

# Preventing catastrophic events in construction

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# Preventing catastrophic events in construction

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The construction industry recognises the hazardous nature of its activities, which can be seen in the high toll of accidents its workers suffer compared with other industries - ranging from lost time injuries to fatalities. There is also a high incidence of ill-health among construction workers, including fatal diseases such as cancer arising from asbestos exposure. However, the industry may not be sufficiently aware of the potential for it to be associated with more major or catastrophic events (those involving multiple deaths and/or significant damage to property and infrastructure).

Larger construction organisations have been applying 'holistic' risk management techniques to manage project risk. Low probability but high-consequence issues have often been included in these considerations. Most issues addressed have had purely commercial consequences eg sudden loss of a major contract or customer. However, some issues do have significant health and safety implications.

This project has examined these 'low probability but high-consequence' safety hazards by looking at:

- the types of catastrophic event which have occurred or which might occur during construction;
- the reasons for occurrence when there have been (or could have been) catastrophic events during construction, including an examination of the underlying factors;
- the controls which should contribute to an avoidance of a catastrophic event; and
- where the UK construction industry could improve.

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# **PREVENTING CATASTROPHIC EVENTS IN CONSTRUCTION**

## **Executive summary**

The construction industry recognises the hazardous nature of its activities, which manifests itself in the high toll of accidents its workers suffer compared with other industries. These range from lost time injuries to fatalities. There is also a high incidence of ill-health among construction workers including fatal diseases such as cancer arising from asbestos exposure. However, the industry may not be sufficiently aware of the potential for it to be associated with more major events (those involving multiple deaths and/or significant damage to property and infrastructure). These major or catastrophic events may have wide implications such as extensive delay or project failure, significant business impact, loss of money and loss of reputation for all concerned.

Health and safety risk management in the industry has traditionally focused upon preventing accidents arising from the most significant hazards such as falls from height (the biggest killer on site) but more recently there has been a welcome growth in the understanding of latent health problems, which can emerge years after exposure.

And increasingly, larger construction organisations have been applying ‘holistic’ risk management techniques to manage project risk and *low probability* but *high-consequence* issues will have been included in these considerations. Many of the issues addressed have had purely commercial consequences e.g. sudden loss of a major contract or customer. However, some have health and safety implications - this project has examined these ‘*low probability but high-consequence*’ *safety hazards*.

In even more hazardous industries such as the chemical, oil and gas and the nuclear and rail industries, major hazard scenarios are required to be examined in depth. These potentially catastrophic events are sometimes referred to as ‘Top Events’. It is appreciated that they can have a disastrous impact on a company’s reputation and well-being and upon society. The process of examining the risk of a catastrophic event requires that a ‘safety case’ is prepared, based upon a safety risk assessment.

This project has looked at the risks of ‘Catastrophic Events’ in the UK construction industry as follows:

- § The types of catastrophic event which have occurred or which might occur during construction
- § The reasons for occurrence when there have been (or could have been) catastrophic events during construction, including an examination of the underlying factors
- § The controls which should contribute to an avoidance of a catastrophic event
- § Where the UK construction industry could improve.

To examine these issues the following approach was taken:

- § Review the literature
- § Find out what people thought, by consultation and by means of an on-line survey and focus group events
- § Examine a number of ‘case study’ events which were, or could have been, catastrophic
- § Review all the information gathered and suggest where the industry should focus its attention to make improvements.

It was clear that there have been Catastrophic Events with major consequences. Their importance was recognised by the industry, although it is considered that in their day-to-day work few people realised the severity of what might happen if things went seriously wrong. Examples of Catastrophic Events are given in the report.

Certain issues emerged which were considered to require attention from the industry: these are discussed in detail in the report and are summarised as follows:

**Issue 1: The industry should recognise that catastrophic events need further attention**

We found that Catastrophic Events are a significant cause for concern and have not received the attention they deserve. Accordingly they should be considered in an appropriate manner and preventative action should be taken as an inherent part of normal construction activity.

**Issue 2: Corporate risk management systems should be improved**

We found that many events had occurred which had significantly impacted at board level upon both construction organisations and upon clients. In order to respond to obligations imposed by legislation and The Turnbull Report<sup>1</sup>, companies’ organisational risk management should include consideration of how well Catastrophic Event risks are being managed. The use of *industry-relevant indicators* should be explored to support such activity.

**Issue 3: Knowledge, skills and experience of safety risk management should be raised**

The case studies frequently demonstrated a failure among project personnel at all levels to adequately identify the full extent of hazards and address the risks arising; other sources demonstrated a considerable degree of uncertainty and a lack of confidence in the industry’s knowledge, skills and experience of safety risk management. This suggested that more emphasis needed to be given to:

- § Education of those who will be entering the industry
- § CPD and on-the-job training
- § Development of more effective safety risk management systems.

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<sup>1</sup> The Turnbull Report, *Internal Control: Guidance for Directors on the Combined Code* (1999) applies to listed companies but is good practice for all companies.

This issue offers the best promise for long-term incremental improvement and involves all stakeholders.

#### **Issue 4: Communication and interface management should be improved**

The research emphasised the need for effective communication about hazards and particularly the importance of effective management of risk at interfaces between and within organisations. The report explores areas where improvements can be made.

This issue underpins the improvement of performance in other issue topics and involves all stakeholders.

#### **Issue 5: Competence is key**

As expected, the issue of competence (which underpins CDM 2007<sup>1</sup>) was seen to be important. In particular the competent fulfilment of the role of Principal Contractor<sup>2</sup> on site was identified as central to avoiding Catastrophic Events in construction.

The industry should develop proposals for ensuring that inappropriate Principal Contractors (or more accurately inappropriate persons) do not become responsible for sites where there are risks which could lead to Catastrophic Events; all stakeholders need to be consulted on how this might be achieved.

#### **Issue 6: Effective management of temporary works is crucial to success**

It was apparent from many case studies that insufficient consideration was being given to the management of *temporary works* in its widest sense. This work must be taken seriously and include all temporary works aspects, including issues relating to cranes and scaffolding.

The potential impact of failures of temporary works needs to be considered carefully to reduce the likelihood of a Catastrophic Event occurring and the industry needs to seek to improve performance in this vital area. All stakeholders should be consulted on how to achieve this improvement.

#### **Issue 7: Independent reviews should be employed**

Evidence was found that the effective use of independent review, from an early stage and ongoing, would have reduced the risk of a catastrophic event.

Evidence was also found of projects where there was inadequate independent review of what was happening on site and there was concern in the industry that levels of effective supervision had been stripped away over recent decades.

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<sup>1</sup> CDM 2007, the *Construction (Design and Management) Regulations 2007*

<sup>2</sup> Noting that on smaller projects where there is no legal requirement for a Principal Contractor, the Main Contractor will assume overall responsibility for site safety.

These issues need to be explored further and encouragement given for clients to seek independent authoritative advice.

### **Issue 8: The industry should learn from experience**

Learning from experiences was not found to be well-rooted in the industry. There was lack of confidence that:

- § Learning was shared rapidly
- § Lessons were incorporated into the education and training process
- § Information could be easily accessed

There was however activity which needed to be encouraged and supported:

- § The work of SCOSS<sup>1</sup> and CROSS<sup>2</sup> (which needs to be more widely appreciated and publicised)
- § The work of the various industry bodies and groupings<sup>3</sup> that provide guidance. Ways to improve their effective performance should be investigated and their activities should be inclusive of all industry stakeholders.

### **Key definitions**

We found terms which are in use but which need to be better defined and understood; they are explored in the Glossary to this report.

### **Conclusion**

Catastrophic Events in construction are real issues which require proper consideration by all stakeholders, led by directors and senior staff. There are opportunities for improvement of performance and all stakeholder groups should be involved in agreeing what should be done and making the necessary changes.

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<sup>1</sup>SCOSS, the *Standing Committee on Structural Safety* (see Glossary)

<sup>2</sup>CROSS, *Confidential Reporting on Structural Safety* (see Glossary)

<sup>3</sup>For examples, see 9.1.1

## ACKNOWLEDGEMENTS

CIRIA and Loughborough University wish to acknowledge the advice, help and assistance which they have received during this research, as follows:

§ As well as the HSE staff mentioned in Section 1.5, assistance was readily offered by many people. Particular thanks go to Philip Wright, who started this work with an internal HSE discussion paper about major accident hazard risk in construction.

§ The membership of the Project Steering Group which was formed to guide and comment upon the work was:

Lee Boshier	Loughborough University
Vaughan Burnand	Constructing Excellence, Strategic Forum
Paul Bussey	Scott Brownrigg, DIOHAS (Designer's Initiative on Health and Safety)
John Carpenter	Consultant, Secretary to SCOSS, Reviewer of this report
Chris Chiverrell	CIRIA
Mike Cross	HSE Project Sponsor
Paul Ebbutt	LUL
Sarah Fray	Institution of Structural Engineers
Alan Gilbertson	CIRIA Project Manager, Researcher, Author
Laura Hague	Mott MacDonald, Consultants' Health and Safety Forum
Paul Hoyland	Balfour Beatty Civil Engineering Limited
John Lane	RSSB (Rail Safety and Standards Board), Chairman of this steering group
Gordon Masterton	Jacobs, Chairman of SCOSS and of the CIC Health and Safety Committee
Susan Mackenzie	HSE, Specialised Industries Hazardous Installations Directorate
Steve Parncutt	HSE Construction Engineering Specialist Group
Alan Powderham	Mott MacDonald
Peter Robertshaw	Osborne, representing the UK Contractors Group
Clive Sherwood	Charteris Insurance
Stephen Taylor	HSE Construction Engineering Specialist Group
Tim Watson	Consultant, CPA (Construction Plinthire Association)
Philip Willis	Jackson Coles, DIOHAS (Designer's Initiative on Health and Safety)

§ Work on the case studies was particularly assisted by Phil Deebank (HSE), Andrew Ratray (HSE), John Anderson (Consultant), Paul Scott (Agetro Ltd) and Tim Watson (Consultant).

§ Speakers who kindly presented at two CPN<sup>1</sup> events about the topic were:

Allan Mann	Jacobs
John Hodgkins	Balfour Beatty
Charles Bradley	DBA Risk Management

§ Finally, many people gave their time to complete the on-line survey, attend events and provide the benefit of their experiences and opinions; without them the quality of the research would not have been the same.

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<sup>1</sup> CPN – CIRIA's *Construction Productivity Network*



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# **PART ONE – Report on the construction industry and Catastrophic Events**

## **1. Preface**

### **1.1 Health and safety in construction**

Health and safety has always been important in the construction industry, which suffers from a higher incidence rate of death, injuries and ill-health compared with other sectors.

Over recent decades there has been a concerted and increasingly successful effort to improve performance, driven by legislation, industry improvements and societal change. Harming people is no longer seen as an inevitable by-product of constructing. Companies and individuals have striven to improve performance and they have had some success. However, much remains to be done.

### **1.2 Other dangerous industries**

At the same time, the huge risks which exist in particularly dangerous industries such as chemical and nuclear have received particular attention. Regular disasters which have affected large numbers of people, such as Bhopal, and major losses such as Piper Alpha have fostered a rigorous assessment of risk, using advanced analytical techniques. Despite these advances, catastrophes do still occur; BP's environmental, financial and reputational disaster in the gulf of Mexico being the latest (although it is rarely mentioned that there were multiple fatalities at the time of the initial explosion). These types of event are known as events with 'Major Accident Potential' and also sometimes as 'Top Events' in the chemical industry – avoiding them is an essential issue for every Board involved in such projects.

### **1.3 Catastrophic Events in construction; the brief**

This report examines the risk of Catastrophic Events faced during construction by the construction industry and asks the questions, what are Catastrophic Events in construction? (and) what can be done to seek to prevent them? The research has sought inputs from people active in the industry and examined a large number of actual (case study) events, looking for trends and messages. The brief for this work was in no way prescriptive and the researchers were free to pursue their enquiries and to draw conclusions, with a view to challenging the industry to address issues which appeared to offer the best chance for improvement in performance.

### **1.4 This report in context; messages for the construction industry**

Inevitably, given the size and variety of work undertaken in construction and the very flexible systems involved, in conjunction with the complexity of human behaviour and interaction, the findings of the research did not evidence simple conclusions. However, from the vast amount of information received some important messages did emerge which are worthy of further consideration by the industry. The report therefore does not offer panaceas, but points out where thought and effort is most needed to reduce the risk of further catastrophic events on our sites.

It is for the construction industry to respond.

## 1.5 Message from the HSE



### **Mike Cross, Head of HSE Construction Engineering Specialists**

It is vitally important for HSE to have a clear understanding of the hazard and risk profiles of the industries we regulate in order to inform how we should go about that work most effectively. Construction has always been regarded as one of GB's most dangerous industries based on its high incidence rates of deaths and injuries. Comprehensive data from RIDDOR and elsewhere about these deaths and injuries has allowed a detailed analysis of causes and trends in conventional incidents to inform priorities and workplans. However, low probability high consequence events are much less amenable to this sort of analysis and this project was initiated to improve the understanding by HSE and the industry so that effective action can be taken. It is a very important first step - my hope is that it elicits a positive response from the construction industry to the issues it has raised.

## 1.6 Messages from the authors of this report



### **Alan Gilbertson, CIRIA**

This work has brought me close to many sad events, in which people have been killed and injured, including both people in our industry and members of the general public. I have also seen how often there has been 'a close shave' where only 'luck' decided how severe the consequences were. I hope that our industry will take the issues we raise seriously and respond in a positive manner; there is always room for improvement and we can all make a difference. Recent events in the Gulf of Mexico have also reinforced the extent to which commercial issues can be deeply affected by an engineering failure.



### **Joseph Kappia, Loughborough University**

My background is in human factors research and the construction industry is an example of an industry where human behaviour and interaction is central to all aspects of performance. My research on this project into performance as it affects safety, and particularly the more extreme events, has demonstrated the variability and complexity of the industry and of its processes. The behaviour of people lies at the heart of nearly all the events we examined as case studies and it is through addressing their skills and behaviour and the systems within which they work and interact that the industry should be able to forge ahead.



**Lee Boshier, Loughborough University**

To the layperson the construction industry may not appear to present the types of risks associated with other industries (such as the petrochemical industry) or indeed the threats associated with large scale natural hazards (such as earthquakes and floods). However, this report highlights that high impact, but low probability, events on construction sites need to be taken seriously. Rather than reactively dealing with the aftermath of such events, a proactive and proportionate approach to risk management is advocated. Amongst other matters, this report places the responsibility for risk management across many disciplines at organisational, project and site levels.



**Alistair Gibb, Loughborough University**

In my earlier career in construction I have sadly had a number of personal experiences of major incidents which have brought home to me the need for this work – ALL risks need to be managed and, whilst there has been a helpful emphasis in the last few years on the less obvious hazards such as occupational health, we must not allow this to detract from the need to consider ‘What is the worst thing that could happen on our project?’

## 1.7 Messages from the project steering group

In traditional CIRIA fashion, the work has been overseen and guided by a strong industry project steering group. Representative members of the steering group have provided these messages:



**Vaughan Burnand, Chairman of Constructing Excellence and Chairman of the Health and Safety Panel of the Strategic Forum**

Our progress in Construction Health and Safety has been good with excellent reduction in fatalities and AFRs as we work towards a zero harm industry. However we must learn from ours and other industry’s experiences because we are all too close to potential catastrophic events. The words ‘we were lucky’ is too often applied to near hits, accidents, reportables and even fatalities. We need to really understand and communicate the root causes of these events rather than breathe sighs of relief. This paper makes an excellent start.



**Paul Bussey, Associate, Scott Brownrigg; Architect and member of DIOHAS**

As an Architect primarily representing the Designers Initiative on Health and Safety (DIOHAS), and as a Registered CDM-C, it has been a great insight to me, working with the engineering and contracting world analysing and mitigating Catastrophic Events. The potential for such "low likelihood but high consequence events" occurring on most Architectural Projects is low, but not insignificant. This research will hopefully cast more light on the proportionate consideration of whether or not these are "greater than normal" significant risks under the current CDM 2007 Regulations or need further legislative clarification.



**Paul Ebbutt, Principal Client Engineer, Civils – London Underground**

Catastrophe in construction does happen and the experience is that there will be significant impact on business; the operations, the customers and the staff. Clients have a key role in construction projects; they should take appropriate professional advice and also take note of comments and observations from all levels of the project organisation. This includes listening to the bad news as well as the good news. The level of risk and responsibility passed onto the small and medium enterprises (SMEs) in projects is of concern. Clients must accept responsibility for the risks associated with their project ambitions and for the way risks are managed in the project. Risk cannot be just passed on down the supply chain.



**John Carpenter, Consultant, Secretary to SCOSS, Reviewer of this report**

Any process which is designed to identify major hazards and then plan for their safe management will not only help to avoid catastrophe, but is likely to bring overall benefit to the project as a consequence of the forethought and associated planning activity. This Report is an important step in this direction.



**Laura Hague, Mott MacDonald, representing the Major Consultants Health and Safety Forum**

Designers have a key role to play in managing risk on construction sites. By identifying risks early in the design process we can have a significant impact in eliminating and minimising the major hazards of construction and maintenance. As always, effective communication with other stakeholders on the project is essential – as the HSE put it - getting the right information, for the right people at the right time. This is our challenge and one that the whole industry must rise to.



**Paul Hoyland, Balfour Beatty Civil Engineering Limited**

This report is particularly relevant for an industry such as tunnelling, where the consequences of collapse can be so catastrophic. There is no doubt that a focus on recognising and addressing all high consequence risks is essential, including those risks which are considered to have a low probability.



**Gordon Masterton, Jacobs, Chairman of SCOSS and of the CIC's Health and Safety Committee**

Many construction projects carry the risk of a catastrophic event occurring. Recognising this risk is its first step in its prevention. This report provides essential guidance to all involved in construction and applying the guidance will go a long way towards creating an industry that is even safer for its workers and the public. We cannot rest until we achieve an industry that has zero tolerance to injury and can embark on major projects confidently planning for zero injury to workers and public.



**Alan Powderham, Mott MacDonald, member of SCOSS**

Major hazards in construction are an ever present threat and, while their occurrence is relatively rare, we must maintain our awareness and vigilance to avoid them. Civil engineering projects typically involve the challenges presented by a wide variety of risks. These range across programme, commercial and technical aspects and are often inter-related. However, while it is essential to adopt a holistic approach to safety, we must, at the same time, avoid the temptation to adopt too generic an approach. We must differentiate between safety risks and risks in general. If safety is not adequately maintained, any effort in risk management as a whole may be critically compromised. I commend this report as a rich source of knowledge and distilled experience as a basis for a more informed approach to addressing major hazards in construction.



**Peter Robertshaw, Osborne, representing the UKCG**

The UKCG and I have been delighted to be involved in this project, to identify potential means to prevent future saddening losses from low-probability, high-consequence events. I consider that this report can help the industry to manage the risks associated with such events, as only with knowledge can we truly manage and hence reduce the risk to our fellow workers. The industry should embrace this report and make it something that is read by both our current and future construction industry leaders.



