use a 'systems view', covering project/operation lifecycles and any 'knock-on' effects. Updating budget-holders and investors regularly on what has actually been achieved will mean that further interventions can be proposed and considered.

When costing the problem, the organisation can use exposure data (e.g. on noise or dust levels); or behavioural safety observation data (e.g. on manual handling) and related accident and absence data. This can also be supplemented by information on any associated civil claims and enforcement action penalties. When costing the solution, the organisation can estimate the cost of improving health and safety management, such as the use of lifting devices or occupational hygiene controls, including noise attenuation and containment / extraction of dust. It should also cost the ongoing evaluation of the activity (monitoring and analysis) to gauge its efficacy.

It can be helpful to translate current corporate losses from health and safety failure into what the organisation concerned would have to do to recoup them financially. For example, if the company is losing £20,000 to back pain absence, assuming it makes £10 profit on each of its components, it would need to manufacture and sell an additional 2,000 of them. In the public sector, this can be equated to client delivery (e.g. number of social worker visits) that could be funded, if the losses were avoided.

For organisations with a strong corporate social responsibility culture - the societal costs of non-intervention can also be very persuasive. The reputational enhancement may be difficult to quantify and monetise, but the loss of reputation can be less so in terms of losing a major client or a projected drop in share price. This has been clearly demonstrated by the reputational and financial impact suffered by major companies and regions/economies following high-profile disasters such as Deepwater Horizon and Fukushima.

For free resources on making the business case, see IOSH 'Li£e Savings'.

Key points: many of the costs, human and financial, that are associated with failure to capitalise on engineering can be 'hidden' - while many of the benefits can be long-term, societal and not attributed or recognised properly, if at all. So to be persuasive, it is necessary to address both of these problem areas, by building an accessible and authoritative evidence-base and improving communication and influence.

Relevant training

Professional bodies offer a range of professional development courses. For example, IOSH, the Chartered body for health and safety professionals offers the following related courses:

- Meaning business - developing and delivering the business case for health and safety (1 day)
- Risk communication (2 days)

For details see www.iosh.co.uk/training/training_for_professionals/courses_at_the_grange.aspx

ANNEXE 1

Engineering-related design successes

Listed below are some examples of UK engineering-related successes from the last few decades, helping to demonstrate the key role of good design, early planning and appropriate material selection in safe and sustainable project delivery. This list is not intended to be comprehensive, but to highlight some cost-effective cases of good engineering in action.

1. The Thames Barrier - this barrier protects around 1.25 million people, £80 billion worth of property and infrastructure, much of the London tube network and many historic buildings, power supplies, hospitals and schools. Since 1982, it has been effectively deployed 106 times to protect London from flooding. It cost £535 million to build and the running costs are estimated at £6 million per year. Without the barrier, London's defence walls would need to be so high that they would deprive people of much-loved river views and iconic skylines.
2. Landsdowne Chemicals - this chemical manufacturer employed an innovative engineering control to eliminate their workers' and customers' potential exposure to Hydrazine Hydrate, a carcinogen. As well as controlling exposure, the automated system allowed Landsdowne to increase production capacity five-fold with the same staff numbers and their state-of-the-art sealed containers gave them an advantage against EU competitors.

Research for the HSE examined the commercial case for applying the Construction (Design and Management) Regulations 1994 (CDM). The report contains case studies, a number supported by persuasive estimated project-cost savings (excluding any monetary values for health and safety benefits, which would be additional), some of which are listed 3-9 below.

3. Heathrow Terminal 5 - during this project there was an initiative to ensure safe and efficient flow of supplies via a 'consolidation centre'. The estimated savings over the course of the project were around £80 million. The health and safety benefits included well-organised, cleaner work areas and reduced and controlled site traffic.
4. Colchester Garrison - this involved construction of a range of buildings at one large site making use of prefabricated 'volumetric' units. The estimated savings were around £4 million. The health and safety benefits included less working outdoors, manual lifting, working at height and interface with on-site traffic.
5. Newport relief road - this road-building work involved construction of a length of dual-carriageway, using the 'comprehensive' approach and investigation of the sub-surface zone. The estimated savings were around £500,000. The health and safety benefits included reduced overall injury risk during excavation of services, by using good planning to avoid the need to make late changes under pressure.
6. Bridge on the Newport relief road - this project opted to spend more on materials in order to reduce hazardous tasks from the ongoing maintenance schedules and avoid lane unavailability penalties. The estimated savings were around £210,000 over the projected life of the bridge (i.e. 40 years). The health and safety benefits included avoiding the need to replace lamp-posts adjacent to live traffic and major internal maintenance in confined spaces.
7. North Circular Road (A406) - during this project, 'observational' methods were used to manage difficult foundation conditions. There were an estimated 5% direct cost savings, plus a time saving of 18%. The health and safety benefits included that the observational method allowed for a much more open site, where lower risk plant operations and routine lorry loading could take place. There was a reduced risk of collisions, which could have led to catastrophic collapse, death and injury.
8. Royal Bank of Scotland - for the new office build at this bank, floor plates were constructed which were 'value engineered' to reduce costs and increase programme security. This meant that the costs were reduced by £1 million. The health and safety benefits included reduced risk from work at height and manual handling.
9. St Giles Church lighting - as part of a refurbishment project, a new lighting scheme was designed for this church. This allowed fittings to be lowered, so that 're-lamping' could take place at ground level by unskilled people. It was estimated that a return on investment would be achieved after 12 years, followed by decades of free maintenance and lamp changing. The health and safety benefits included eliminating the risk of falls from height.

