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The business case for **engineering** in **health and safety**

A paper provided by the **Joint Institution Group on Safety Risk - JIGSR**

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Joint Institution Group on Safety Risk

The mission of the group is to work together by consensus to promote action and enhance awareness and knowledge of health and safety risk issues in the interests of the engineering profession.

The aims of the Group are:

- To raise awareness of health and safety risk issues of interest to the profession - in particular acting as a forum for the exchange of information between members
- To promote and support more widely initiatives and activities originating in member organisations where engineering benefits the wider community
- To promote joint action on agreed topics of mutual concern and interest where there are agreed benefits to the wider engineering community

This group was formally know as the Inter-Instutional Group on Health and Safety.

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Cover images (clockwise from top left)

- Thames barrage, London
- 2012 Olympic Velodrome, London (courtesy of IOSH)
- Chernobyl nuclear reactor, Ukraine
- Piper Alpha disaster, North Sea

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Executive summary

This paper highlights the essential and growing role of engineering in supporting health and safety 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 that good engineering is 'socially responsible business' will help to: encourage more investment and action to prevent injury and illness (e.g. through design and engineering solutions); increase resilience to disasters and their potential impact on infrastructure (e.g. through better materials and assembly and continuity planning); manage health problems at work (e.g. through ergonomics and work adaptation); and improve people's health and wellbeing (e.g. by accommodating physical activity and providing conducive working environments).

A greater understanding of health and safety 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[1] and work closely with health and safety professionals, risk managers, human resources 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'[2]
- Prepare and present an economic case to complement the legal and moral one, using for example, the IOSH 'Li£e Saving' resources[3]
- 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[1] 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[1] 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 health and safety 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. The HSE estimates[4] 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[5] 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[6].

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; releases of radioactivity; gas and fume releases; structural collapses; 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[7]. 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[8].

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[9]. Embedding sensible risk management throughout the education and training system will help achieve this[10].

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[11,12]. 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[13]. 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[14]. 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[15]. The IOSH website provides free tools and case studies to help employers track their costs[3].

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[16]. 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[17,18] 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 and Athletes' Village in London[19]. It is also highly relevant 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'[20]. 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 - both need to be properly managed.

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'[21].

* For example: the costs of loss of business, damage to reputation, unscheduled downtime, temporary staff, civil actions, poor staff morale and engagement and prosecutions.

Key points: making the case that good engineering is 'socially responsible business' will help to: encourage more investment and action to prevent injury and illness (e.g. through design and engineering solutions); increase resilience to disasters and their potential impact on infrastructure (e.g. through better materials and assembly and continuity planning); manage health problems at work (e.g. through ergonomics and work adaptation); and improve people's health and wellbeing (e.g. 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 help 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[22] and the Royal Academy of Engineering / Engineering Council's Guidance on Ethics[23]. 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[17,18]. 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 Annexes 1 and 2**). 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[25]. 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[19].

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)[1]. 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[26]. 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[20,27].

It is not only large firms and major projects that make savings - smaller ones do too. One medium-sized engineering firm[28] 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[24] 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[29].
While on the other hand, poorly designed or installed interventions are both ineffective and wasteful. For example, one small

† Elimination; substitution; engineering controls; administrative controls; and personal protective clothes and equipment, see the HSE's website www.hse.gov.uk/construction/lwit/assets/downloads/hierarchy-risk-controls.pdf

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[30].

And it is very important to learn from mistakes. There have been many disasters and incidents costing numerous lives and/or 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 Annexes 1 and 2.

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[31], 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'[2]. 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 and safety 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[17,18]. 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

‡ For male workers the estimated total lifetime costs to society range from £121-176,000 per case and for female workers, it is £96-117,000 per case. Figures given are in 2006 prices. [source RR474, 2006][30]

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'.][3]

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.

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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 http://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.

- 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[8].
- 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[32].

Research for the HSE examined the commercial case for applying the Construction (Design and Management) Regulations 1994 (CDM)[24]. 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 below.

- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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,[29] two of which are listed below:

- 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.
- 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 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.

- A 2004 peer review of HSE reports on causes of construction accidents[33] 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[25] (in chronological order) in which better design could have helped avoid or reduce the suffering and loss include:

- 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.
- 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.
- 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.
- 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[34].
- Heathrow Express Tunnel (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[35]. The collapse could have been avoided but for sub-standard construction and repairs and a failure to manage parallel tunnelling in failing ground[36].
- 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[37].
- 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[38].
- 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.
- 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'[39]. In March 2013 BP had spent / provisioned more than US$40 billion in related costs for the incident[40].
- Fukushima Dai-ichi nuclear plant 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[41]. 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[42].

> Feedback, additional case study material on successes and failures and further references are welcomed – please send to richard.jones@iosh.co.uk

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The **Joint Institution Group on Safety Risk - JIGSR** (formally known as the Inter-Institutional Group on Health and Safety) is made up of representatives (members and staff) from the following organisations:

- Hazards Forum
- Institute of Ergonomics and Human Factors
- Institute of Marine Engineering Science and Technology
- Institution of Chemical Engineers
- Institution of Civil Engineers
- Institution of Engineering and Technology
- Institution of Mechanical Engineers
- Institution of Occupational Safety and Health
- Institution of Structural Engineers
- Royal Institute of British Architects
- Royal Institution of Naval Architects
- Safety and Reliability Society
- Health and Safety Executive
- Engineering Council

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- https://www.icheme.org/resources/joint-institute-group-on-safety-and-risk.aspx

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