**Clive Sherwood, Charteris Insurance, representing the ABI**

The Insurance industry plays a major role in encouraging good risk management practices within the Construction industry. Insurers do not just deliver claims services, we also promote important prevention principles and ensure that Catastrophic events are understood and help to reduce risk in the future.



**Philip Willis, CDM Co-ordinator at Jackson Coles, Chairman of DIOHAS**

With thirty years in the construction industry in architectural practice and as a CDM Co-ordinator, I was delighted to participate as a member of the steering group in view of the obvious contrast with my day to day work. Normally working with designers in the identification, elimination and control of hazards with the potential to affect people over long periods; from the inception of a design to the demolition of the resulting structure, on this project we were concerned with incidents capable of affecting very much larger numbers of people in a single instant.

## **1.8 The structure of this report**

This report is designed to present the results of research in a form which is accessible for busy people in our industry. It is in the following parts:

- § An executive summary
- § Part one of the report (sections 1 to 4) which discusses our findings in terms of the issues which we identified in Part 2, focused towards identifying key issues which the industry needs to address
- § Part two of the report (sections 5 to 10) which provides details of the research undertaken and analysis of what was learnt, underpinning the discussion in Part 1
- § Supporting appendices, including a Glossary discussing commonly-used terms.

References are generally provided as footnotes but in Section 6: Literature Review they are provided at the end of the section.

## **2. Catastrophic Events in construction**

### **2.1 CONSTRUCTION – A DANGEROUS INDUSTRY**

Around the world, construction has the reputation of being a dangerous industry and in the UK statistical records place it amongst the most dangerous, albeit it has made great improvements in the last decade. In 2009–2010 there were 42 fatal accidents giving a rate of 2.2 per 100 000 workers. This is the third highest rate of fatal injuries, behind only agriculture and extractive industries. Most incidents affect only one worker but occasionally two or more may be killed or injured by a single event. More rarely still, members of the public have been killed during construction work, although thankfully in recent decades this has (research suggests ‘by chance’) been a rare occurrence in the UK.

Understanding why the industry is so dangerous has been the focus of research activity in recent years. The studies undertaken by Latham<sup>1</sup>, Egan<sup>2</sup> and Wolstenholme<sup>3</sup> and the behaviours researched by Loughborough University and others (in particular for the Donaghy Report<sup>4</sup>) suggest an industry which has many unique features, including an ever-present need to manage a wide variety of risks at all levels of operation and throughout the design and construction process.

The industry is unique compared to other sectors in the way which ever-changing teams of people interact to achieve a succession of essentially unique structures on different sites. The industry therefore needs to be (and is) highly flexible and responsive - and it has to manage risk in constantly-changing and highly varied environments which present many hazards.

### **2.2 SAFETY RISK MANAGEMENT IN CONSTRUCTION**

In response to the dangers inherent in UK construction, legislation has been passed which supplements the basic legal requirement for employers and others to ensure the health and safety of employees and others at risk. The key legislation is CDM 2007 (see Glossary), which sets out clear responsibilities for duty-holders, complemented by other specific legislation about particular issues such as the use of work equipment.

In response to the legislation, designers and contractors have to identify hazards, eliminate them if possible, reduce the level of risk from the remaining hazards and control the residual risks. This can be described as ‘safety risk management’ and CDM 2007 explains what actions are required, including cooperation and coordination between the duty-holders and the provision of information where it is required.

CDM 2007 also defines the scope of ‘construction’ and it must be recognised that:

- § Construction activity involves work on a wide range of ‘structures’
- § New-build is only part of the work activity; maintenance, cleaning, refurbishment, adaptation and finally demolition are all considered to be construction activities.

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<sup>1</sup> Latham, M, *Constructing The Team*, HMSO, 1994

<sup>2</sup> *Report of the Construction Task Force*, Foreword by Sir John Egan, HMSO, 1998

<sup>3</sup> Wolstenholme, A, *Never Waste a Good Crisis*, Constructing Excellence, 2009

<sup>4</sup> Donaghy, R, *One Death is Too Many*, TSO, 2009



## 2.3 CONSTRUCTION HAZARDS

In order to manage the risk, the hazards themselves must first be recognised. Some generic hazards are highlighted by specific regulations (eg working at height, working with asbestos) but many are not. Both designers and contractors are required to be able to envisage the dangers presented by the hazards which are or might be present and be able to understand them and handle them during the safety risk management process.

Some hazards are ubiquitous and they should be easily recognised and dealt with during risk assessment. Safe ways of working will have been developed and documented by contractors for dealing with generic hazards. However, many hazards will be affected by site conditions and project specifics. For example, working on scaffold erection will involve much work which is generic, but the specific challenges on a particular site must be taken into consideration before planning and organising the work. The identification and consideration of hazards must therefore take account of site and project specifics.

## 2.4 CATASTROPHIC EVENTS

Some of the hazards on a project could have very severe consequences and, for the purposes of this report, these will be termed 'Catastrophic Events', involving multiple casualties on and/or off-site or other gross impacts.

**Catastrophic Events are events that are beyond the ordinary or routine and are characterised by being of low probability but high consequence.**

Examples of occurrences which may be Catastrophic Events are:

- § Structural collapse of permanent structure
- § Collapse of temporary works
- § Collapse of plant or equipment, such as cranes
- § Fire
- § Tunnel collapse
- § Disruption of underground services.

Typically, these events will involve the uncontrolled release of large amounts of stored energy and as such will – once they start – be very difficult (or impossible) to control.

Catastrophic events would be those having the following potential consequences:

- § Potential for multiple deaths and serious injuries in a single incident and/or
- § Serious disruption of infrastructure (eg road, rail ) and/or services (eg power, telecoms)

In addition, such events may well have the following features:

- § Ability to adversely affect organisations commercially, either directly or through loss of reputation
- § Creation of public demand for action, possibly leading to demand for a public enquiry and/or changes to relevant legislation.

The fact that such events are exceptional in the UK (compared to other countries) is a tribute to the levels of skill and care evidenced in UK construction. However, the fact that such events do occur, no matter how infrequently, and the fact that the potential for their occurrence is ever-present is sufficient reason for them to be considered, particularly when it is borne in mind that most of the case studies discussed later in this report were only *potentially* catastrophic because of chance (ie 'luck') and not because of the success of precautions being taken on those projects.

It might be suggested that attention to catastrophic events might displace attention from more ordinary or 'routine' hazards and risks. On the contrary, in examining catastrophic event risk, it is hoped that other hazards and risks would necessarily be discussed. Moreover, raising safety risk management up the commercial agenda should similarly improve the level of attention given to the subject as a whole and the levels of knowledge and skill evidenced by those in the industry.

It might also be suggested that mentioning the commercial consequences of a catastrophic event risks confusing safety risks and risks in general; for example, balancing safety risk against cost or risk to programme. This is not intended – indeed, in the UK it would not be legal as safety risks must be effectively managed, using the 'so far as is reasonably practicable' test.

## 2.5 THE CONSEQUENCES OF CATASTROPHIC EVENTS

When one of these rare events does occur the consequences can be far reaching. Apart from the high human cost, the direct financial costs can be enormous. The site might be taken over by the police and HSE for days or weeks as evidence is collected. Time and cost will also arise from the work necessary to make the site safe again and clear away materials and equipment. However, these immediate impacts can easily be dwarfed by the impact of the event upon project completion and, in the long-term, damage to reputation leading to loss of future business.

There can also be wider implications. The public and media are much more exercised by single, catastrophic events, than by a steady toll of 'routine' incidents, which can lead to an outcry for 'something to be done' including demand for more legislation.

During consultation it became evident that there is also a post-event human toll, as there is for any incident. Pressures upon those involved (both directly and because of a role within a company) are invariably enormous and (because of the protracted investigative and legal processes) also lengthy, running into many years. Quite apart from the diversion from other duties, emotional impact can affect performance.

**The potential consequences of catastrophic events may be *wide-ranging and long-lasting*.**

For all of these reasons, directors and senior managers need to understand the immediate and underlying causes of catastrophic events and have in place effective strategies that can adequately address the potential for them to cause major disruption to their businesses.

**The potential impact of a catastrophic event upon a company means that directors and senior managers need to consider the risks they are exposed to and manage accordingly.**

The research undertaken (see Section 7, the on-line survey) suggests that ‘Catastrophic Events’ are *not* being consciously considered on *all* projects.

Requirements for directors to consider risks which could seriously affect a company’s well-being are now established following the Turnbull Report<sup>1</sup> quite apart from risk of prosecution under Health and Safety Legislation and the Corporate Manslaughter and Corporate Homicide Act 2007.

Exactly how directors and the senior managers who support them should monitor the state of play in their organization requires serious consideration. Over-emphasis on trends in day-to-day issues such as lost time injuries and compliance with safety regulations may lead to a misplaced feeling that all is well, while potential catastrophic events are not appreciated or the factors which influence their likelihood considered. This issue was a factor in the BP’s Texas City disaster in 1995, where reported safety performance was improving but inadequate safety-critical maintenance was not being monitored or reported directly to directors. Recently, work on the subject of appropriate performance indicators for the chemical industry has been carried out in the UK<sup>2</sup> but so far no similar work which is directly relevant to the construction industry appears to have been carried out.

**We found that many events have occurred which have impacted at director level upon both construction companies and upon client organisations.**

**Organisational risk management of companies should respond by including consideration of how well the risk of catastrophic events is being managed; the use of *industry-relevant indicators* should be explored to support such activity.**

In considering the use of relevant indicators for use by top managers, the issue of incident reporting needs to be addressed. It is human nature to under-report incidents, yet they may provide organisations (and the wider industry) with warnings which need to be heeded and acted upon.

## **2.6 CONSIDERATION OF POTENTIAL CATASTROPHIC EVENTS DURING SAFETY RISK MANAGEMENT**

Hazardous situations which could potentially cause a catastrophic event need to be identified and managed *as part of the safety risk management process*. The aspect of safety risk management which relates to a potential catastrophic event is *considering what catastrophic event (or events) might occur and then managing the risks involved in a proportionate manner*.

<sup>1</sup> The Turnbull Report, *Internal Control: Guidance for Directors on the Combined Code*, 1999

<sup>2</sup> HSG 254, *Developing process safety indicators*, HSE, 2006

It was notable that the on-line survey showed overwhelming support (93%) for the proposition that where construction involves a major risk such as risk to lots of people, extra precautions should be taken. Therefore, ensuring that potential catastrophic events are identified and dealt with in a proportionate manner appears to be sensible. Exactly how the construction industry seeks to ensure that this happens then becomes the issue.

How the issue of catastrophic events is managed in the chemical/oil-and-gas industry (which is regulated by COMAH, see Glossary) is briefly discussed in section 2.8 for perspective. It is not suggested that parallel processes are required in the construction industry, but the techniques used may be helpful and they may be adapted to suit the construction industry.

## 2.7 LEADERSHIP

The need for directors and senior managers to engage with ‘Catastrophic Event thinking’ can only be helpful to the consideration of wider health and safety issues because of the increased level of attention and commitment being shown by leaders to the safety risk management process.

Leadership is an essential ingredient for change – and changing the way a company works so as to avoid a catastrophe is a good investment for leaders.

**‘One of the true tests of leadership is the ability to recognise a problem before it becomes an emergency.’  
Arnold Glasgow**

The HSE website provides advice about leadership<sup>1</sup>.

## 2.8 MAJOR HAZARD INDUSTRY PERSPECTIVE

Industries which are defined as “major hazard”, e.g. on-shore chemicals, offshore and nuclear are required by legislation to prepare some form of safety case, in which potential catastrophic events are identified and their risks reduced on a statistical basis, to an acceptable level.

The detailed statistical techniques used in major hazard industries are very unlikely to be directly relevant to the construction industry because:

- § The relevant statistics which would be needed are rarely available as the failures do not normally involve issues such as, for example, malfunction of equipment in normal operation, for which there may be a statistical chance of malfunction, but do normally involve issues such as out-of-process working or the occurrence of unforeseen ground conditions
- § Most catastrophic events in the construction industry involve human factors to a large degree, as evidenced by the research undertaken in this project

It is not therefore appropriate to examine the statistical element of the major hazard risk assessment process in detail here but the technique used may certainly be relevant, vis:

- § What ‘Catastrophic Events’ are of concern?

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<sup>1</sup> See <http://www.hse.gov.uk/leadership/principlesleadership.htm>

- § How might they happen?
- § How can the hazards involved be eliminated or the risk reduced/controlled

When considering a particular potential catastrophic event, fault tree analysis may be employed to understand the hazards involved and their risk profile. For example, the event might happen in this manner (or this manner etc) and for each scenario: what would instigate this? What would allow it to happen? What would ensure it couldn't happen? – etc until the subject has been 'unwrapped' and appropriate decisions can be made.

## **2.9 THE OBSERVATIONAL METHOD ('OM')**

The observational method is a well established technique used to manage safety risks, primarily during construction. It has been traditionally applied to tunnelling and groundworks but its rigorous and comprehensive approach could well serve as a template for addressing the issue of major hazards in construction in general. The objectives are to save cost or time while maintaining an acceptable level of safety. Its focus on safety and the key interface between design and construction has also enabled OM to play a major role in recovering projects that have suffered from a crisis during construction. The emphasis on prediction, monitoring, feedback, and teamwork also creates a strong opportunity for learning<sup>1</sup>.

## **2.10 INTERNATIONAL PERSPECTIVE**

Whilst only a handful of non-UK case study events have been considered in this research, the issue is significant around the world. Some countries appear to suffer catastrophes more often, although no statistics have been found to support this<sup>2</sup>. Whilst the reasons for frequency of occurrence may be cultural, many of the findings of this research will be of interest and relevance in other countries, because of the universal nature of construction.

## **2.11 HEALTH ISSUES**

This research did not set out to consider health risk. However, in a similar manner to the growing industry appreciation that health risk has a major impact and is in fact much greater in total impact than accident risk, there may be catastrophic health risk arising from construction which has to be considered. Therefore accidental releases of harmful materials which could have a catastrophic effect upon people should be taken into account when considering the possibility of catastrophic events.

## **2.12 CRIMINALITY**

Our examination of case study events did consider whether there had been direct, wilful criminality as a causative factor. Arson was identified as the main problem but other causes (including wilful damage by discontents, hooligans or terrorists) might need to be considered as potential hazards.

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<sup>1</sup> Powderham A. J. 2002 *The observational method – learning from projects*, Proc. Institution of Civil Engineers, Geotechnical Engineering 155 Issue 1, January 2002.

<sup>2</sup> The HSE report *Tower crane incidents worldwide* RR820, 2010, examined recent tower crane incidents worldwide but drew no statistical conclusions about variations between countries in overall frequency of occurrence.

## 2.13 POST-CONSTRUCTION

Post-construction events were outside the remit of this research. However, the comment was made that many causes of collapse could occur at any time. The need for designs to be robust in use and not to suffer disproportionate collapse is dealt with during the design process, in accordance with design codes and various regulations, including the Building Regulations.

Our comments are directed mainly towards incidents which occur because of events during construction, when a structure will pass through various states which will not recur later, in use. Nevertheless, it is fair to say that there will be similarities between some events which are ‘during construction’ with ‘in-use’ events. A good example would be the collapse of a department store in Korea which according to reports<sup>1</sup> occurred shortly after construction, killing over 500 people. It could equally have occurred during construction, and had many of the hallmarks of a catastrophic construction event, which it would have been had it occurred a little earlier. It could easily have done so as the failure mechanism was progressive and probably started during construction. This distinction is not important, as the lessons learnt and the messages identified are largely common.

## 2.14 EXAMPLES OF ‘CATASTROPHIC EVENTS’ IN THE UK SINCE 2000

The following list shows a sample of recent catastrophic or potentially catastrophic events.

<b>Basingstoke fire*, 2010</b>	<b>Dean Farrar St. Victoria building collapse, 2007</b>
<b>Camberwell fire*, 2010</b>	<b>Manchester house collapse, 2007</b>
<b>Glasgow fire*, 2010</b>	<b>Warrington mobile crane overturned, 2007</b>
<b>Dartford telecoms tunnel damage, 2009</b>	<b>Sheffield gas main damage by piling, 2006</b>
<b>Withington hospital gas explosion, 2009</b>	<b>Truro scaffolding hit by van, 2006</b>
<b>Kings Dock Mill Liverpool crane collapse, 2009</b>	<b>Colindale fire*, 2006</b>
<b>Talbot Road fire* Blackpool, 2009</b>	<b>Wembley stadium roof near-failure, 2006</b>
<b>Peckham fire*, 2009</b>	<b>Battersea tower crane collapse, 2006</b>
<b>Glasgow fire*, 2009</b>	<b>Milton Keynes scaffold collapse, 2006</b>
<b>Belfast tunnelling incident, 2009</b>	<b>Edinburgh scaffold collapse, 2005</b>
<b>High Wycombe fire*, 2009</b>	<b>Telstar House London demolition collapse, 2005</b>
<b>East London line GW9 bridge ‘drop’, 2008</b>	<b>Aberystwyth scaffold collapse, 2005</b>
<b>Manchester fire*, 2008</b>	<b>Durrington tower crane collapse, 2005</b>
<b>Weston-Super-Mare pier fire, 2008</b>	<b>Gerrards Cross cut-and-cover collapse, 2005</b>
<b>Royal Marsden fire, 2008</b>	<b>Albion St Glasgow steel frame collapse, 2005</b>
<b>Belway Homes, Edinburgh fire, 2008</b>	<b>Tower Bridge Road building collapse, 2004</b>
<b>Teeside scaffolding collapse, 2008</b>	<b>CTRL Lavender Street tunnelling incident, 2003</b>
<b>Nottingham MEWP collapse, 2007</b>	<b>CTRL crane collapse, 2002</b>
<b>Commercial Rd building collapse, London, 2007</b>	<b>Stockton gas main severed, 2002</b>
<b>Turnford tower crane hook failure, 2007</b>	<b>Dundee earth bund cofferdam failure, 2001</b>
<b>Newcastle fire*, 2007</b>	<b>Canary Wharf tower crane collapse, 2000</b>
<b>Hull piling rig collapse, 2007</b>	<b>Glasgow house wall collapse, 2000</b>
<b>Croydon tower crane collapse, 2007</b>	<b>Livingstone cinema wall collapse, 2000</b>
<b>Colquitt St Liverpool tower crane collapse, 2007</b>	<b>Cardiff Fanum House scaffolding collapse, 2000</b>
<b>Date Street Manchester fire, 2007</b>	<b>Edinburgh MEWP collapse, 2000</b>
<b>Cutty Sark fire, 2007</b>	<b>Edinburgh partial wall collapse, 2000</b>
<b>Wirral mobile crane collapse, 2007</b>	

\* fires in timber-framed construction

<sup>1</sup> Collapse of Sampoong Department Store, The Korea Times, 14 October 2004

## 2.15 IMAGES

The following selection of images demonstrates the type of event under consideration. They are not intended to relate to the case study events reported in Part Two of the report.