In addition, the business benefits of good health and safety management to SMEs were explored via six case studies, two of which are listed below:

10. Data Scaffolding - this firm bought high quality metal scaffolding components (instead of wooden scaffold boards) to prevent workers falling through; engaged external health and safety services; and trained staff in safe erection and dismantling. As well as good health and safety and morale, this has led to a drop in insurance premiums by over half in 4 years, saving tens of thousands of pounds. And ease of use allowed a saving of around £70 per man day per job. The firm felt that the good reputation enabled them to expand towards larger-scale commercial projects, which reap higher returns.

11. Huntsman Quarries Ltd - this firm improved worker involvement and health and safety training. There were also improvements to the safety of maintenance operations on rock crushing plant, cutting the time for routine maintenance, yielding an extra 5% productive time each day. Reported benefits included increased employee productivity due to fewer accidents; improved morale and reputation; and 15% lower insurance premiums, saving around £15,000 a year.

ANNEXE 2

Engineering-related design failures

Listed below (in chronological order) are some examples of disasters from the last few decades, mainly in the UK, where failures in design and generic organisational and cultural deficiencies played a major part. This list is not intended to be comprehensive, but to serve as a reminder that similar fundamental causes of disasters are more deep-seated than failed engineering components or human error and affect all areas of engineering.

1. A 2004 peer review of HSE reports on causes of construction accidents concluded that "… almost half of all accidents in construction could have been prevented by designer intervention and that at least 1 in 6 of all incidents are at least partially the responsibility of the lead designer in that opportunities to prevent incidents were not taken." The report also concluded that around 13 deaths a year could be prevented by designer action and proportionate savings in injury and ill health made. Furthermore, there were also incidents where the original design made maintenance activities difficult and unsafe. Generally, it was felt the design community did not give adequate information about the suitability or otherwise of their products for particular situations.

Some further historic disasters in which better design could have helped avoid or reduce the suffering and loss include:

2. Ronan Point (1968) - a gas explosion in this 22-storey (about 200 feet high) block of flats killed 4 people and injured 17. The design and construction made the incident worse because of a 'domino-effect'. The partial collapse of Ronan Point led to major changes in the building regulations.
3. Herald of Free Enterprise (1987) - this car ferry sailed with its bow doors open and capsized, killing 193 passengers. The main cause was poor corporate safety culture, but post-incident a number of design improvements were made to Ro-Ro ferries.
4. Piper Alpha (1988) - a series of explosions and fire on this offshore platform killed 167 people and the cost at the time was estimated at £1.7 billion. As well as cultural, system, procedural, communication and leadership failures, inherent design flaws were a contributory factor.
5. Heathrow Express Tunnel Collapse (1994) - during construction of the Heathrow Express rail link, a tunnel collapsed 30 metres below ground. Thankfully, no-one was injured, but losses are estimated to be as high as £400 million. The collapse could have been avoided but for sub-standard construction and repairs and a failure to manage parallel tunnelling in failing ground.
6. Port Ramsgate (1994) - an elevated walkway collapsed killing 6 passengers and seriously injuring 7. The walkway design did not provide the support and articulation necessary and the design calculations of the loadings were inadequate. The design errors were compounded by defective fabrication and a lack of adequate maintenance procedures.
7. Hatfield railway (2000) - a derailment caused the death of 4 passengers and the injury of over 70 people, 4 of them seriously. The accident was due to multiple and pre-existing fatigue cracks in the rail. The underlying cause was failure to manage inspection and maintenance.