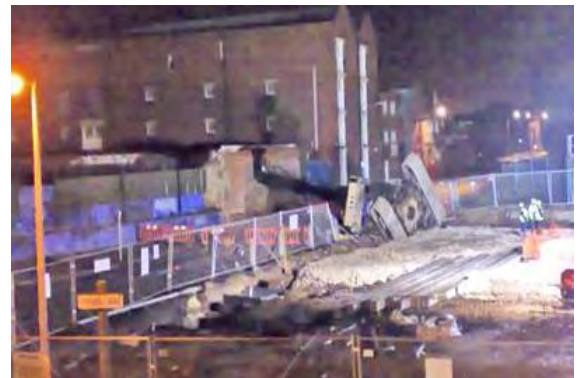
**Kings Dock Mill Liverpool crane collapse, 2009** (courtesy Vertikal.net)



**Weston-Super-Mare pier fire, 2008**



**Teeside scaffolding collapse, 2008**  
(courtesy HSE)



**Hull piling rig collapse, 2007**  
(courtesy CNplus)



**Croydon tower crane collapse, 2007**  
(courtesy Vertikal.net)



**Commercial Rd collapse, London, 2007**



**Cutty Sark Fire, 2007**  
The Cutty Sark on fire



**Cutty Sark Fire, 2007**  
The remains after the fire



**Liverpool crane collapse, 2007**



**Battersea tower crane collapse, 2006**





**Colindale timber-framed fire, 2006**  
(courtesy London Fire Brigade)



**Gerrard's Cross cut-and-cover collapse, 2005** (View from inside the remaining tunnel)



**Dean Farrarh Street building collapse (aerial view)** (courtesy HSE)



**Dean Farrarh Street building collapse (street view)** (courtesy HSE)



**Durrington tower crane collapse, 2005**

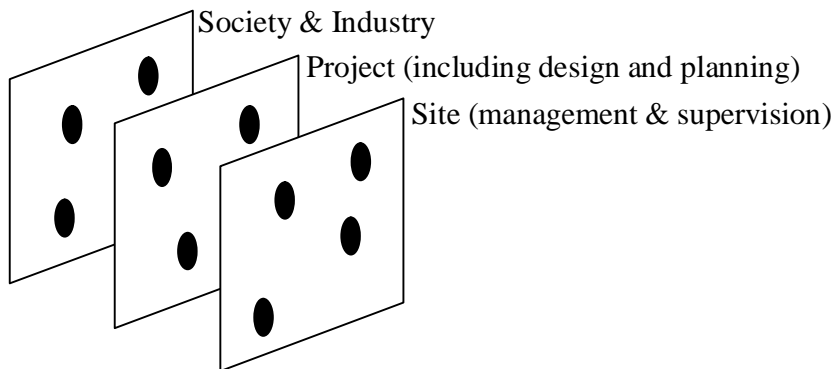
### 3. Why do Catastrophic Events happen?

#### 3.1 INTRODUCTION

It was confirmed by the research (see Part Two in this report) that there is no simple answer to this question. However, the research provided insights into which issues were more important and the key points are presented here.

Underlying many of the issues is the *complexity* of the construction industry (see Glossary) .

For those unfamiliar with the concept, Reason's plates (see 10.2 for more detail) provide a visual basis for discussion of complexity:



The concept revolves around the ease with which the plates as a whole can be pierced – the fewer 'holes' in each plate and the smaller they are – the better, ie the defence against an event will be better. An alternative representation would be to have plates for organizations involved or individuals involved.

Reason's Plates' concept ties in well with a number of case study events where there were several players who failed to act, for a variety of reasons. If one of them had acted, events might have been different and the catastrophic event avoided.

#### 3.2 ATTITUDES TO RISK

##### 3.2.1 Perceptions

It is a truism that no-one *wants* an accident. However, individuals and organizations are *conditioned by their experiences and what they see going on around them*. This has a significant effect upon perception of low-likelihood events, as people will not have experienced them first-hand and may not even have heard about them from others.

The profile of risk tolerance in society often demonstrates a perverse tolerance of risk from every-day incidents such as car accidents (frequently seen and heard/read about at local level but involving small numbers of people per event) but intolerance of less commonly manifested hazards such as train crashes (rarely experienced or read about but potentially involving significant numbers of people).

*In society therefore, there is fear of ‘Catastrophic Events’ despite a lack of real knowledge and understanding of them.*

It has been suggested<sup>1</sup> during consultation that some of those who work on sites are ‘risk tolerant’; this research suggests that on the contrary, they just do not appreciate the hazards, possibly because there is frequently an element of ‘making do’ in site work. In a similar manner, directors and senior managers may not appreciate the potential impact of catastrophic events.

***This research supports the view that what the industry needs is more awareness, information and guidance on the hazards which exist, including the risk of Catastrophic Events.***

### **3.2.2 Elimination of hazards**

This research has shown that *elimination of hazards* is a missing link in many peoples thinking.

Hazards need to be *consciously recognised* before they can be eliminated and their risks then minimised; *this should include ‘Catastrophic Event’ safety risk management.*

In balancing risks during ERIC thinking (**E**liminate hazards, **R**educe risks, **I**nform others, **C**ontrol residual risks), there will be options which do cost more than others but are safer and judgements have to be *consciously* made as to which to adopt. See also Glossary for more about ERIC.

It had been thought by the researchers that incidents might include a significant proportion which arose from issues which were in some way new. However, the case studies which have been examined arose almost without exception from factors which might have been predicted, particularly if (a) there had been a conscious effort to do so, by competent people, and (b) if there had been a degree of review during the whole process of safety risk management. Even where risks were very difficult to predict, because for example of variations in ground conditions, the difficulty of prediction could itself have been identified as a risk and firmer measures put into place.

### **3.2.3 Safety risk management skills**

We found a lack of confidence, with reports that contractors risk assessments and method statements were being prepared by ‘experts’, but not ‘owned’ by site managers and not being reviewed and adapted for each site. Respondents seemed to feel that they have not been trained adequately (not just in small companies!). This was not measured but there were clear deficiencies in many of the case studies and the on-line survey also revealed issues of concern.

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<sup>1</sup> ‘But we *like* risk’ – why workers act dangerously: Construction Research and Innovation Vol. 1, Issue 1, Chartered Institute of Building, 2010

### **3.2.4 Safety risk management culture**

Safety risk management can be used formally as a tool to decision-making but it can also become *embedded* as a feature of the culture of an organization or of an industry. It is felt from the responses received that the industry is starting to adopt a safety risk management culture, particularly in higher-risk sectors such as rail.

### **3.2.5 Systemic failure and pan-sector issues**

A systemic failure event is not related *specifically* to an event, but is instead related to *the manner in which an industrial sector, organisation, or project, is managed, organised or perceived*. For more on systemic failure see Glossary.

The research found evidence of many underlying causes of events which could be described as ‘systemic’ and there were few events where there was no aspect of systemic failure.

Serious pan-sector systemic issues are evidenced when a number of events which are or might have been catastrophic occur in the space of a few years, such as the series of tower crane accidents in the UK during the decade 2000-2010. In these types of events, good practice is clearly not good enough and extraordinary steps are necessary to make a difference (in this case, the development of equipment to reduce reliance on human intervention, regulation, training, inspection).

### **3.2.6 Particular issues**

Key points from the research which are highlighted in the overall conclusions (see Section 10) are as follows:

- Catastrophic events are different and complex
- Reducing major hazard risks must be addressed at society, project and site levels
- People, process and product all play their part, both in causing and preventing catastrophic events
- Competent people are the key to success
- Risk identification, assessment and management is essential
- Projects are complex with many interfaces that must be managed effectively
- Gaining and communicating knowledge throughout the team and across industry is crucial

And the research suggested that these practical things can be done:

- Eliminate risk wherever possible and as early as possible
- Don't let time and cost pressures deflect effort
- Expect change and deal with it
- “Check, check and check again”

## **3.3 MANAGEMENT OF CATASTROPHIC EVENT RISKS**

### **3.3.1 Overview of performance**

Although international statistics are not available to compare the performance of the UK construction industry in relation to catastrophic events, the research did not suggest a worse than

average performance. Other countries have suffered similar events and as the UK's performance on safety matters generally is good, it is therefore likely that performance with respect to catastrophic events is also good.

Attention then turns to how it can be made *even better* because, as was demonstrated in Section 2, the consequences of a catastrophic event can be severe. All reasonable possible steps should be taken to avoid one, although deciding what is reasonable will always be open to debate and challenge. This overview is provided as context before examining how industry might respond to the research by identifying key issues. By thinking about these issues consciously, we should improve what is already world-class performance, bearing in mind that by their very nature there may always be an unpleasant surprise in store and that preparing and planning to prevent such events is sensible.

**'Chance favours the prepared mind'.  
Louis Pasteur**

### 3.3.2 Proposed industry 'key response issues'

Many detailed points have emerged which are documented in Part Two of this report, and these are summarised in section 10 (Summary of key issues from the literature review; on-line survey; case studies and industry consultation).

Eight proposed 'industry response issues' have then been identified which respond to the individual points as a family. They are:

§ **Issue 1: The industry should recognise that catastrophic events need further attention**

The research concluded that the special nature and importance of catastrophic events needs to be recognised and responded to (see 10.1).

§ **Issue 2: Corporate risk management systems should be improved**

The research concluded that industry needs to respond to the risk of catastrophe at the highest level (see 10.2, 10.3).

§ **Issue 3: Knowledge, skills and experience of safety risk management should be raised**

The research concluded that more can be done to raise the overall standards of performance by people (see 10.2, 10.3, 10.4, 10.5, 10.6, 10.7).

§ **Issue 4: Communication and interface management should be improved**

The research recognised the particular complexity of construction and the need to improve systems and performance in communication and interface management (see 10.1, 10.6, 10.7).

§ **Issue 5: Competence is key**

The research confirmed the importance of competence (see 10.4) and the range of complex issues identified suggests that gaining competence requires diligent attention to a range of competences. The importance of temporary works issues (see 10.6 and featured in issue 6) pointed up the particular importance of the role of the Principal Contractor<sup>1</sup>.

§ **Issue 6: Effective management of temporary works is crucial to success**

Issues relating to the management of temporary works were identified as of particular importance in the research (see 10.6).

§ **Issue 7: Independent reviews should be employed**

The research identified the importance of independent checking and reviewing (see 10.9).

§ **Issue 8: The industry should learn from experience**

The research identified the benefit to be gained by learning from events as they occur and not losing the benefit of past experiences (see 10.7).

If industry addresses these issues, they should provide a framework for responding to the individual issues which are described in more detail in Part Two of this report.

Issues 1, 2 and 8 are directed at ensuring that the salient points are understood and that the need to deal with them is addressed at the highest level in organisations.

Issues 3 to 7 address particular areas of activity which feed into the family of challenges identified in Section 10.

The issues are discussed further in section 4.

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<sup>1</sup> Noting that on smaller projects where there is no legal requirement for a Principal Contractor, the Main Contractor will assume overall responsibility for site safety.

## 4. What are the issues which the UK construction industry needs to address?

### 4.1 INTRODUCTION

The key issues proposed for industry action in 3.3.2 are as follows:

- § Issue 1: The industry should recognise that catastrophic events need further attention
- § Issue 2: Corporate risk management systems should be improved
- § Issue 3: Knowledge, skills and experience of safety risk management should be raised
- § Issue 4: Communication and interface management should be improved
- § Issue 5: Competence is key
- § Issue 6: Effective management of temporary works is crucial to success
- § Issue 7: Independent reviews should be employed
- § Issue 8: The industry should learn from experience.

All of the discussion which follows draws upon the research undertaken and is presented for further consideration and response *by the industry as a whole*.

### 4.2 ISSUE 1: THE INDUSTRY SHOULD RECOGNISE THAT CATASTROPHIC EVENTS NEED FURTHER ATTENTION

As evidenced by the research, potential catastrophic events are agreed to be important by all concerned.

The response at board level was not researched, but there was considerable interest from senior representatives of some major contractors.

One important output from the on-line survey was the overwhelming support for the suggestion that *where there was potential for a major hazard event, more precautions should be taken*. Exactly how that might be done would depend on individual circumstances, but it is considered that, as for designers' safety risk management, where there is still much improvement to be made, much more thought is needed and leadership shown to inform and inspire the people who are making the day-to-day decisions.

**We found general agreement that catastrophic events are a significant cause for concern and that they should be considered in an appropriate manner in the industry, taking additional steps beyond those normally taken. The industry will have to work out how that should be done; a forthcoming CIRIA guide on this topic will provide suggestions and case study examples.**

### 4.3 ISSUE 2: CORPORATE RISK MANAGEMENT SYSTEMS SHOULD BE IMPROVED

No firm statistical basis was identified to quantify the impact of catastrophic events. One indicator could be the insurance market, which responds when claims threaten to destabilise the 'book' which has been underwritten. This has happened in recent times due to tunnelling claims and currently there is concern about major losses from fires on developments using timber frame construction.

However, whereas insurance does cover some of the direct costs, it was noted that (quite apart from issues of conscience and impact upon them personally) there were other commercial impacts which should concern directors:

- § Uninsured costs
- § Risk of legal action against companies and directors
- § Senior management time devoted to the problem
- § Loss of focus
- § Damage to reputation and hence access to new work
- § Difficulty with insurance going forward

In some case studies examined, smaller companies had closed down as a consequence of a major event, and in one case the Managing Director had fled abroad.

The impact upon clients' revenue streams due to delays was also in some cases significant, due to delays in completion. Of course, for the individuals who lost their lives or health, the impact was *always* catastrophic.

**Catastrophic events can cost lives, money and reputation.  
Directors and senior managers need to take this on board and  
manage the risks in an appropriate manner.**

Directors are *expected* to manage risks to their company, in accordance with legislation and (for listed companies) following the Turnbull Report, and for the reasons stated above they have good reason to do so. The damage done to BP by events at Texas City and the Gulf of Mexico demonstrate the risks. Within the UK construction industry the demise of Jarvis might also be cited, following a period of decline which dates from the Potters Bar catastrophe.

An appropriate response is obviously to monitor performance, but with low frequency events there will normally be nothing to monitor directly. Leading indicators could be identified which might be considered when seeking to identify useful information which could be monitored, and in turn used to demonstrate how catastrophic event risks are being handled in an organization involved in construction. Similar work has already been undertaken in the chemical industry<sup>1</sup>.

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<sup>1</sup> HSG 254, *Developing process safety indicators*, HSE 2006, free download at <http://www.hse.gov.uk/pubns/priced/hsg254.pdf>



**The use of *industry-relevant indicators* should be explored, relevant to the risk of catastrophic events, to support the organisational safety risk management of companies, building on the work in HSG254, ‘Developing process safety indicators’.**

#### **4.4 ISSUE 3: KNOWLEDGE, SKILLS AND EXPERIENCE OF SAFETY RISK MANAGEMENT SHOULD BE RAISED**

Competence is achieved through the right combination of education, training and experience. This subject is therefore central to improving performance.

The management of catastrophic event risk has to be set in the context of the wider performance of the industry (designers and constructors) in managing health and safety risk.

**The case studies frequently demonstrated a failure to adequately identify the full extent of hazards and address the risks arising appropriately; other sources demonstrated a considerable degree of uncertainty and a lack of confidence in the industry’s knowledge, skills and experience of safety risk management.**

These views were widely held. Whilst these views might be seen as depressing, they do in fact provide hope that accidents can be further reduced through addressing the issues.

Two areas of skill identified by the research as needing improvement were:

- § Appreciation of hazards of all types
- § Safety risk management skills

The issues pin-pointed by the research as requiring to be addressed by the industry were:

- § Education in risk management principles as a basis for subsequent development
- § Continuing education, training and experience (CPD) for all in the industry (i.e. all CDM duty-holders)
- § On-the-job training and mentoring by qualified senior colleagues
- § Improvement of management systems within organizations, to make them more relevant/useful and less bureaucratic.

*Education* in our universities and colleges needs to be reviewed to understand why the research has suggested that the necessary underpinning is not being delivered. The academic ideas do not require substantial periods to impart and other aspects can be effectively provided by cross-reference during project work (where risk aspects should be integral or the work will not be founded in reality). During topic lectures generally risk issues underpin many topics, including reliable strength, safety factors and code approaches (eg, normal/extreme design cases). It could be argued that an understanding of hazard and risk is a key learning in all education.

The need for more *continuous education, training and experience* (CPD) in the industry was evidenced by the acknowledged concerns expressed above.

*On-the-job training and mentoring* has to be recognised as the main way people learn in the construction industry. The lack of confidence detected may be acting as a drag on that learning; if people have not been inspired during their education, have not developed a good skill-set and do not have confidence in the systems they operate, they will find it difficult to inspire and develop those entering the industry.

The *management systems* which are in use in organizations are presumably many and varied. It must be recognised that the explicit legal requirement to assess risks consciously and then manage them in an appropriate manner is relatively new (although it has been implicit for far longer); our collective response is therefore necessarily explorative and whatever systems are in use in different organizations must be generally susceptible to improvement. Reliance upon ‘health and safety experts’ rather than the integration of safety risk management into general design and construction activity may be one cul-de-sac which should be avoided and also more guidance appears to be required on how to reduce bureaucracy.

It has to be recognised that increased education, training and experience working with competent colleagues using robust, practical systems are all necessary for an individual’s competence to grow and that only through attention to all aspects will the industry as a whole improve its performance. The industry is already on that journey but there are clearly opportunities for improvement, to build on what has been achieved and accelerate the rate of improvement. The challenge involves educators, qualifying bodies, trainers and organisations.

**More emphasis needs to be given to safety risk management through:**  
§ Education of those who will be entering the industry  
§ CPD and on-the-job training  
§ Development of more effective safety management systems.

The development of more sophisticated integrated design/construction approaches such as the safety-driven-innovation approach in which cost reductions are sought hand-in-hand with enhanced safety control, will require the development of a cadre of designers and constructors who can understand the rigours of the approaches and the investments which are required (in terms of commitment and partnering) to realise the benefits<sup>123</sup>.

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<sup>1</sup> Powderham, A. J. 2008 *Safety as a driver for innovation in design and construction of underground structures*, Proc International Conference on Deep Excavations, Singapore, 2008.

<sup>2</sup> Powderham, A. J. 2009 *The Observational Method - using safety as a driver for innovation*, Vienna Terzaghi Lecture, Proc Osterreichische Geotechniktagung, OIAV, ISSMGE, Jan 2009.

<sup>3</sup> Powderham A.J. 2010 *Managing risk through safety-driven innovation*, keynote paper , Proc. DFI/EFCC Conference, London, May 2010.