8. THORP nuclear fuel re-processing facility (2005) - this facility experienced a loss of containment of 83,000 litres of nuclear material between 2004-05. This was believed to be due to suspended tank movement, causing a fatigue fracture of connected pipe work. Design inconsistencies and modifications had failed to take account of these risks and the leak went undetected for 8 months.
9. Buncefield oil storage depot (2005) - a massive early Sunday morning explosion at this oil depot (Richter scale, 2.4), destroyed or damaged property for miles, injuring 43 people. Fortunately, no one was killed. A defective safety device failed to prevent overfilling of a large unleaded petrol storage tank, which led to a huge vapour cloud. The explosion caused an estimated £1 billion worth of damage and distress.
10. Fukushima Dai-ichi nuclear disaster in Japan (2011) - an earthquake and tsunami caused major destruction to this plant. There were several explosions and reactor meltdown leading to major radioactivity release. The plant planned for a tsunami height of 5.7 metres, and was overwhelmed by the 14 metres that occurred. The consequences of this disaster led regulators worldwide to reassess plant-vulnerability to floods from tsunami, swollen rivers or failed dams. It has been estimated that the disaster could cost Japan up to US$250 billion over the next 10 years.
11. Deepwater Horizon (2010) - the explosion and sinking of the Deepwater Horizon oil rig claimed 11 lives and left oil gushing unabated into the Gulf of Mexico for 3 months, releasing nearly 5 million barrels. There were systematic failures in risk management, with a defective cement-design process and failure of the 'blow-out preventer'. In March 2013 BP had spent / provisioned more than US$40 billion in related costs for the incident.

Feedback, additional case study material and further references are welcomed - please send to richard.jones@iosh.co.uk

Richard Jones
Chair: Business Case
July 2013

7.3 Life Long Learning for Health and Safety Risk Management

Introduction

i. Managing health and safety risks effectively is a vital requirement for technicians, engineers and managers whatever their engineering disciplines. They have a key role in ensuring that the safety and health of the workforce and the public is given prominence in all that they do - whether this is in ensuring day-to-day safety, dealing with hazards to health, or minimising the potential for major accident-events affecting society. This requires understanding of, and competence in, the key issues underpinning high standards of health and safety risk management from design, through to operations and the management of projects, and in relation to the entire engineering life cycle of a process, product or project. It includes an understanding of legal requirements, good practice and the organisational and cultural issues that need to be addressed to ensure high standards - such as leadership and communication skills.

ii. The requirements to achieve this as part of accredited academic programmes in engineering, and Initial Professional Development (IPD) phases (i.e. up to professional qualification) are set out in the requirements of engineering institutions and other engineering professional bodies. These comply with the requirements of the Engineering Council as contained in UK-SPEC (http://www.engc.org.uk/ukspec). The Inter-institutional Group (IIG) on Health and Safety and member institutions continue to work with the Health and Safety Executive (HSE), academe and industry to develop teaching materials that will improve the capability of academic bodies and institutions to meet these requirements.

iii. However, it is vital that the capability to understand and manage health and safety risks continues to receive attention as technicians and engineers progress through their careers - whether their role is primarily in an engineering capacity or that of a manager or senior manager. The importance of this is reflected, for example, in the Engineering Council's Guidance on Risk for the Engineering Profession (www.engc.org.uk/risk).

iv. Beyond IPD, although Continuing Professional Development (CPD) must be demonstrated, some engineering bodies do not issue explicit guidance in respect of continuing learning in health and safety risk management in their discipline. The IIG, in discussion with the HSE, has therefore produced the attached short document ('schedule') in order to provide a broad framework for discussion, offering guidance and describing in broad terms the continued learning that is likely to be required as part of CPD in relation to this subject.

v. A version of this schedule was first developed some years ago as a discussion document within the health and safety committees of the Institution of Civil Engineers and Institution of Structural Engineers. As the topic has gained greater prominence in discussions between the IIG and the HSE, it was felt to be helpful to re-consider the original document in the broader context of all of the professional bodies which constitute the IIG. The attached document has been developed against this background and in this context. It reinforces and expands upon the requirements of UK-SPEC as we interpret it.

vi. It should be noted that there are legal requirements relating to 'competence' in health and safety matters and the schedule does not deal with specific guidance in respect of these. Requirements for 'competency' encompass learning, experience, currency, attitude and education and are often task-related and thus cannot be reduced to a high-level document. Furthermore, the schedule does not attempt to deal with specialist skills.