## 4.5 ISSUE 4: COMMUNICATION AND INTERFACE MANAGEMENT SHOULD BE IMPROVED

Systems for communication in construction are inevitably many and varied and the skills available vary too. Time pressures, contractual issues and interpersonal relationships will all influence the degree of success there is in achieving successful communication.

The underpinning influence which needs to be recognised is the organizational complexity of most construction projects. Not only is there complexity, it is usually handled by different teams of people on each project. Although some of the individuals (during the construction phase) may be co-located at site, many will meet only occasionally, if at all.

It is essential to appreciate this complexity and the fragility of the processes involved, arising from the difficulties. The people managing through all the difficulties appear to accept these problems (they have no choice) but they *are* real difficulties, as evidenced by the case studies examined (see Section 8).

**Construction projects invariably involve complex relationships,  
making good communication essential.  
Managing communication about safety risk is essential.**

It is appreciated that interfaces between people and between organizations are important when considering safety risk and the following key issues were identified during the research:

- § Failure to work as a team in identifying risk of catastrophic events
- § Failures in communication about particular problems ('silo mentality')

There was also evidence (from consultation) of in-company resistance to facing up to potentially catastrophic hazards which had been identified: the 'good news' syndrome in which senior managers make it plain that they do not want to hear about problems – just progress.

Reference was made during consultation to the need for procurement to be undertaken in a manner which encouraged cooperation and communication, as required by CDM 2007. The research identified both human failures and organizational failures in the case study analysis; both people and company behaviour will however be affected by the contractual environment and further examination of this subject may be fruitful.

Taking CDM as the basis for interface management, the research suggests that there is often scope for better management of interfaces involving the designers and contractors, assisted by both the CDM Co-ordinator (including where temporary works design is concerned) and the Principal Contractor (or the Main Contractor for smaller projects), whose role on site is crucial in managing safety risk.

**'Risk thrives at interfaces'.  
John Carpenter, Secretary of SCOSS**

Organisations and individuals seeking to improve their management of these issues need to examine their cultural values as well as their systems; one question which was suggested for assisting in making improvements was ‘What to do when you see a potential problem’. This issue underlies many of the difficulties which adversely affect efforts to improve in-company and inter-company communication and cooperation; if people feel that raising a concern is not acceptable, they may well keep quiet.

#### 4.6 ISSUE 5: COMPETENCE IS KEY

In many of the case studies it was apparent that hazards had not been appreciated and risks managed in a competent manner. This must spring partly from the concerns about knowledge, skills and experience expressed earlier but also from the lower degree of competence available on some projects, for a variety of reasons including smaller, less structured organisations being in control and sometimes the need for intermittent working by visiting teams, without a continuous site management presence.

Examination of the case studies suggested that the issue of competence (which underpins CDM 2007) was as expected seen to be important – but *in particular* in the fulfilment of the role of Principal Contractor. The organization fulfilling the role needed to be *active on site*. This role was vital because it often involved managing smaller companies with less reliable competence and also managing the interfaces between a number of organisations.

In particular, management of work on smaller projects which carries potential catastrophic event risk needs to be improved but is obviously problematic, due to cost constraints. Note that whilst the largest events are likely to occur on large projects, there is scope for catastrophic events to occur on smaller projects, or small elements of larger projects, and about half the case studies examined involved work by smaller, less structured organisations. Some of these projects involved smaller organizations working for larger companies but without adequate supervision and control by the Principal Contractor<sup>1</sup>. It has been notable that recent prosecutions have laid blame on Main/Principal Contractors as well as those immediately culpable and this will hopefully encourage them to choose and supervise their subcontractors more carefully.

**The issue of competence (which underpins CDM 2007) was as anticipated seen to be important – but *in particular* the competent fulfilment of the role of Principal Contractor on site was identified as central to avoiding many catastrophic events in construction.**

At present any person can set up a contracting company and any client can appoint such a company to carry out work next to a road, railway or adjacent structure etc. Although not within the definition used in this project to define criminality (see Glossary), the behaviour of some (particularly small or occasional) clients and some contractors was criminal in terms of compliance with CDM; they may be described as ‘evasive duty-holders’. Under current UK legislation there is no system of licensing (or ‘permitting’) of contractors and/or responsible

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<sup>1</sup> Noting that on smaller projects where there is no legal requirement for a Principal Contractor, the Main Contractor will assume overall responsibility for site safety.

individuals. Without that, society is reliant on the better training of the workforce as a whole having a trickle-down effect.

**The industry should consider how best to ensure that all those responsible for sites where there are risks which could lead to catastrophic events have the necessary competence.**

It must be borne in mind that using permits to work would bring with it additional bureaucracy and cost, which would have to be weighed against the potential benefits.

Many catastrophic events have occurred on projects where the designers and constructors *would* have been able to show competence. In the case studies examined, although there was more evidence of incompetence than of error by competent people, there will always be incompetent people even in nominally competent organisations. For example, in the USA there have been many tower crane collapses despite apparently strict controls, suggesting that driving out poor attitudes and lack of competence etc is far from easy, even when there is strong inducement to do so.

It therefore appears that improving general levels of competence should be the prime objective. The bodies responsible for education, training and qualification will need to consider how to ensure that this objective is achieved, as discussed in 4.4 above.

This research has highlighted the heavy responsibilities placed upon site managers within contracting organisations, who are required to fulfil a wide range of roles. However, to maintain control of safety, any site manager's skill-set *must* include good safety risk management skills and in selecting and training for this role those who lack this skill, regardless of their other skills, will present risks which should not be taken.

**Only managers who are clearly competent in safety risk management should be put in charge of sites.**

Principal Contractors need to appreciate this and have in place systems to ensure that site managers have (a) been trained to a high level of competence and (b) have a high level of commitment to safety.

One aspect of risk which was noted in some case studies was management of change; three categories of risk were considered (a) design change, (b) change of planned method of work and (c) unplanned, last-minute change of method of work. Whilst design changes are clearly a concern, they did not feature highly in the case studies, but changes in work method did. Some were very late changes and obviously thereby at risk of not being thought through. One aspect of safety risk management which was evidenced was 'dynamic risk assessment' (see Glossary). It was apparent that considerable care is needed in the use of this technique where risk of a catastrophic event has been identified; additional time should be allowed and a fresh view sought before pressing ahead. It is likely to be the Principal Contractor who is best placed to ensure that the decision-making process and preparation of a thought-through amended and complete method statement is properly carried out without rushing and preferably with independent review.

## 4.7 ISSUE 6: EFFECTIVE MANAGEMENT OF TEMPORARY WORKS<sup>1</sup> IS CRUCIAL TO SUCCESS

It was found that failure in the selection of temporary works solutions, plant and equipment and failure to design and manage their use in a competent manner was a significant factor in about half of the case studies examined.

Some of the actual or potential ‘catastrophic events’ identified during the research involved ‘temporary works’ when the interfaces with plant and equipment used for construction were included in this term and their management needed to be considered carefully.

**It was apparent from many case studies that insufficient consideration was being given to management of *temporary works* in its widest sense.**

**Temporary works design, planning and execution must be taken seriously for *all* temporary works aspects, and include interfaces with plant and equipment.**

The recently revised UK Code of Practice BS5975<sup>2</sup> now extends the principles espoused in the Bragg Report<sup>3</sup> to prevent formwork collapses to all forms of temporary works. It is clear that there is widespread ignorance in the industry about this important change and steps need to be taken to raise awareness of the Code of Practice and to ensure it is implemented proportionately to ensure improved management of Temporary Works.

As this research started, a new grouping ‘The UK Forum for Temporary Works’ was being formed and it would be sensible that it should be developed into a pan-industry body to give focus to this important aspect of construction.

**The potential impact of failures of temporary works needs to be carefully considered to reduce the likelihood of a ‘catastrophic event’ occurring, and the industry should consider how best to improve performance.**

## 4.8 ISSUE 7: INDEPENDENT REVIEWS SHOULD BE EMPLOYED

Independent review is a term which may be used to describe any process where people outside a working team are involved in looking at what is being done and take an independent view on it and make comments. There are many types of independent review activity in the construction industry and some of the more common ones are identified and discussed in the Glossary.

The purpose of all independent reviews is for ‘a fresh pair of eyes’ to take a view and make comments as appropriate. All people have blind spots and respond to pressures they are under;

<sup>1</sup> See Glossary for definition of *temporary works*.

<sup>2</sup> British Standard Code of Practice BS 5975: 2008 ‘*Temporary Works Procedures and the Permissible Stress Design of Falsework*’

<sup>3</sup> *Falsework: Final report of the Advisory Committee on Falsework* HMSO 1975 (The Bragg report).

independent review must therefore be undertaken by people who are experienced in the work being undertaken and able to express their independent review in a constructive manner, focusing on important issues and not unimportant minutiae.

From examination of the case studies it was found that independent reviews could have assisted in identifying hazards and improving the management of risks. One of the solutions identified by the tunnelling community is the use of independent review: although this is not explicitly stated in the British Tunnelling Society/Association of British Insurers Joint Code of Practice<sup>1</sup>, it is however suggested in the code of practice that there is independent supervision of checking and the insurer should appoint an independent auditor.

The use of independent ‘peer review’ has been recommended<sup>2</sup> by SCOSS (see Glossary) and it is commonly used in major hazard safety case exercises. Independent review should obviously be commenced at an early stage to achieve maximum benefit and minimum risk of embarrassment and entrenched positions.

Use of independent review is common practice on major projects, with clients paying for it in order to check solutions are adequate and that low-risk cost savings have not been missed. Internal semi-independent review is also common in many organizations. The Gateway Process espoused by the OGC<sup>3</sup> includes elements of independent review, with ‘gateways’ at which certain checks must be made (although not necessarily of a technical nature).

The issue of review as it impacts work on site was also considered; evidence was found in the case studies of projects where there was inadequate independent review of what was happening on site. When this concern was tested in a workshop meeting, opinion was divided.

Notable changes in practice which were mentioned as having taken place on many projects in recent decades include:

- § Loss of RE (Resident Engineer) and CoW (Clerk of Works) function on site, replaced with site QA (Quality Assurance) function which may be weak or non-existent.
- § Loss of regular site visits by designers
- § Reduction in building control activity and reluctance of some building control professionals to ‘make waves’ due to perceived commercial pressure
- § Subcontracting of risk to many small companies who have weak controls, often associated with the loss of a ‘controlling mind’
- § Return to ‘traditional’ price-led risk-shedding procurement, despite partnering and other cooperative forms of working demonstrably delivered better coordination and cooperation as required by the CDM Regulations and producing safer working, as reported by Constructing Excellence<sup>4</sup>, which reports accident rates 61% lower than industry average.

Assessment of the extent and impact of such changes was not however included in this research.

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<sup>1</sup> The joint code of practice for risk management of tunnel works in the UK, 2003, Pub. The British Tunnelling Society

<sup>2</sup> SCOSS Guidance Note *Independent Review through Peer Assist*, SC/09/034, 2009

<sup>3</sup> OGC, Office of Government Commerce, see <http://www.ogc.gov.uk/>

<sup>4</sup> Constructing Excellence, see <http://www.constructingexcellence.org.uk/> for the Demonstrating Excellence Report July 2004

## 4.9 ISSUE 8: THE INDUSTRY SHOULD LEARN FROM EXPERIENCE

The industry and those who work in it should ideally learn from the experience of the industry as a whole, in the UK and where possible around the world. However, the mechanisms to achieve that (appreciating what is being learned, capturing it, testing and peer-reviewing it, making it available in a digestible form, storing the information and making it accessible, incorporating it into education and training) are currently poorly developed in the construction industry. In the most part the industry hears of incidents through the trade press or on the grapevine which inevitably fails to convey fully and accurately the detail or the important lessons to be learned.

This situation compares unfavourably with the aviation industry where there are better systems in operation. The net result for the construction industry is that individuals have little support, beyond the updating of published codes of practice and industry guidance and these documents rarely explain the background to the advice they proffer.

Within organizations, corporate memory resides with individuals, and few organisations (it is believed) have formal post-contract review processes which feed back into future decision-making, although there are understood to be exceptions.

**‘Corporate memories are weak and it is incumbent on every engineer in each generation to study failures and gain wisdom from them’.**  
**Dr. Allan Mann**

In the UK, official reporting of safety failures in the construction industry is through RIDDOR and via insurance companies. It is known that the levels of RIDDOR reporting are low (about a half of incidents are reported<sup>1</sup>). Although deaths are probably nearly always reported, many events involving injuries or dangerous occurrences go unreported. It is also not a requirement to report all ‘close call’ events where (by luck) a dangerous situation occurs but an accident or a dangerous occurrence (as narrowly defined) is averted. Reporting is thought to be patchy with high levels of reporting among the major contractors and low levels among smaller firms.

HSE has recently strengthened its own system for promulgating safety alerts and notices, now making them available to subscribers via E-bulletins and other electronic media. However, HSE faces certain constraints with regard to information release when there are potential criminal proceedings in play. This leaves a key role for the industry and its intermediaries to fill in order to get information out as quickly as possible.

Also in the UK, there is a system of informal reporting of matters of concern generally, called CROSS established in 2005 by SCOSS, see Glossary. The on-line survey unfortunately revealed a low level of familiarity with CROSS (despite the average respondent being more likely to be ‘active’ on safety matters).

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<sup>1</sup> When RIDDOR statistics are compared with LFS (Labour Force Survey) data.



**There was concern that learning from experience appeared not to be well-rooted in the industry. There was *lack of confidence* that:**

- § Learning was well-shared, rapidly and widely**
- § Lessons were incorporated into education and training processes**
- § Information could be easily accessed.**

When there is change in work processes in the UK, the industry appears to be slow to learn, or re-learn, and institutionalise - for example through industry codes and guidance - how to do things safely. Learning from other countries would appear to be useful for everyone and it is possible that more could be done to promote the international sharing of experiences and ideas.

If 'close calls' were to be reported by RIDDOR or to CROSS, the industry would have a better view of where potential issues are brewing but (by chance) not yet visible. Reporting to CROSS should be non-threatening; however knowledge of CROSS was found to be inadequate. It is therefore necessary to identify how better reporting under RIDDOR and CROSS could be achieved, such as the promotion of a culture of reporting as per the airline industry (starting during education). Leadership (instilling a professional duty to report) is required.

In the practice areas identified in the study (tower-cranes, tunnelling etc) groups of people were identified who *are* working together to fill knowledge gaps and (in some instances) to seek agreement on how to respond to events which had arisen. It is beyond the remit of this study to track down and fully understand all the groups which exist. However, certain features of the groups became apparent which are worthy of consideration:

- § Some groups are formed by Institutions or are closely associated with them
- § Many other groups are either funded by vested interests or are voluntary. They operate in a variety of ways, being for example based on membership of an industry organisation or a local gathering of interested parties.
- § Whilst major contractors share experiences through 'safety alerts' the wider industry does not have visibility
- § In some particular risk sectors, there may be more than one group operating (sometimes at regional level) and there may also be independent sources of knowledge and experience such as in universities and other organizations or in different regions
- § The HSE is often involved with such groups in an advisory capacity and in assisting in promulgating good practice guidance
- § The speed at which such groups which provide industry guidance are able to respond to events is variable
- § By the very nature of the UK construction industry, only a proportion of organizations who are active in a particular risk sector will engage with the relevant group; many will not have the time or inclination
- § Disciplines who are not directly involved in a topic area such as 'tower cranes' are unlikely to have sight of the workings of the group (in particular designers, who make decisions affecting risks during construction).

These points are made here with a view to seeking improvements in what is already a lively picture of activity.

**There is much industry activity which needs to be considered, including:**

- § The activity of Institutions and their sub-groups**
- § The work of the various industry bodies and groupings**
- § The work of SCOSS and CROSS**

**This work should be recognised, celebrated, developed and encouraged.**

#### **4.10 CONCLUSION**

Based upon the research reported in Part Two, a number of key issues have been identified which require further consideration. The importance of the risk of catastrophic events has been supported during consultation and it is expected that the industry will be keen to participate.

All of the issues identified require concerted action and agreeing the actions to be taken should involve all of the stakeholders; the issues cannot be pigeon-holed; the industry is complex and this means that potential changes need to be seen and discussed in their overall context.

It is possible that during discussion within industry the stakeholder groups will identify further issues which are seen as key to future improvement in safety risk management and performance.

**Risk of catastrophe is a real issue which requires proper consideration by all stakeholders, led by directors and senior staff. There are opportunities for improvement of performance and all stakeholder groups should be involved in agreeing what should be done and making the necessary changes.**

## **PART TWO – Supporting Research**

**Section 5 Research Approach**

**Section 6 Literature Review**

**Section 7 On-line Survey**

**Section 8 Case Studies**

**Section 9 Consultation with Industry**

**Section 10 Research Conclusions**

## **5. Research Approach**

### **5.1 INTRODUCTION**

This section describes the research design and provides an overview of the research methods used, with a particular emphasis upon the adoption of qualitative methods and the use of triangulation (see Glossary) to help facilitate rigorous data collection and analysis. The research approach is highlighted and the specific methods of data collection and data analysis (through the development of a ‘research instrument’) are explained and justified.

### **5.2 CONTENTS OF SECTION 5**

#### **5.3 Aims and objectives of the project**

#### **5.4 Research requirements**

#### **5.5 Accessibility of the data**

#### **5.6 Schedule and structure of the research**

§ Scope

§ Specific areas of inquiry

§ Project steering group

#### **5.7 The research methods**

§ Literature review

§ Online survey

§ Consultation events

§ Industry consultation

§ Case study investigation

§ Research instrument for case studies

§ Content analysis

§ Triangulation

#### **5.8 Summary**

### **5.3 AIMS AND OBJECTIVES OF THE RESEARCH**

The aim of the research was to identify and understand the immediate and underlying causes of catastrophes on construction projects, the effectiveness of current control measures and the need, if any, for further preventative action. The focus of the work has been to inform future HSE activities and raise industry awareness of any existing and emergent problems. As a means of achieving this aim, the research objectives were to:

§ Revisit and update previous related work

§ Strengthen the evidence base and analysis

§ Present the findings in a way that will stimulate industry action

### **5.4 RESEARCH REQUIREMENTS**

Key to the research was the notion of developing a rich understanding of the causes and underlying influences of catastrophic events (or potential catastrophes) in construction (see

Glossary). It was therefore clear that the depth of information required to meet the aims and objectives of the project would necessitate the collection of in-depth data from a range of sources.

In this respect an approach to the data collection process was preferred that followed a more qualitative approach although whilst also allowing for the processing of statistical data. Consequently a robust methodology was required that would enable the team to gather a diverse type of qualitative data related to how catastrophic events unfold on construction sites in the UK.

## 5.5 ACCESSIBILITY OF THE DATA

As is the case with much research, particular problems associated with data collection are in gaining physical access to respondents in their work environment, maintaining access and creating sufficient scope over the research period to fully address the aims and objectives. Requests for access and co-operation may fail due to: lack of perceived value of the research; or the sensitive nature of the research topic; and/or concerns of privacy and confidentiality. Access to participants may also be limited which may have implications on sample size, subsequently affecting validity and reliability of findings. In addition to these factors, organisations (or individuals) may not be prepared to participate if there are any cost implications or “down time” while completing lengthy questionnaires or interviews. In order to combat these problems, a particular strategy was adopted that included:

- § Adopting a multi methodological approach,
- § Using existing industry contacts within the research team;
- § Utilising personal contacts and professional networks;
- § Providing a clear account to organisations of project aims, objectives and type of access required;
- § Establishing credibility with intended participants;
- § Identifying benefits to the industry and wider construction communities; and
- § Using appropriate and suitable language.

## 5.6 SCHEDULE AND STRUCTURE OF THE RESEARCH

### 5.6.1 Scope

To support the strategy, a compact research schedule was facilitated that enabled a range of data collection strategies to be utilised over the duration of the project (with the most intensive data collection activity occurring during a 6-month period between November 2009 and April 2010). The schedule of the research included the following interconnected tasks:

**Literature review:** An iterative process conducted between October 2009 and June 2010.

1. **Online survey:** Between January and March 2010 a bespoke on-line survey was accessed by a wide range of industry practitioners.
2. **Consultation events:** Two Construction Productivity Network (CPN) events were organised by CIRIA in January 2010 (one in London and one in Manchester) and an additional consultation event was run in London in April.
3. **Industry consultation:** This consultation consisted of individual interviews and discussions that were conducted by the research team between October 2009 and April 2010. This included discussions at Steering Group meetings.

4. *Case study investigations*: Detailed information about 62 incidents on construction projects in the UK was scrutinised between November 2009 and April 2010.
5. *Triangulation*: The results of all the above phases (1 – 5) were consolidated and rationalised to produce meaningful discussion points for the industry.

### 5.6.2 Specific areas of inquiry

The research that was undertaken consisted of a number of distinct but interlinked sub-tasks that included:

- A. Examination of the literature
- B. Population of a database of a range of ‘major hazard’ events (case studies)
- C. In-depth interrogation of the case studies using both generic and incident-specific approaches
- D. Identification of the causes (triggers and causative factors) of the ‘major hazard’/catastrophic events
- E. Identification of the current state of control measures in the UK
- F. Analysis of the information gathered to ascertain the:
  - § Key messages that will assist with follow on actions
  - § The role of industry in addressing associated risks
- G. Assessment of industry awareness of, and attitude to, catastrophic event potential
- H. Verification of the results using experts to ensure credibility

### 5.6.3 Project Steering Group

CIRIA invariably works through Project Steering Groups (PSG) so the early establishment of a suitable PSG was an essential component of the project. The PSG was primarily established to contribute towards:

- Input of ideas
- Provision of contacts
- Establishing industry credibility for the project
- Iterative assessment of the quality of the research
- Assistance with dissemination

The PSG consisted of 20 members from across the construction industry that met on four occasions during the project, during the months of December 2009 and February, May and July of 2010.

## 5.7 THE RESEARCH METHODS

### 5.7.1 Introduction

It has already been highlighted that to gather the diverse range and types of data that was needed to address the project’s aims and objectives, it would be necessary to utilise a number of research methods. These research methods will now be explained in further depth.

## 5.7.2 Literature Review

The aim of the literature review was to inform professional and public understanding of the immediate and underlying causes of catastrophic events, the effectiveness of current control measures and the need, if any, for further action to improve the management of risks and their potential for causing catastrophic events, including taking additional proportional mitigation measures. This consisted of an iterative process that was conducted between October 2009 and June 2010. The review provided the contextual and theoretical underpinnings to the project and awareness of the ‘state of the art’ of major hazards and catastrophic events in construction. This review explored a wide body of literature, including industry reports, regulatory documents, media articles and research papers associated with major hazards and catastrophic events in construction. The literature review was organised into five sections (and is presented in the next section of this report):

- § Types of major hazards, accidents and incidents
- § Risk and causality
- § People, processes & products
- § Legislation
- § The way forward

## 5.7.3 Online Survey

Between January and February 2010 a bespoke on-line survey was accessed by a wide range of representatives from industry. The survey that consisted of structured (largely closed) questions provided an opportunity for interested parties to air their views, grievances and suggestions regarding catastrophic events in construction.

The use of online resources as a method of accessing people for survey based research has increased dramatically as a result of the access to the internet. Consequently, the internet has become a valuable resource for accessing large numbers of respondents due to its ability to have a wide reach whilst being extremely cost and time effective. The internet has facilitated the gathering of robust samples as well as those which are nationally representative. To this extent, the project chose to use an online system in order to reach widely dispersed target groups; the findings of which are presented in Section 7 of this report.

A valuable reason for using online is that the anonymity the respondent feels allows for the generation of more ‘truthful’ responses (Saunders *et al.*, 1997). Respondents are free to answer the questions without the immediate influence of an interviewer or observer. They are also not restricted by time constraints as the respondent can take their time navigating through an online survey. This positive aspect may be especially useful when surveying topics of a particularly sensitive nature. Secondly, another advantage of self completion interviews is that the questions are always standardised, i.e. each respondent is presented with exactly the same question asked in the same format. Online surveys also reduce any interviewer bias arising through the use of more than one interviewer on a research project.

A full-featured survey software system allowed for the efficient creation of a custom survey which invited construction professionals to participate, and the administration team to analyze the results. Participant responses were received and interrogated progressively, giving an instant insight to further contact details from individuals and an aggregation of the survey results. Utilising this critical feedback and data allowed for delivery of more targeted, segmented communications and activity within the study. Advantages of the system utilised in this study were:

- § **Diverse Question Styles** – Allowed respondents to choose from a variety of question types, including multiple choice, short answer, long answer, range, true/false, yes/no, and open-ended responses
- § **Flexible Survey Format** – Enabled each question to be presented on its own page, or grouped together for strategic impact
- § **Complete Customisation** – Allowed the administrators to tailor the look and feel of the survey
- § **Detailed Reporting** – Allowed administrators to view multiple reports on the survey respondent's individual or multiple answers.

#### 5.7.4 Consultation events

Two Construction Productivity Network (CPN) events were organised by CIRIA in January 2010 (one in London and one in Manchester) and an additional consultation event was ran in London in April. These events were designed to elicit the views of industrial stakeholders and to assist in the focus of the research. Members of the research team from CIRIA and Loughborough University were present at each event which involved a total of 73 participants:

- § **London CPN event** - 28 participants plus five speakers
- § **Manchester CPN event** - 25 participants plus five speakers
- § **London voting workshop** - 20 participants plus representatives from Constructing Excellence

#### 5.7.5 Industry Consultation

This consisted of meetings with individual industrial contacts to obtain detailed, and confidential, information about individual and institutional experiences of major hazards and catastrophic events in construction. A wide range of individuals were consulted throughout the research including members of the Project Steering Group – see section 9 for further details.

This consultation consisted of nearly a hundred individual interviews, discussions and conversations conducted by the research team between October 2009 and April 2010.

#### 5.7.6 Case Study Investigation

Detailed information about 62 incidents on construction projects in the UK was supplied in confidence by HSE representatives. This information provided rich context specific information about the underlying (direct and indirect) causes of incidents that did result (or could have resulted) in a catastrophic event on a construction project.

A case study method was considered an ideal approach when it became clear that a holistic and in-depth investigation into catastrophic events was required. The individual cases were selected largely based upon the required levels of details that were required to undertake the necessary analysis. The case study research took a multi-perspective approach which meant that the research considered not just the perspective of individuals, but also of the relevant groups and the interaction between them. This aspect is a salient point in the characteristic that the research possessed. This gave the research a range of applications for the case study models:



- § To describe the incident/event itself
- § To describe the context in which the incident/event occurred;
- § To explain complex causative factors
- § To explain control failures contributing to incidents/events
- § To describe individual actions contributing to events; and
- § To describe interactions between people and groups involved

Data were collected from several sources including: HSE Reports, independent accident reviews, first hand individual accounts of incidents, accounts from HSE investigations; and media accounts from industry publications. The information was detailed using a case study research instrument, which used a series of 67 structured questions to examine each case study in detail (Appendix 8.1). The questioning process assessed the general project details, the hazard event and underlying causes, technical issues and the effectiveness of regulation and control. A series of open ended questions were also used to capture any unique features of the incident.

Case studies were selected to represent a wide range of construction projects. Of an initial outline of 120 incidents, enquiries were made for 87 cases, of which meaningful scrutiny was given to 62 cases that possessed sufficient levels of detail to be considered as case studies. These case studies were then grouped into five broad practice areas for further analysis (Collapse of permanent structures, Collapse of temporary works, Cranes, Fire and Sub-terrain activities).

### 5.7.7 Research Instrument for case studies

A research instrument was developed which formed a template for gathering all case study data (quantitative as well as qualitative). Following the gathering of specific project information researchers were encouraged to provide specific accounts of the event itself according to five principal questions:

- § What happened?
- § Why was this (actually or nearly) a catastrophic event?
- § Are the technical reasons for the problems experienced known?
- § Are the key underlying reasons for the problems experienced known?
- § What were the sources of information?

Knowledge of the case study from these principle questions were further developed using 67 interrogation questions (Appendix C) which were assessed by a team of researchers using influence criteria of “High”, “Medium”, “Low” or “Zero”. In the first instance this data was assessed quantitatively using numeric ‘scores’; these were then augmented with the addition of descriptive (qualitative) observations for each question through a “comments” and summary statement.

The research instrument helped the research team to focus the investigations on exploring both the actual facts from the reports and the perceptions of investigators. The *comments section* (which contained the issues and topics) formed the basis for the qualitative coding structure required for the data analysis and identification of emergent themes. The template proved invaluable in gathering a range of in-depth data in an efficient and effective manner.

### 5.7.8 Content analysis

The content analysis of the case studies involved using a set of procedures to make valid inferences from the multiple sources of information. The procedures involved the grouping of words or information deemed to have similar connotations (e.g. grouping together of similar entries implying a concern for CDM regulations). The essence of this was to reduce and re-classify the vast amounts of textual material into more relevant and manageable categories. Two approaches were used for the grouping of data namely “a priori” and “emergent”; with *a priori* the categories were established prior to the analysis based upon suggestions from the steering group members, literature review and other sources of information during the development of the research instrument. In comparison *emergent* categories were established as they emerged from the data. This systematic process dealt with the objective description of facts (i.e. from reports) but also included the subjective interpretations of latent content of the events described. The process thus required understanding and co-operation between the researcher and the consultation participants. As the research dealt with often separately constructed data from both historical fact to perceptual judgment both coding processes were used.

To make valid inferences it was important that the classification or grouping procedure was reliable in the sense of being consistent and the extent to which it measured or represented the issue of concern it was meant to represent. As such the content analysis procedure involved four basic criteria for judging the soundness of the information:

***Dependability*** - whether or not causative issues were observed more than once;

***Credibility*** - establishing that the results were believable from the perspective of the researcher and consultation participants;

***Transferability*** - the degree to which the information could be transferred to other case studies, contexts or settings; and

***Confirmability*** - the degree to which the results could be confirmed or corroborated by others (researcher or consultation participants).

### 5.7.9 Triangulation

The project adopted a ‘triangulated’ research strategy, which occurs when research uses multiple sources of data that is collected using a variety of methods. Two specific methods used were: ‘*Data source triangulation*’, when the researcher looks for the data using different sources of information; and ‘*Methodological triangulation*’, when one research method is supported by another, to increase confidence in the validity of the data as well as the rigour of the data interpretation. Importantly for the scope of this project, triangulation is an approach that allows for a multi-perspective approach to the investigation of questions and is also a good foundation for the multi-disciplinary ‘team’ approach that was adopted on this project.

## 5.8 SUMMARY

This section of the report has highlighted that it was necessary to gather a diverse range, and types, of data to address the project’s aims and objectives. Consequently, it was necessary to utilise a number of research methods and adopt a triangulated research strategy to ensure that the data was valid and reliable and that the ensuing data analysis was rigorous. The specific findings from these components of the research are presenting in Sections 6-8 of this report and summarised in the discussion provided in Part 1.

## **6. Literature Review**

### **6.1 INTRODUCTION**

This review explores a wide body of literature, including industry reports, regulatory documents, media articles and research papers surrounding the broad topic of Major Hazards in Construction. The aim of this review is to inform professional and public understanding of the immediate and underlying causes, the effectiveness of current control measures and the need, if any, for further action to improve the management of risks and their potential impacts. Achieving a sustained improvement in safety in the industry requires a concerted effort by all stakeholders, directed at all levels in the influence hierarchy.

This review is organised into six sections:

- § Types of major hazards, accidents and incidents
- § Framework regulations
- § Lessons from other hazardous industries
- § Risk and causality
- § People, processes and products
- § Complexity, communication and interfaces
- § Summary

#### **6.1.1 Key points from the literature**

- § Focus has been directed at easily promotable risk and hazard reducing goals (for example ‘zero accidents’), rather than the processes and methods needed to achieve them.
- § Despite attempts to learn lessons over the years, major accidents continue to be a threat.
- § Complex chains of events (including organisational policies and decisions, individual behaviours and mechanical or technological failures) often combine to result in major hazard events or catastrophes.
- § The major consequences and impacts of major hazards and catastrophes could be: multiple deaths and serious injuries to site personnel and the general public; the serious disruption of infrastructure and key services; damage or even destruction of organisations commercially; and political implications – public enquiries, demands for new legislation. A framework needs to be developed for consolidating and simultaneously considering these different types of major hazard consequences and their impacts.
- § The literature identified failures based on fundamental systemic failure, ie failures within systems of organisation, communications and procurement.
- § Greater emphasis should be placed on the concept of ‘people, process and products’ in particular when developing the competence of the industry’s people in relation to risk and major hazards.
- § There is a need for further research and for advancing the use of confidential reporting mechanisms

### **6.2 MAJOR HAZARDS, ACCIDENTS AND INCIDENTS**

On all projects, the management function should conduct a rigorous risk analysis for the project. It will then use this information to develop a comprehensive risk management plan and generate a

range of cost estimates to communicate the uncertainty in the project to the internal and external potentials of hazards. A “*hazard*” is a condition or event with the potential to cause harm. “*Risk*” (R) is the probability (P) that harm from a particular hazard will occur combined with the likely severity (S) of the harm; or, in simple terms,  $R = S \times P$  (ACE 2006).

An accident may be defined as any unplanned event that results in injury or ill health of people, or damage or loss to property, plant, materials or the environment (HSE 1983). However the International Association of Oil and Gas Producers (OGP) (OGP 1999) prefers the advanced use of the term “*Incident*”, which is defined as “an event or chain of events which has caused injury, illness and/or damage (loss) to assets, the environment or third parties”. Catastrophic events are incidents are the issues, or result of an identified or apparent hazard with large scale implications. In this review the terms event (major hazard event) and incidents are used intermittently as it is felt that these reflect in greater detail the nature of occurrences that are under review.

### 6.2.1 What is a major hazard?

An important consideration of risks arising from major hazards and catastrophes is the analysis of the probability of an event occurring. This is particularly true when addressing risks from events which occur infrequently (low probability) but have a severe and significant impact when they do occur (high consequence), such as a commercial airline crash, nuclear accidents, toxic chemical spillage, earthquakes or hurricanes. Such events have a far higher perceived impact (on the affected working groups, the general public as well as the commercial and physical infrastructure - built environment and business) than events which occur more frequently, but with less severity per event, such as a individual trip, fall or a single car crash. The main characterisation of Major Hazards (for the purposes of this review) is that the associated risk is of “low probability: high consequence” which may be measured by way of one or more of the following impact features (risk profiles):

- A. Potential for multiple deaths and serious injuries affecting workers and members of the public (MOPs) on and/or offsite in a single incident
- B. Serious disruption of infrastructure and services
- C. Potential to damage or even destroy organisations commercially; and
- D. Political implications – public enquiries, demands for new legislation

The assessment of an event by ‘low probability: high consequence’ plays an important role is assessing the risk of a catastrophe. However, in mitigating for major events and catastrophes the risk profiles (A – D) can prove problematic as it can be difficult to identify which characteristic is most prevalent in an individual case.

Where the risk profile is placed in a hierarchy of consequence will depend on the perspective and discipline of decision makers (i.e. accountant may consider organisational commerciality as most important). The requirements of health and safety to address the risk to people (A), the built environmental (B), commercial enterprise (C), and or public or political profiles require uniquely separate interventions which may not always be in harmony. For example, measures necessary to safeguard personnel in emergencies may have adverse environmental effects, and vice versa. However, joint and consolidated consideration of health and safety, built environmental, commercial and political matters provides a framework within which such issues can be resolved, and so an appropriate balance might be struck (Bell and Healey, 2006). Value judgments across types of impacts will often have to be made. From a policy perspective, severe economic disruptions such as temporary business closures cannot be seen as ‘equivalent’, for example, to

severe safety impacts such as deaths. As such frameworks for addressing different types of consequences and their impacts are required.

## **6.2.2 Top Events**

A concept to consider is the notion of a “Top Event”. Top Event is a term used largely within nuclear and petro-chemical industries and is a component part of a Fault Tree Analysis (FTA) process which falls under the wider body of theories contributing to systems thinking. The United States’ Nuclear Regulatory Commission produced a “Fault Tree Handbook” (Vesely *et al.* 1981) which was developed to serve as text for courses on Systems Safety and Reliability, and to make available otherwise undocumented material on fault tree construction and evaluation for nuclear industries. It was recommended that a fault /top event tree methodology should be more widely used to assess the potential for major hazards and catastrophic events during the early development stages of nuclear systems.

A fault tree analysis can be simply described as an analytical technique where a systems critical safety failure is specified and the system is then analysed in the context of its environment and operation to find all credible ways in which the failure can occur. The fault tree itself is a graphical model of various parallel and sequential combinations of faults that may (or may not) contribute to the predefined event. These faults could be innate product failures, human errors, and faults with systems for implementation or any pertinent events which may lead to the failure. The graphical model (or tree) thus depicts the logical interrelationships of the immediate events/incidents and underlying factors/incidents/events that lead to the ultimate failure at the top of the tree – the “Top Event” (Vesely *et al.* 1981).

However it is pointed out that a fault tree is rarely a model for mapping all possible system failures or possible cause for system failures (Vesely *et al.* 1981). Each fault tree is generally tailored to the particular top event which corresponds to a particular aspect of a system failure; therefore each fault tree may only include the faults that contribute to that event, and are not exhaustive of all potential top event scenarios (and the immediate or underlying events that might be credible to that particular failure).

Complexity surrounds the process modelling required for predicting top events (major hazards and catastrophes). This is further complicated by the often subjective nature of data available to conduct the analysis for particular disciplines. However, the complexity of the process is not overwhelming and the benefits of the outcome can be extremely valuable. There are many methods and tools available for quantitatively combining and assessing risks. However the selection of a method may involve a trade-off between top events and risk profiles based on the sophistication of the analysis method and the ease of use. In the wider analysis, adherence to sound risk analysis techniques will lead to more informed decision making and a more transparent allocation of project risk. Whether it is relevant to Construction however requires further consideration.