vii. The intention of the attached schedule is therefore to initiate a discussion as to whether individual professional bodies have fully recognised the need to define continued learning requirements for health and safety risk management over a notional career. It has been written in such a way as to prompt discussion in individual bodies - and also among engineers and managers more widely - as to whether the suggested key CPD requirements outlined in the schedule are currently being adequately addressed and, if not, what more can and should be done by the engineering profession.

viii. As a first step in this process, it is suggested that the relevant groups concerned with health and safety risk management and membership/CPD in the engineering bodies consider the points made in the schedule. To facilitate this discussion, the IIG suggests that the following questions are discussed. It is hoped that the output of this discussion will indicate what, if anything, needs to be done by individual bodies and by the profession more widely:

a. Do you agree that the issues identified in the attached schedule broadly reflect the requirements for CPD in the area of health and safety risk management over a notional engineering career?

b. In general terms, at the level of detail intended to be addressed in the schedule, are there other potential requirements for continued learning in this area that should be addressed?

c. Within your professional body, do you believe that the issues identified (and any others that you regard as potentially important) are currently being adequately emphasised in your guidance to members and addressed (as shown by your verification procedures)?

d. What practical steps might be taken to address any potential shortfalls?

e. In considering the areas raised in the schedule, are there good practices within your professional body that might advantageously be shared with others who are considering this issue?

f. Are there any issues which require further consideration or guidance more widely across the profession? If so, do you have any recommendations on how these might be addressed?

g. What would Member Institutions see as next steps to improve CPD in this area and would that be at the IIG level or within Member Institutions?

The IIG would welcome feedback.

John Carpenter
January 2013

Schedule: Life Long Learning for Health and Safety Risk Management

This Table is intended to reflect our interpretation of the requirements of UK-SPEC. Although ‘IPD’ is shown following ‘Education’ (for simplicity) in practice there may well be an overlap. The Education/IPD phases are included for completeness: the essence of the Table lies in the CPD section. The levels of attainment are intended to be cumulative during the progression of a career.

	Career Level	Typical level of attainment (cumulative throughout notional career)	Typical means to attain required level
IPD Phase	**Education**	As set out in the relevant discipline’s accreditation documents and complying with UK-SPEC learning outcomes	Via accredited degree course (CEng, IEng); via work experience, completion of an appropriate apprenticeship, and/or an approved qualification e.g. Level 3 BTEC (EngTech).
	Trainee Engineer and Trainee Engineering **Technician**	**CEng, IEng, EngTech** 1. Has knowledge and understanding of current legislation and best practice relevant to area of work including knowing limits of own knowledge and where to find information. 2. Understands and is able to apply the hierarchy of risk control including ALARP/ SFARP during design and over the whole life-cycle. 3. Understands personal and collective responsibilities and liabilities relevant to the industrial sector, and the relevance of lessons from others. **CEng, IEng** 4. Understands the critical importance of minimising the risk of catastrophic events and the particular measures required to prevent this occurring. 5. Is aware of current initiatives and industry concerns in respect of health and safety risk - including occupational ill-health, ergonomics and the need to take a systems/holistic view of risk. 6. Understands the interaction of safety/health risk with other business related risks ‘and is able to maintain a learning and questioning approach to the maintenance of high standards of health and safety within this framework.	**Experience and training (CEng, IEng, EngTech)** In line with requirements of Institution’s ‘Core Objectives’ (excluding items such as First Aid and Fire Warden training) whilst ensuring that a broad capability is established. Includes an element of formal training (to industry recognised standards where available). Utilising mentoring and supervision from qualified/senior engineers to enhance the learning experience. Where possible, maximising opportunities to work in a range of different areas before specialising.

CPD Phase	**Qualified Engineer and Qualified Engineering Technician**	**CEng, IEng, EngTech** 1. Is fully familiar with and able to routinely apply, means to eliminate hazards and reduce risks in own area of work/expertise. 2. Able to manage and apply safe systems of work. 3. Aware of good practice and current concerns. 4. Is able to communicate effectively with others. **CEng** 5. Able to undertake monitoring of relevant safe systems of work. 6. Seeks to improve systems. 7. Able to relate health and safety risk management to wider benefits of effective management and its relationship to business success. 8. Knows when and how to obtain specialist advice and input. 9. Leads by example and through effective communication with staff and stakeholders.	**CEng, IEng, or EngTech** Achieves on-going CPD on health and safety risk matters. Ensures CPD training is specifically obtained on new or revised regulations and for industry developments. Achieves self-development in this area.