## **6.2.3 Types of accidents and incidents**

Due to the nature of work conducted on construction projects several major hazards and risk potentials exist during the active phases of construction. Typically, larger, more complex projects are likely to have more major hazards to be managed. However, smaller projects are not exempt.

Over the course of history major incidents, including ‘near misses’<sup>1</sup>, occur which result (or could result) in multiple fatalities, serious disruption of infrastructure, public services and with the potential to damage or even destroy organisations commercially. Although the immediate physical risk is to workers in close proximity to the event, there is often a high risk to the general public. Examples include the collapse of buildings, tunnels and scaffolds during construction and failure of major plant such as cranes and piling rigs. The identified events featured in this review are:

- Collapse of Permanent Structures
- Collapse of Temporary Works
  - Static – eg Facades, propping, formwork
  - Dynamic – eg tower cranes, mobile cranes, large mobile plant
- Major Fires
- Collapse of Tunnelling
- Major Disturbance of Underground Services

As alluded to earlier, some sectors of the industry call such major incidents ‘Top Events’. While the key scope of investigation on such incidents is often the ‘most severe impact, there is always the existence of relatively minor but cascading incidents (or decisions) that can lead to the major incident. In this respect, key features of safety and the related concepts of risk and hazard need to be defined and explored, as follows.

#### **6.2.4 Collapse of permanent structures**

A structure is safe if it will not fail under foreseeable demands and if it is unlikely to fail under extraordinary demands or circumstances (Elms 1999). A number of reports and research provide commentary on collapse of permanent structures including: Dam’s (Muhunthan and Pillal 2008); Bridges (Burgoyne and Scantlebury 2008; Collings 2008); Buildings (Barber 1963; Griffiths 1968; Barber 1971).

Collings (2008) reviewed the histories of large bridges that failed or required repair due to a weakness in design either during construction or shortly after being brought into service. The identified failures played a significant role in developing the civil engineering profession’s knowledge of structural action and materials behaviour. The failures have helped to define the known limits of the design rules used and have spurred research into particular fields.

However Collings (2008) also states that there are still issues to be addressed by the profession, particularly in the dissemination of the vast amounts of information available to an increasingly specialised group of designers. Ongoing work hopes to capitalise on historical knowledge applied in the context of construction catastrophes.

The Standing Committee on Structural Safety (SCOSS) was formed 30 years ago and is primarily charged with giving warnings to relevant bodies where unacceptable risk is believed to exist. They identify trends and practices in the field of structural engineering and have considered 200 topics which have led to authoritative guidance or a change in design requirements. However, continuing structural failures indicate that civil and structural engineers need to remain vigilant and continue to manage risk carefully (Carpenter 2007).

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<sup>1</sup> ‘Near miss’ should in the context of this report perhaps be ‘near hit’ or ‘near accident’.

A more formal system to obtain additional data on trends in failures (and potential failures) CROSS (Confidential Reporting on Structural Safety) was launched in 2005. In a similar vein to SCOSS, CROSS aims to improve structural safety and reduce failures by using confidential reports to highlight lessons that have been learnt, to generate feedback and to influence change (Soane 2007). With a similar view of training, education and the sharing information Soane (2007) suggests that the lessons highlighted by CROSS should be widely disseminated throughout the industry to enhance shared understanding on risk and hazards.

### **6.2.5 Collapse of Temporary Works: Static**

Temporary works include any temporary structure or provision required to facilitate the construction of the permanent works. Typically items of plant and equipment used in the construction process are not included as temporary works, but the support of such items would be. For example whilst a piling rig is not temporary works the temporary working platform is. Temporary works will include, but are not limited to formwork, falsework, scaffolding, temporary platforms and structures.

Any failure of temporary works may lead to the collapse of the permanent structure or item of plant that is being supported. This could cause injury or death to those working on or near to it, as well as loss of time and money. Scaffolding and temporary works must be capable of being constructed without the need for major intervention into the existing building fabric. This must be borne in mind by designers and erectors of scaffolding and temporary works (HSE, 2003). Much of the literature has concentrated on falsework and scaffolding.

### **6.2.6 Falsework and Scaffolding**

Falsework is used to support a permanent structure or item of plant/equipment while it is not self-supporting, either in new construction or refurbishment.

Historically there have been many studies of temporary structure failures: Feld (1968) pioneered the observation of falsework and formwork collapses; Elliott investigated several cases of falsework bridge failure (1973); predominantly in North America. Allen (1979) and Fraczec (1979) investigated errors in concrete structures; and Houser (1979) performed an extensive observation of European failures by collecting 800 cases from insurance files, many of which dealt with construction-related failures. In the general analysis, the causes of many of these past failures of falsework were foreseeable and could have been prevented by proper consideration when planning, erecting, loading or dismantling the falsework. Investigations into falsework collapses have identified a lack of co-ordination between the various trades and suppliers of falsework as a major cause (HSE 2003). Failures often occur on fairly simple structures erected by smaller falsework contractors, who may not employ design staff. The law requires falsework to be erected and dismantled only under the supervision of a competent person; and as early as possible, a person should be appointed for each site as a temporary works co-ordinator, with responsibility for co-ordinating the various items and stages of use of the temporary works (HSE, 2003 and BS 5975:2008)

As a consequence of growing concern over an area of work not well regulated at the time, the Bragg Report was commissioned with a wide remit to investigate the use of falsework. Bragg made a number of pointed recommendations:

- 1 To provide a 'full written brief' to be implemented in conjunction with the design procedure outlined in the Report
- 2 For the design to be checked, approved and countersigned by a competent supervisor

- 3 That the permanent works designer should have the opportunity to comment on falsework proposals
- 4 To nominate a single individual (with appropriate responsibility and authority) to act as Temporary Works Co-ordinator (TWC)
- 5 For suppliers to provide relevant test data to justify loads used.

Although some are now incorporated into industrial practice, others remain a concern and accidents which may be regarded as “foreseeable” are not being prevented by proper consideration when planning, erecting, loading or dismantling the falsework.

According to the HSE (2003) the causes of many past failures were foreseeable and could have been prevented by proper consideration when planning, erecting, loading or dismantling the falsework. Investigations into falsework collapses have identified a lack of co-ordination between the various trades and suppliers of falsework as a major cause. Failures often occur on fairly simple structures erected by smaller falsework contractors, who may not employ design staff (HSE 2003).

'Independent tied' scaffolds will normally be provided for painting, pointing or other maintenance work. They consist of two rows of standards (the vertical supports) connected by ledgers and transoms (the horizontal elements). 'Independent' scaffolds are not quite what their name suggests. They are termed 'independent' because they derive no vertical support from the building and 'tied' because they must be tied to the building for horizontal stability. Because of the need to avoid damage, tying scaffolding to the facade of historic buildings can sometimes present difficult problems. Sometimes, if the building is fragile, it will not be capable of providing the horizontal restraint that the scaffolding needs and this must be achieved in other ways, such as by providing external scaffold buttresses or by tying the external scaffold to an internal 'birdcage' framework scaffold (Hume 1997).

### **6.2.7 Collapse of Temporary Works: Dynamic**

Construction projects are highly mechanised and the working environment is dominated by material handling and lifting equipment (Shapira *et al.* 2007); and because of their high adaptability and productivity, cranes are the most common form of lifting equipment seen on UK construction sites (Hanna and Lotfallah 1999). However, occupational fatalities and injuries caused by the operation of cranes pose a serious public problem.

Eight people in the UK have been killed in incidents involving tower cranes since 2000 (HSE 2009). The Lifting Operations and Lifting Equipment Regulations 1998 sets out the legal requirements. In February 2010, new laws to improve the safety of tower cranes on construction sites were laid before the UK Parliament. The regulations include a statutory registration scheme for tower cranes. Developed by the HSE, the measures are in response to increasing concerns about crane safety.

Following an investigation on three construction sites Sertyesilisik *et al.* (2010) conducted case studies and interviews with general site staff, managerial staff, and appointed persons into lifting operations on construction sites. They explored the different options, their effectiveness, and the relative effect on safety of processes, factors and levels of worker competence required when operating equipment. The findings revealed six main points to improve safety in lifting operations: through planning; training; equipment selection, use and inspection; feedback /



communication; use of the appointed person's role; and development of safety databases. Thorough the effective planning of lifting operations the authors identified that positive effects on safety could be achieved; they concluded that there were needs for tighter accreditation of all qualifications in the lifting operations field (Sertyesilisik *et al.* 2010).

Guidance was subsequently prepared under the aegis of the Strategic Forum and this, together with other industry guidance accessible through the HSE website, is considered as industry best practice; this includes advice that companies should avoid authoritarian working culture to facilitate efficient feedback to improve safety; that the appointed person should have a site based role; and that site inspections and maintenance should be monitored on a national database form.

## **6.2.8 Major Fire**

Although much has been written about in-use fires, little has been found about fires during construction.

The UK Timber Frame Association has published brief guidance (UKTFA, 2007). The guidance concentrates on measures to prevent fires, detect fires, control fires and escape from fires.

## **6.2.9 Collapse of Tunnelling and Major Disturbance of Underground Services**

The design and construction of underground structures create unique challenges. Ground related problems and conditions can often adversely affect costs, completion time, profitability, and health and safety issues on a project of any scale. These risks can affect all those involved in construction - including the client, designer and the constructor. Guidelines, titled 'Managing Geotechnical Risk', produced by Clayton in association with the Department of Environment, Transport and the Regions, provide best practice guidance on the management of geotechnical risk by all parties concerned, and also explain why such risks occur (Clayton 2001). These guidelines suggest that once the design begins to be formulated and investigation is proceeding it is possible to develop geotechnical risk registers (Clayton 2001).

Powderham and McDonald (2008) present examples of two case histories from major transportation projects to illustrate this theme. Both examples featured substantial challenges in underground construction and show how safety was a key driver for innovation. One example was the Heathrow Express (HEX) which was set to provide a new major rail link between Central London and Heathrow. It involved substantial underground construction in the Central Terminal Area (CTA) of the airport. In October 1994 the project suffered a major setback when the CTA station tunnels, some 30m below the surface, collapsed (HSE 2000 and Carpenter *et al.*, 2008). This was a 'NATM' (New Austrian Tunnelling Method) and although there were no injuries, many people were put at risk and the consequential cost was significant. The HSE report (HSE 2000) cites the direct cause of the tunnel collapses as a chain of events involving:

- Substandard construction in the initial length of the CTA concourse tunnel
- Grout jacking that damaged the same length of the CTA tunnel plus inadequately executed repairs
- Construction of a parallel tunnel in failing ground
- Major structural failure and progressive failure in the adjacent ground along with further badly executed repairs

Although these immediate causes were identified, there were particular underlying causes more related to overall management functions such as decisions and actions surrounding procurement and site control which impacted on risk management. The event was identified as having all the hallmarks of an ‘organisational accident’ (HSE 2000). In particular hazards were not identified by all the parties and risks were not controlled (HSE 2000). There were also significant technical shortfalls including decisions on tunnel construction without correlation with available data on the settlement of the ground surface above the tunnel. A number of the lessons arising from this collapse can be applied to engineering projects generally.

### 6.3 FRAMEWORK REGULATIONS

While the issues detailed in 6.2 are cause for concern, there is a broad system of *Framework Regulations* which create duties for employers, employees and the self employed to ensure, so far as is reasonably practicable (see SFARP in Glossary) that workplaces are safe, which should include consideration of potential catastrophic events. The aim is to improve health and safety management and to make more explicit what is required from employers. Existing health and safety regulations are a continuum of a larger legal framework of law. Acts and regulations which currently remain prominent are:

- § Health and Safety at Work etc Act 1974 (HSW Act)
- § Construction (Design and Management) Regulations 2007
- § Management of Health and Safety at Work Regulations 1999 (MHSWR)
- § Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)
- § Provision and Use of Work Equipment Regulations 1998 (PUWER)
- § The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR),

Since the introduction of legislation in the early 1990s, a more systematic and better-organised approach to safety was encouraged. The Construction (Design and Management) Regulations 1994 (CDM) came into effect on the 31st March 1995, implementing EC Council Directive 92/57/EEC<sup>1</sup> which relates to the provision of minimum health and safety requirements at temporary or mobile construction sites. The regulations have been superseded by the Construction (Design and Management) Regulations 2007. The fundamental principles on which the CDM Regulations are based are:

- § Competence
- § Communication
- § Coordination and Cooperation

The CDM Regulations bring health and safety management, on an obligatory basis, into the planning and design of construction work. In principle the contractor should no longer be left with the sole responsibility of health and safety.

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<sup>1</sup> In the European context, the 2004 Bilbao Declaration resulted in the formation of the European Construction Safety Forum that was facilitated in its work by the European Agency for Safety & Health at Work. The European Federation of Engineering Consultancy Associations (EFCA) and the Association for Consultancy and Engineering (ACE) published has published the useful “*Designing for Safety in Construction*” as an outcome of its work with the European Construction Safety Forum.

## 6.4 LESSONS FROM OTHER HAZARDOUS INDUSTRIES

In terms of Major Hazards, cues may be taken from the oil and gas industries where the consideration of major incidents and catastrophes are paramount to operations. The HSE commissioned the Health and Safety Laboratory (HSL) to carry out a review of the existing literature on the causes of major hazard incidents and the relevant control measures and behaviours that can prevent incidents occurring. The industries covered by this programme included: nuclear industries, offshore oil and gas industries, and onshore industries including chemical industries, mines, biological agents, explosives and gas supply/pipelines. The subsequent research (Bell and Healey 2006) was an important step in identifying the risks associated with major hazards as opposed to general risk and contributed to the major hazard agenda by taking stock of the existing evidence base, identifying gaps in major hazard analysis and suggesting how these gaps might be addressed by further research.

The review by Bell and Healey (2006) detailed fourteen major accident case studies dated from 1966 to 2003, including: Aberfan (1966); Flixborough (1974); Three Mile Island (1979); Bhopal (1984); Chernobyl (1986); and the Challenger (1986) and Columbia (2003) Space Shuttle Disasters. The review surmised that in most cases, the combination of management decisions, specific events and circumstances on the day of the incidents were extremely complex; and numerous factors contributed to the incidents (Bell and Healey 2006). Some of the main causes of the major incidents focused on the contribution of human and organisational factors as underlying causes and that despite attempts to learn lessons over the years, major accidents continue to be a threat. After reviewing a range of previous catastrophic events Kletz (1996) observed that it is also important to recognise that new problems can arise out of the solutions to old problems.

By mapping the causes of the incidents by the varied industry sectors Bell and Healey (2006) identified that there were consistencies in the dominant failings, and this was true not only for the major hazard industries. The information collated from the case studies and research papers showed that in the majority of major incidents, complex chains of events combined to result in the incident. These included organisational policies and decisions, individual behaviours and mechanical or technological failures. While there were wide and varied individual behaviours that resulted in the immediate cause of an incident they all related to wider underlying organisational factors symptomatic of poor safety culture in the respective industries. It was identified that in all sectors several individuals, organisations, professions and disciplines were involved and that poor safety culture (and failings at wider organisational levels) may have been due to pervasive differences between organisational groups (operators, engineers and directors) that hinder effective learning and communication.

By contrast Weame (2008) utilised a case study methodology to report on 18 cases of engineering failures across several industries to demonstrate lessons that may be common. Causes of the failures ranged from faults in prioritising responsibilities, procedures, use of expertise and lack of thought about unusual operations, to lack of inspection, checking and attention to warning signs. Each of these causes of failure was seen in more than one case, but none was considered dominant.

The investigation highlighted: faults in design decisions and assumptions in seven cases; faults in the operation and maintenance of assets in a further seven cases; and fault in manufacturing and construction in four cases. While the distribution of faults was not statistically significant, it served to highlight that engineering failures were not necessarily design faults; and occurred at

any stage during the project life-cycle, from initial project specification, asset operation, maintenance, or rebuilding for a change of use.

The reported causes of the failures identified in Weame (2008) indicated that none of the incidents were caused by “hitherto unknown physical phenomena” but were the result of failures to use available information for:

- § prioritising
- § responsibilities
- § procedures
- § expertise
- § attention to unusual operations
- § lack of inspection
- § lack of checking
- § lack of attention to warning signs.

These failures identified as “institutional risks” were primarily due to failures within systems of organisation, communications and procurement.

## **6.5 RISK AND CAUSALITY**

Risk is an estimate of the probability of loss from a range of hazardous opportunities.. It is easier to identify hazards than to evaluate associated risk and in risk assessment; professional judgement is by far the most important component. Various methods of assessment can be used to provide indications as an aid to professional judgement, but these methods cannot be considered as a substitute for it. Of course, professional judgement can be wrong on occasion.

In recent years, site health and safety management has gained in importance (Boyd 2009; Rawlinson and Farrell 2010). Following the implementation of the revised Construction Design and Management (CDM) regulations in 2007, client focus has turned to site health and safety as a factor when awarding work (Klein 2008). Corporate Social Responsibility (CSR) has to varying extents encouraged growth in, and raised the profile of, site health and safety management further within the construction industry as a whole (Boyd 2009). Notwithstanding the basic desire to protect their workforce, the construction industry has devoted considerable effort to improve health and safety performance (HSE 2009).

Project risk management (PRM) can provide a decisive competitive advantage to building sponsors. For those sponsors who address risks consciously, anticipate adverse changes, protect themselves from unexpected events and gain expertise to price risk, gain a leading edge (Barkley, 2004). However, the realisation of this commercial advantage on design-intensive multi-disciplinary capital projects hinges to a large extent on the approach to the initial identification of hazards. The very way the identification process is conducted will have a direct influence on the contribution that risk analysis and management makes to the overall project management of construction projects. However, safety planning in construction project management is often separated from other planning functions, such as scheduling. This separation creates difficulties for the analysis of what, when, why and where safety measures are needed for preventing accidents (Chantawit et al. 2005).

A list of risk control measures has been developed applicable to all places of employment (The Commission on Risk Assessment and Risk Management 1997; HSE 2006; ACE 2006), namely:

- a) The avoidance of risk.
- b) The evaluation of unavoidable risks.
- c) The combating of risks at source.
- d) The adaptation of work to the individual, especially as regards the design of places of work, the choice of work equipment and the choice of systems of work, with a view, in particular, to alleviating monotonous work and work at a predetermined work rate and to reducing their effect on health.
- e) The adaptation of the place of work to technical progress.
- f) The replacement of dangerous articles, substances or systems of work by non-dangerous or less dangerous articles, substances or systems of work.
- g) The development of an adequate prevention policy in relation to safety, health and welfare at work, which takes account of technology, organisation of work, working conditions, social factors and the influence of factors related to the working environment.
- h) The giving to collective protective measures priority over individual protective measures.
- i) The giving of appropriate training and instructions to employees.

These general principles of prevention are probably less problematically applied within the manufacturing industries where there is, generally, a constant, stable workplace. Within construction, while there may be similarities between projects, every site is unique, every building/structure is unique and the set of persons involved is unique; furthermore, a construction site is constantly changing from day to day (ACE 2006). In many of the construction cases considered in this review, a clear lack of planning contributed to the catastrophic event. If this is to be regarded as true then the majority of accidents are not caused by careless workers but by failures in control which ultimately is the responsibility of management. However aside from major events, a recurring theme within the industry is that people are often injured or killed during very simple, routine work activities (Baxendale and Jones 2000) and outside of construction related activities (Gibb et al. 2006), although it must be appreciated that events are rarely the result of isolated incidents or faults but a culmination of small, medium or large failures of people (worker or manager), machinery or systems.

The ERIC acronym (Eliminate, Reduce, Inform, and Control) represents a generic set of principles applicable in the construction industry (CITB, 2007) – see also Glossary.

To a greater or lesser extent, many contractors have readily adopted health and safety issues as a high priority. The industry in Great Britain has been instrumental in moving towards the creation of a fully competent health and safety scheme through the Construction Skills Certification Scheme (CSCS) and the CSCS card as a minimum requirement for entry to work (CSCS 2009). However this does not necessarily correlate to a competent risk and hazard aware workforce (Spanswick 2007; Donaghy 2009). This industry direction correlates with current government approaches, and the creation of bespoke safety management programmes by industry innovators. However, it has been suggested that this is largely to do with the influence of corporate social responsibility placed on organisations, in which case the industry is accused of focusing on the promotable rather than the practical solutions towards hazard and risk, and bureaucracy has overtaken practicality in the direction of health and safety management on construction sites (Chantanawit 2005).

In order to further investigate current industry innovation and direction in site health and safety management, Rawlinson and Farrell (2010) conducted an examination of contractors' promotional material. This provided a measure of the extent to which industry has currently homogenised with contemporary government and academic approaches, or indeed has appeared

motivated by health and safety factors. In the analysis Rawlinson and Farrell (2010) suggested that industry focus may have shifted from how to achieve the goals towards setting the goals themselves; contemporary direction has arguably become focused on the packaging and presentation of construction site health and safety management, rather than the fundamental methods and processes of implementation. It is also suggested that innovation and developments in construction site health and safety management may become diluted during the implementation of corporate social responsibility (Rawlinson and Farrell 2010).

### **6.5.1 The balance of operational risk against cost**

Operational Risk Management (ORM) is defined as a continual cyclic process which includes risk assessment, risk decision making, and implementation of risk controls, which results in acceptance, mitigation, or avoidance of risk. ORM is a broad approach to operational risk, including the risk of loss resulting from inadequate or failed internal processes and systems, human factors, or from external events. However, the mitigation of risk must often consider complex and competing operational, legal, political and economic demands impacting on decision makers. One key consideration is “cost”.

The development of a cost conscious culture of companies dedicated to efficiency and profitability should be the principal quantifiable benefit of the CDM regulations. It was estimated that on small to medium sized construction sites a reduction in accidents of 33 percent could bring estimated benefits to the industry of £220 million each year (Joyce 2007).

### **6.5.2 The causes of accidents**

Within the industry there is a commonality of events and causal factors that can contribute indirectly to an accident (Baxendale and Jones 2000). In a special issue of the ‘Proceedings of the institution of Civil Engineers’ Civil Engineering’ journal several leading authors investigated case studies of engineering failures. The authors point out that with ever-increasing specialisation in civil engineering projects, communication and understanding at every point are vital to preserving safety (Mann 2008). Others have suggested that more attention could be paid to the psychological aspects of learning from failure (Kletz 2008). An interesting message relayed is that just as ‘problems’ have been rebranded as ‘challenges’, perhaps ‘failure’ should be replaced with something less emotionally charged. But after almost all of the incidents reported, opportunities for the industry to improve safety are missed (Byfield 2008).

Protecting construction workers and others against risks to health and safety arising from work activities, requires a firm set of procedures, protocols and criteria for assessing successes and failures. The HSE’s philosophy for securing the health, safety and welfare of persons at work is set out in “*Reducing Risk Protecting People*”. The document commonly referred to as “R2P2” (HSE 2001), sets out the basis and criteria by which the HSE, in complying with its functions, decides upon the degree and form of regulatory control that it believes should be put in place for addressing occupational hazards. It considers the way scientific evidence (or the lack of it) and uncertainties are taken into account and how the balance is struck between the benefits of adopting a measure to avoid or control the risks, and its disadvantages. The findings of the R2P2 investigation studies reveal a combination of factors for each fatal accident of which the most frequently cited are:

- a) the incidence of training factors, experience;
- b) information and advice deficiencies;
- c) risk perception;
- d) rescheduling of work without planning;
- e) minor / one-off jobs;
- f) compliance; and
- g) equipment operability, space, personal protective equipment (PPE) issues and tools not designed to fit the user / task.

Government departments have paid considerable attention to these findings (Donaghy 2009). However given the speed at which the industry is subject to change (technology, process and procedure), stakeholders must review practice, change and review in the context of future safety challenges.

In a detailed study of 100 construction accidents, (Haslam *et al.* 2003a, 2003b; Gibb *et al.* 2005, 2006) identified where safety on construction projects is compromised and why. Illustrating the hierarchy of influences in construction accidents through 13 broad causal factors (see Table 1). Gibb *et al.* 2005 also point to failings in education, training and the industry's lack of a safety culture typified by only a superficial appreciation of health and safety considerations from workers both on and off sites. The authors conclude that stakeholders responsible for the immediate accident circumstances, shaping factors and originating influences must all work hard to remove flaws in their safety systems to ensure that accidents are reduced (Haslam *et al.* 2003a, 2003b; Gibb *et al.* 2005, 2006). It should be noted that the accidents studied were not major accidents although the research team did attempt to evaluate the likely outcomes if the accident conditions had been slightly different, with many of the incidents having the potential for major injuries or fatalities, although generally not multiple fatalities which are the focus of this research.

**Table 1: Results and implications for the industry (Gibb *et al.* 2005; 2006)**

<b>Workers</b>	Problems arising from workers or the work team, especially worker actions or behaviour and worker capabilities, were judged to have contributed to over two thirds (70%) of the accidents. These problem points to inadequate supervision, education and training.
<b>Communication</b>	Poor communication within work teams contributed to some accidents, due to the physical distance between work colleagues or high levels of background noise.
<b>Non –construction activity</b>	Many accidents occurred when those involved were not actually performing a construction task (e.g. moving around site).
<b>Workplace factors</b>	Workplace factors, notably poor housekeeping and site layout and space availability problems, were considered to have contributed in half (49%) of the accident studies. Standards of housekeeping and workplace layout are low in construction compared to other industrial sectors.
<b>Poor analysis of causality factors</b>	Despite poor weather often being cited as one of the reasons for construction's poor safety record, there was little evidence in support of this.
<b>Equipment</b>	Shortcomings with equipment, including personal protective equipment (PPE), were identified in over half (56%) of the incidents. Poor equipment design and inappropriate use of equipment for the task were prominent aspects. Designers, suppliers and purchasers of equipment appeared to give insufficient attention to the safety of users.
<b>Material</b>	Deficiencies with the suitability and condition of materials, including packaging, featured in more than a quarter (27%) of incidents. The operation of the supply/purchase appeared to act as a barrier to innovation as far as safety is concerned.
<b>Risk management</b>	Originating influences, especially inadequacies with risk management, were considered to have been present in almost all (94%) of the accidents. Frequently, no risk assessment had been undertaken covering the circumstances involved in the accident. Where a risk assessment had been carried out, it was often found to be superficial and unlikely to have prevented the accident.
<b>Habitual factors</b>	PPE was relied upon habitually as a substitute for risk elimination or reduction at source.

<b>Design</b>	It was judged that up to half of the accidents could have been mitigated through a design change and it was found that, despite the CDM regulations, many designers were failing to address the safety implications of their designs and specifications.
<b>Investigation protocols</b>	Accident investigation by employers or supervising contractors was frequently superficial and of little value to improving safety. HSE investigations seemed to focus on safety failures in the activity being undertaken, without capturing the upstream influences upon these.
<b>Client safety consciousness</b>	The influence from clients on safety appeared limited in the construction sectors predominant in this research (civil engineering, major building, residential). This was, again, despite the responsibilities on clients imposed by CDM.
<b>Generic safety risks</b>	Many of the incidents were caused by commonplace hazards and activities that will continue to occur on site whatever design changes might be made. The widespread presence of the many generic safety risks accompanying construction needs to be tackled before the benefits of design improvements will be realised.

### 6.5.3 Hazard causation models

According to many sources (Reason 1997, 2007; Haslam *et al.* 2003a, 2003b, Gibb *et al.* 2005, 2006; Carpenter *et al.* 2008) engineering failures are nearly always caused by the aggregate effect of a number of influences that come together at one particular time to cause collapse, distress or ultimate failure. The nature of the failure may often be ‘systemic’ i.e. it is not related specifically to an event, but is instead related to the manner in which an organisation, or project, is managed and organised. If this is not identified and acted upon there is a chance of the same, or similar failure, occurring again even if the individual associated with the original fault is replaced. Such an organisational failure may lie within the project team structure, within the management of one or more of the parties involved, or in the manner in which they inter-relate through contractual arrangements (Carpenter *et al.* 2008).

Evidence taken from industry reports on practice and experience (Toft and Reynolds 1994; Lancaster, 1996) and empirical evidence (Vaughan 1996) from research suggests that a number of approaches to hazard causation exist which may be used to frame the way analysis of hazards can be undertaken:

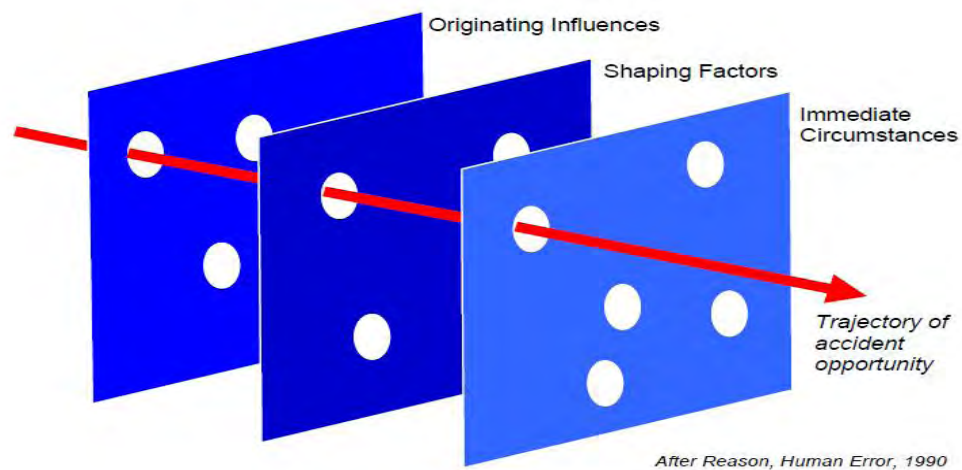
- § **Hazard Barrier Target Model** - sees hazards as the result of a continuous threat (the hazard) on a target. This target is shielded from the hazard by a barrier (which may be one barrier or several). These barriers need to be maintained. The maintenance of the barrier has to be secured by a – barrier – management system, also called safety management system or SMS. Barriers may be imperfect or absent as a result of technical or human failure.
- § **Barrier model** - In many systems not one but several barriers can be identified that shield the target from the hazard.
- § **Domino model** – This simple model sees hazards as a chain of events which is initialised by some event, just as the tipping of the first domino in a row of dominos make the whole row fall.
- § **Tripod** – specifies the nature of the various events in three kinds, *faults*, *latent failures* and *preconditions*. This way of distinguishing between different types of events is meant to take away the usual way of designating the cause of the incidents as the last fault or mistake made, which usually also puts the blame on the operator
- § **Functional resonance** – this defines incidents as independent simultaneous events that may occur randomly.
- § **Human error** – Human performance to a large extent depends on preconditions shaped by the organisation or system in which people work. Failures to any aspect of management, organisation or system may lead to human error.



§ **Contributory factors** – This may be seen as a compendium of negative factors: choice of developer and contractor; general shortage in innovation; relationship between main contractor and sub-contractor (characterised by price competition); price competition and subsequent impact on quality and safety; inadequate training in construction and design and the minor role of post-initial education and lifelong learning.

#### 6.5.4 Reason /ConCA Model<sup>1</sup>

In his book, ‘Human Error’, James Reason introduces a model to describe the causes of accidents. His work concentrates on major incidents such as Chernobyl, Challenger and Kings Cross Underground fire and he argues that most safety systems have a number of layers, or plates. Each of these plates aims to prevent a potential incident passing through them. However, according to Reason, due to human error, none of the plates are impervious – they all have holes. These holes allow the potential incident to pass through the plate, or that layer of the safety system. In most cases, the next layer in the system will intercept the potential incident and prevent its occurrence. However, this next layer also has holes. Reason’s theory explains that when holes in all the plates’ line up, the potential incident become a reality – the accident actually occurs. This theory neatly illustrates the role of chance in accident causality. Reason’s approach brings in the Possibility of multi-causality, as a number of different holes could line up to allow the trajectory of accident opportunity. Whilst Reason’s model was based on major incidents, Gibb *et al.* (2005) applied the approach to the ConCA accident causality research. Thus the plates become the immediate circumstances, shaping factors and originating influences.



**Figure 1: Reason/ConCA Model**

<sup>1</sup> The acronym ConCA refers to [Haslam et al, Causality of Construction Accidents report](#) [Haslam, R.A., Hide, S.A., Gibb, A.G.F., Gyi, D.E., Atkinson, S., Pavitt, T.C., Duff, R. & Suraji, A. Causal factors in construction accidents, Health and Safety Executive, HSE Report, RR 156, September 2003, 222 pp, ISBN 07176 2749 7, [www.hse.gov.uk/research/rrpdf/rr156.pdf](http://www.hse.gov.uk/research/rrpdf/rr156.pdf) ]

## 6.6 PEOPLE, PROCESSES & PRODUCTS

Although construction is one of the most labour-intensive industries, people management issues are given inadequate attention (Dainty *et al.* 2003). Human Resource Management (HRM) arguably has a key role to play – as many problems and operational issues arise on projects due to the management of people (Dainty *et al.* 2003).

However, while people issues may be key, it is important that they are considered in relation to other issues, such as those related to the processes and products that people design and utilise. What is often needed for successful projects is a firm grasp of CDM principles where a robust design is complemented by the designer’s appreciation for materials, structural detail, construction practice and operation and with responsible people in charge (CROSS 2008). This illustrates very well the ‘People, Process and Products’ or ‘3Ps’ approach (See Glossary) that is promulgated by SCOSS (SCOSS 2007, 2008) to illustrate the wide causes of failure. Table 2 gives one such model.

**Table 2: People, process and products - Three P’s**

<b>People</b>	Those involved exhibiting a lack of structural engineering competence such that the safety critical implications of the work were not recognised.
<b>Process</b>	Lack of attention given to the procurement of the work and in particular to ensure that one competent party is responsible for the overall design. A failure to appreciate that these support systems are just as important as primary structural members. Lack of supervision and checking of installations.
<b>Product</b>	Failure of a correctly specified product to perform.

Source: CROSS (2008) SCOSS (2007, 2009)

### 6.6.1 Proximal (near) and Distal (far) Causes - Levels in the Hierarchy

It may be established that the primary components on a construction project are People, Process and Product. It can then be determined that for dealing with Major Hazards the main focus should be on these as possible contributors to major incidents or catastrophic events. However, a major objective of this research is to stimulate industry debate and action to reduce the likelihood and severity of disastrous outcomes during construction. This requires extensive knowledge, not only about what influences safety but also about how this influence occurs.

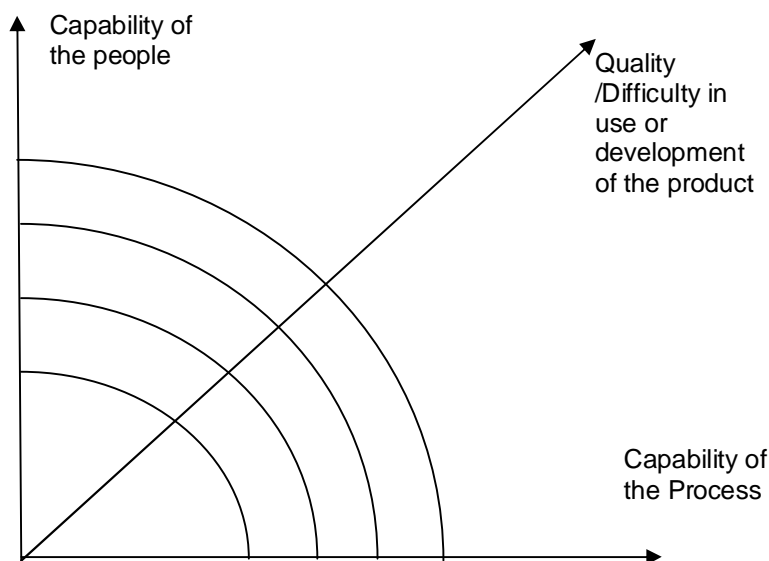
The safety climate of any organisation (and project) consists of employees’ (people’s) attitudes towards, and perceptions of, health and safety behaviour. Construction workers’ attitudes towards safety are influenced by their perceptions of risk, management, safety rules and procedures. The influences of the three P factors will always operate on different levels in the organizational hierarchy (such as the ConCA/Reason Model, see 6.5.4) and at different periods of time because many health and safety initiatives may only exist for finite periods of time (Lingard and Rowlinson, 2005). For instance the site team will probably be directly involved or responsible for immediate circumstances; the project management team and detailed designers will have an influence in the shaping factors surrounding the circumstance; client teams will have an influence over the industry as a whole; and there may be a whole series of shaping factors which stem from the wider society.

As these influences change over time according to the introduction of new practices/processes as influenced by new products and any relevant legislation (introduced as the result of past events), we should also consider factors in a temporal context. This could help to recognise the construction climate at any particular time in history within the context of general safety and the wider legislative frameworks.

By elaborating the wider issues of: time; society; industry; project; and site as well as the individual people involved in the case study events, we may begin to understand the wider climate in relation to safety performance, and thus a more comprehensive understanding of major hazards and their outcomes might be achieved.