	Career Level	Typical level of attainment (cumulative throughout notional career)	Typical means to attain required level
CPD Phase	**Senior Engineer and Senior Engineering Technician**	**CEng, IEng, EngTech** 1. Able to advise less experienced engineers/ technicians in health and safety risk matters. 2. Able to identify H&S training needs of their staff'. 3. Provides positive role model in health and safety risk management matters. **CEng, IEng** 4. Will be capable of identifying the need for health and safety reviews and audits where appropriate, and initiating these within his/ her areas of responsibility. 5. Actively promotes the relationship between good health and safety risk management and good business risk management.	**CEng, IEng, or EngTech** 6. Achieves on-going CPD on health and safety risk matters. 7. Ensures CPD training is specifically obtained on new or revised regulations and for industry developments. 8. Achieves self-development in this area. 9. Interacts with practicing engineers in own team, across their organisation and beyond, as appropriate.
	Manager (or equivalent)	**CEng, IEng,Eng,Tech** 1. Able to inculcate a health and safety culture within team. Ensures anyone reporting to them has the opportunity to maintain competence. 2. Understands the need to benchmark and review progress and performance. 3. Understands the wider occupational health and safety responsibilities of managers and the importance of a holistic approach to risk management. 4. With support, able to implement and maintain a comprehensive health and safety management system. 5. Understands the need to demonstrate commitment to good practice and continuous improvement in health and safety management and demonstrates this in practice and by personal example. 6. Encourages learning and a questioning attitude in relation to health and safety concerns. 7. Ability to listen and recognise when engineers are raising health and safety concerns and deal with them appropriately.	**CEng, IEng, or EngTech** 1. Achieves on-going CPD on health and safety risk matters. This should encompass the wider issues of managerial responsibility. 2. Ensures CPD training is specifically obtained on relevant new or revised Regulations. 3. Achieves self-development in this area. 4. Interacts with practicing engineers in own team, across their organisation and beyond
	Director or Partner (or equivalent)	**CEng, IEng, EngTech** 1. Capable of formulating health & safety policy with advice from a competent source. 2. Has good understanding of current legislation, necessary to fulfil role as Director. 3. Understands the responsibility of Directors towards health & safety risk management. 4. Is aware of good practice in health and safety management relevant to the business and promotes this as a business objective. 5. Ensures that sufficient resource is available to achieve objectives and promotes the case that a successful business requires high standards in health and safety risk management performance. 6. Understands the need to lead from the front and to support staff, and does so.	Achieves on-going CPD on health and safety risk matters encompassing the wider issues of senior managerial responsibility (which should include a formal element for this level). Maintains suitable Interaction across the organisation and with peers within the sector.

Miscellaneous specialist roles such as CDM Co-ordinator, Inspector etc. are for individual institutions to add, building on the above.

8. Abbreviations

ACOPs	Advisory Codes of Practice
ACSNI	Advisory Committee on Safety of Nuclear Installations
CBA	Cost Benefit Analysis
CDM	Construction, Design and Management
CEng	Chartered Engineer, UK-SPEC standard
CPD	Continuous Professional Development
ACOPs	Advisory Codes of Practice
ACSNI	Advisory Committee on Safety of Nuclear Installations
CBA	Cost Benefit Analysis
CDM	Construction, Design and Management
CEng	Chartered Engineer, UK-SPEC standard
CPD	Continuous Professional Development
EngTech	Engineering Technician, UK-SPEC standard
EU	European Union
FTA	Fault Tree Analysis
HROs	High Reliability Organisations
HSB#	Health and Safety Briefing #
HSC	Health and Safety Commission (historical)
HSE	Health and Safety Executive
HSG	Health and Safety Guidance
HSL	Health and Safety Laboratory
IAEA	International Atomic Energy Agency
IEng	Incorporated Engineer, UK-SPEC standard
IET	Institution of Engineers and Technicians
IIG	Inter-Institutional Group on health and safety, now known as JIGSR
IOSH	Institution of Occupational Safety and Health
IPD	Initial Professional Development
JIGSR	Joint Institution Group on Safety and Risk once known as IIG
ONR	Office Nuclear Regulation
PDCA	Plan, Do, Check, Act
PSA	Probabilistic Safety Analysis
PUWER	Provision and Use of Work Equipment Requirement
QCs	Queen's Council
QRA	Quantitative Risk Assessment
RAF	Royal Air Force
RoSPA	Royal Society for the Prevention of Accidents
RRAC	Risk and Regulations Advisory Council
Sars	Safety and Reliability Society
SFAIRP	So Far As Is Reasonably Practicable
SILs	Safety Integrity Levels
SIS	Safety Instrumented Systems
UK	United Kingdom
UK-SPEC	UK Standard for Professional Engineering Qualifications
VPF	Value to be ascribed to Preventing a Fatality

9. References

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