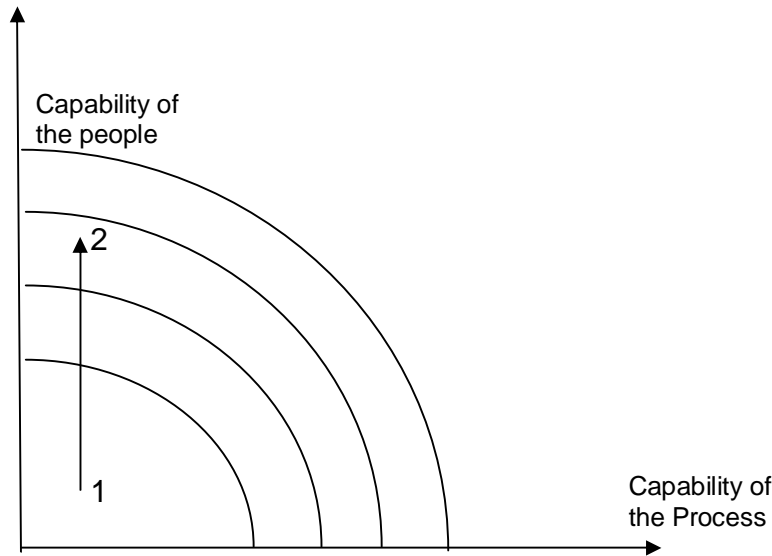
## 6.6.2 Link between People, Processes & Products

The People–Process–Product issues act individually on a continuum although the interrelationship can be explained on a simple graph to map a comprehensive picture. Figures 2 through to Figure 5 show a graphical view of the three Ps borrowed from “Systems Thinking” (Weinberg 1992), although the model demonstrates the “external” aspect of production (project deliverable). Figure 2 shows one relationship among people, process, and product. In an adaptation of the graph, the regions depict the difficulty of developing a product; with products near the origin being easier to build. Easy products do not require much capability from people (vertical axis) or process (horizontal axis). As products move away from the origin, they become more difficult and demand more from your people, your process, or both.



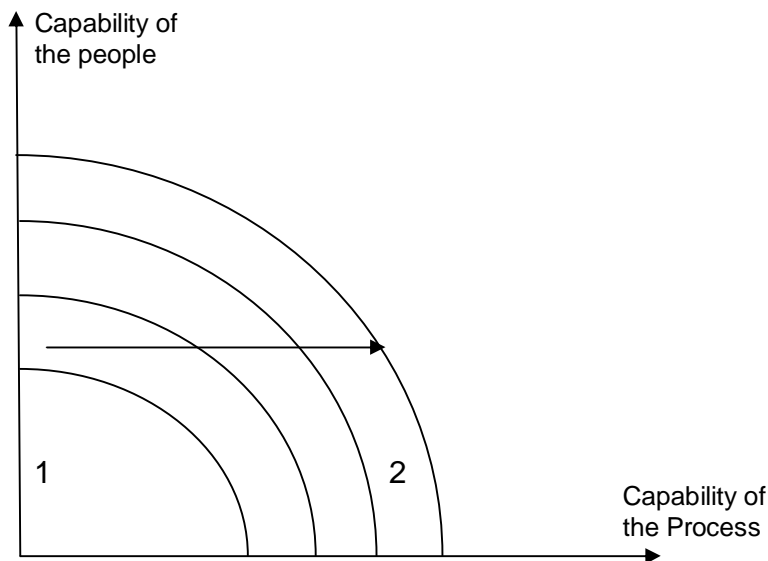
**Figure 2: People, Product and Process**

Figures 3 through 5 show that the added capability needed to build a more difficult product can come through different combinations of improving people (Figure 3), process (Figure 4), or both (Figure 5).



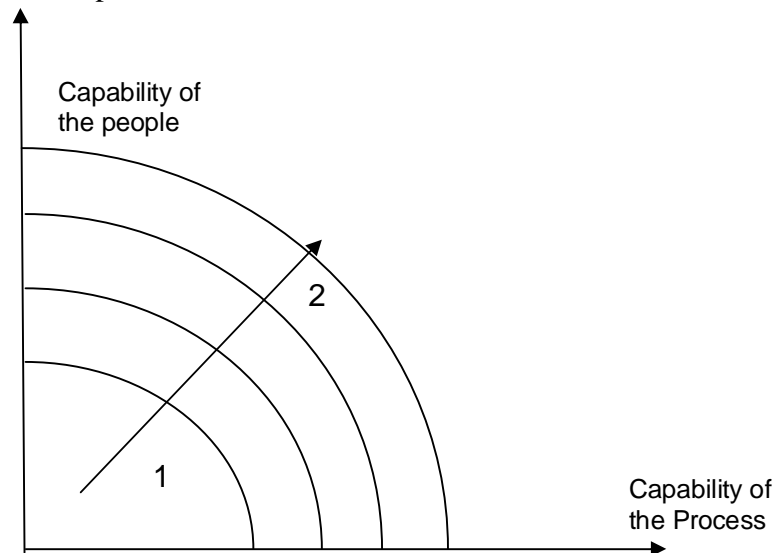
**Figure 3: Building a more difficult product by increasing the capability of people**

In each of these figures, the product moves from a difficulty of 1 to 2. Product 2 has the same difficulty in all three figures. In Figure 3, the needed capability comes from people (vertical movement only). This extra capability could be achieved by adding experts or training your people. Figure 4 shows that the same amount of extra capability can come from improving your process instead of your people. Using an incremental delivery model or stretching the schedule is a way to add capability.



**Figure 4: Building a more difficult product by increasing the capabilities of the process**

Figure 5 shows that the extra capability can come from improving both the capabilities of the people and process. This could be done by bringing in a consultant engineers, increasing training, using off-site on one part of the process and using an incremental delivery system on another. Although this graph (to a greater extent) ignores the extent that quality products contribute towards the final process, it can be used to illustrate how the P's work in tandem.



**Figure 5: Building a better product by increasing the capabilities of both people and process**

The point of the graphs is to illustrate that building a more difficult product requires an increase in capability, be it in people, process, or both. Difficult products demand process models that allow for experimenting and learning. Easy products call for process models that are simple, straightforward, and efficient. Difficult products become easier when you bring in people with knowledge of the product.

It may be established that the primary components on a construction project are People, Process and Product. It can then be determined that for dealing with Major Hazards in construction the main focus should be on these as possible contributors to project failure (or so called ‘Top Events’). Nonetheless, there is a need to question which factor is more important to the dynamics of major hazards and catastrophes; is it people, process or products?

Construction accidents result from a variety of basic root causes such as lack of proper training, deficient enforcement of safety, unsafe equipment, unsafe methods or sequencing, unsafe site conditions, not using the safety equipment that was provided, and a poor attitude towards safety (Toole 2002). Often the role of the various contractors is unclear as some contractors may try to transfer responsibility for safety to others.

Reason (1997) argues that three ingredients are vital for driving a company’s safety engine, all of them the purview of top managers: commitment, competence and cognisance - the three Cs. But managers come and go. This is a fact of life. So how does a company maintain a commitment to safety in the face of personnel turnover, volatile market forces and economic reality? Reason suggests that this is where an organisation’s safety culture comes in to play. Reason states that *“A good safety culture is something that endures and so provides the necessary driving force.”*

## **6.7 COMPLEXITY, COMMUNICATION AND INTERFACES**

Enhancing the potential for successful risk management may lie in directly addressing the perceived constraints. However ensuring an acceptable level of safety is essential and presents special challenges in construction innovation. Innovation is also fundamentally important but its benefits often remain untapped due to complex issues that surround the construction process. Typical constraints include tradition, lack of awareness or expertise, risk aversion, the desire for certainty, and of the time pressures on delivery.

### **6.7.1 Complexity**

Generally, construction project management understands the project as an ordered and simple – and thus predictable – phenomenon which can be divided into contracts, phases, activities, work packages, assignments etc to be executed more or less independently. The project is also seen as a mainly sequential, assembly-like, linear process which can be planned in any degree of detail through an adequate effort and executed in accordance with the plans. As a consequence, project management acts top down, mainly by management-as-planning as suggested by Koskela and Howell (2002). Several authors have looked at project management from the complex systems' point of view (Gidado 1996; Williams 1999; Wild 2002; Kim and Wilemon 2003); however, often these authors use a specific perspective to relay their messages. Williams (1999) characterises complexity as structural uncertainty and uncertainty in goals and methods only, whereas Wild (2002) looks at the social system in projects. These authors usually use complexity as a general characteristic of projects without applying the complex systems theory to their studies. Gidado (1996) as well as Kim and Wilemon (2003) take an ordered approach to assess complexity in projects.

### **6.7.2 Interfaces**

In the analysis of the construction project as a system, there are underlying problems which circumscribe the course which the construction process must steer. Most of these problems assume the role of interfaces, which are a combination of product interfaces, system interfaces, subsystem interfaces, disciplinary interfaces and geographical interfaces to name but a few. Interfaces may be described as the facts, problems, considerations, practices, and or procedures shared by two or more construction disciplines; or a common boundary or interconnection between systems, equipment, concepts, or human beings (Mann 2008).

There has been a significant amount of commentary addressing interfaces between various construction disciplines and practices (Mann 2008). Interface areas can for example, include the linkages between procurement, design management or construction management (in project management); and operation and maintenance, or other 'whole-life' issues (in asset management); as well as other potential synergies in the management of the projects and their resulting built environment assets. Interface areas may also be addressed through relevant issues in Public Private Partnerships (PPP), infrastructure security/resilience or sustainability etc.

Most of the structures that civil engineers create interact with other engineering disciplines. The profession scarcely ever has the luxury of designing a civil or structural entity on its own and even when it does; there may be internal interfaces between 'design' and 'construction' or between 'steel' and 'concrete' for example. Furthermore, on complex projects, within 'design'

there is an interface with analysis and its translation into reality, which is a human problem of comprehension between the ‘analyst’ and the ‘practical engineer’.

Burland (2006) has discussed problems on the interface between structural and geotechnical engineering. Since all these disparate skills are specialised, there are plenty of opportunities for misunderstandings so, whenever there is an interface, the rule is to be on guard. Those involved need adequate dialogue as, although civil engineers think of their work as technical, a vast amount is about comprehending the true system demand and thence communication about intent, design and construction. Within engineering circles worldwide this is a source of concern (Burland 2006) and poor communication is a recurrent theme. There can be particular difficulties across technical and contractual boundaries.

### 6.7.3 Communication

As people develop their professional competence, they acquire a vocabulary and an understanding of the meaning of different words when used in the contexts of their discipline (semantics). They also develop a lexicon – an understanding of how language and technical words relate to each other (Tutt *et al.* 2010). This language diversity is a prominent feature, leading to an inability to interpret messages regarding workplace hazards conveyed by supervisors, managers and peers.

## 6.8 UNDERLYING PROBLEMS WITH REPORTING AND RESEARCH

Because of the low probability of catastrophic events historical data is very sparse. Due to this very limited data, the sample sizes of statistical analyses would be very small, leading to high variances and poor (in the sense of imprecise) risk estimates. Without further knowledge, the likelihood and severity of low-probability, high-consequence events are thus difficult to estimate from historical data alone.

However, much has been written on the need to learn and remember the lessons of the past (Kletz 1991, 2008), and with it comes advanced opportunities for prediction, monitoring, feedback and teamwork opportunities for learning (Powderham 2002). However it is important to recognise the limitations of this type of approach. Some of the most significant limitations include various concerns about potential bias. Media accounts may suffer from biases of both inclusion and exclusion. They may report on sensational stories that are unimportant or inflated from the standpoint of societal impact. On the other hand, they may fail to report on important impacts for any number of reasons, lack of information, lack of awareness, and lack of attention if another issue is dominating the news cycle. These limitations suggest the need to validate and supplement data from accounts with information from actual case studies and other sources. However, it is reasonable to expect that reporting issues may be of lesser concern in the case of truly significant societal impacts; that is, a major fire that causes numerous deaths is likely to be reported in any circumstance.

In the introductory statement to the ‘Special issue’ of the ICE Proceedings, Byfield (2008:3) draws our attention to hindsight as “*something that engineers must learn to harness*”. Certainly obtaining good information on recent engineering failures or near misses can be difficult due to the complex and often protracted legal issues involved. The occurrence of an event can be brought about by a number of cascading problems such as arithmetic error, lack of essential training for key personnel, lack of experience, use of inappropriate software within a design office, or a failure to supervise. However there is often a tendency to draw conclusions from the immediate and sometimes apparently ‘obvious’ causes of a failure; but could engineers not learn

from ‘near misses’ instead? A point Collings (2008) raises repeatedly in a paper on bridge failures suggesting that often precedents are unnoticed and key warnings are ignored. The industry must be mindful of obvious conclusions as vital evidence and experientially crucial knowledge may be lost (Burgoyne and Scantlebury 2008).

Reporting and research into types of events that are embraced by this report should look at the physical causes of the incidents as well as focusing on the systemic management culture and human error processes that contribute to the event. Major Hazard incidents rarely just happen, but are usually the result of failures of technology, failures of people or a combination of both. These causes are seldom simple and singular. In modern technological systems causes sometimes are complex constellations of directly contributing events and existing preconditions and system properties. Failures to report on single incidents or series of subsequent incidents may build up into a catastrophic event. The collection of data surrounding Major Hazard incidents involves three main stages:

1. Ensuring that all significant incidents are reported;
2. Checking for non-reporting of the type of incidents concerned; and
3. Recording details of the incidents reported in order to mitigate for such events in the future.

Unfortunately, the understanding of the underlying causes of many disasters can be stymied by the legal process, which can mean that the evidence is limited in its circulation. The profession needs to study and learn from its failures as much as its successes (Byfield 2008).

There are barriers to reporting and one is that the identity of the author, their employer, the client, the site, or a product may be revealed with negative consequences (Soane 2006). The model for CROSS was Confidential Human Impact Reporting Programme (CHIRP), the UK aviation system which in turn has links to the Aviation Safety Reporting System (ASRS) - the incident reporting service for pilots in the USA. The process for handling reports has been adopted by the construction sector and adapted from their procedures; this is clearly a move in the right direction.

## 6.9 SUMMARY

This section of the report has provided an overview of the extant literature related to professional and public understanding of the immediate and underlying causes of catastrophic events in construction. This literature review has also sought to understand the effectiveness of current control measures and the need, if any, for further actions to improve the management of risks and their potential for causing catastrophic events on construction projects. The review has highlighted that there is a paucity of relevant publications on major hazards in the context of construction. Nonetheless, examples from other industries and a legacy of ‘near miss’<sup>1</sup> events suggest that approaches are needed to improve industry preparedness for future major hazards and their disruptive effects.

The literature reviewed has highlighted a number of key points, namely:

- § Despite attempts to learn lessons over the years, major accidents continue to be a threat.
- § Complex chains of events (including organisational policies and decisions, individual behaviours and mechanical or technological failures) often combine to result in major hazard events or catastrophes.

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<sup>1</sup> Near miss’ should in the context of this report perhaps be ‘near hit’ or ‘near accident’



- § The major consequences and impacts of catastrophes are likely to be: multiple deaths and serious injuries to site personnel and the general public; the serious disruption of infrastructure and key services; damage or even destruction of organisations commercially; and political implications – public enquiries, demands for new legislation.
- § The literature has identified failures based on fundamental systemic failure, for instance failures within systems of organisation, communications and procurement. To date, focus has been directed at easily promotable risk and hazard reducing goals (for example ‘zero accidents’), rather than the processes and methods needed to achieve them.
- § Greater emphasis should be placed on the concept of ‘people, process and products’ in particular when developing the competence of the industry’s people in relation to risk and major hazards.
- § There is a need for further research and for advancing the use of confidential reporting mechanisms

There are a number of circumstances which contribute to the explanation of the problems which may manifest a major hazard into a catastrophe. However, it has been noted that it is impossible to submit broad policy recommendations for the construction industry and the government on the basis of any one single case without raising methodological questions. This is compounded by the ever increasing complexity of building and construction systems.

Past incidents within (and outside of) the construction industry suggest that there needs to be ongoing monitoring of incidents (national and global) and ongoing evaluations of the systems in place. The following sections, that present the findings from an on-line survey, 62 case studies and numerous industry consultations, will provide a more detailed discussion and analysis of these key issues.

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## **7. On-line Survey Analysis**

### **7.1 INTRODUCTION**

As part of the research, an on-line survey was commissioned in order to identify attitudes towards and experience of catastrophic events<sup>1</sup> and associated risk management as perceived by individuals working within the industry. The method is described in Section 5. The online survey achieved 350 active responses which helped to generate narrative accounts of incidents/events; and to provide contacts for any further research. This phase of the research was important as it produced valuable primary data that was used to challenge the stereotypes that are still widely held about catastrophic events and risks generally during construction projects (see section 6, literature review). By bringing individual accounts and perceptions of the industry to the forefront, conducting open discussion and increasing awareness of issues in context by the UK construction community a base for further and ongoing research was formed.

### **7.2 KEY POINTS**

The respondents' view what causes catastrophic events can be grouped as:

- § Client and procurement issues
- § Overall management issues
- § Design issues (permanent and temporary works)
- § Checking and review issues
- § Site management and worker issues.

Key control factors to prevent or reduce catastrophic events can be grouped under the following headings:

- § Good quality, competent people
- § Interfaces, teamwork & coordination
- § Hazard & risk management
- § Design & pre-construction planning
- § Checking and review
- § Project management, procurement and resources
- § Site management and supervision
- § Information and communication
- § Legislation and codes.

And in this respect:

- § The failure to recognise hazardous scenarios was the most significant contributor to catastrophic events. Lack of site control also had a major impact on events.
- § The most significant control failure was not thinking deeply as an individual and as a team about hazards. Having good people and adequate resources could also be controlled better by the industry.
- § Interface problems between various construction practices and issues of communication featured highly in several individual accounts of catastrophic events.

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<sup>1</sup> In this on-line survey the term 'major Hazards' was generally used rather than 'Catastrophic Events' – for the purposes of this section, the two phrases should be seen as interchangeable

Respondents considered that, although the industry generally did actively strive to eliminate hazards, they considered that extra precautions should be taken where the potential for catastrophic events was recognised.

### 7.3 WHAT ARE CATASTROPHIC EVENTS IN CONSTRUCTION?

Respondents were asked “Have you any experience of working on a project where things have gone (or have threatened to go) seriously wrong, harming a lot of people?”. Figure 7.1 shows that, of the 298 active responses, 35% replied “Yes” they did have such experiences; and 65% suggested that they had not. The research used a confidential and anonymised open ended component to gain insight into the type of events experienced by respondents. 100 open ended responses were gathered, identifying more than 80 examples (Table 7.1) which ranged from minor incidents to larger scale events. For example:

- § Lift engineer killed when testing a life
- § Inadequate trench support system used by the contractor in deep open cut works in heavy clay, leading to punching of ‘acrow’ props into baulk timbers. This was resolved by use of trench boxes.

Respondents were asked if they would be prepared to discuss the particular incident further in strict confidence. In doing so the study assessed the level and extent that confidential reporting systems may be developed and utilised in the future. 231 out of the sample indicated a response with 60% replying “Yes”; and 40% not wishing to talk further.

Respondents having been asked about events where there had been (or had threatened to be) harm to ‘a lot of people’, there was some debate about how many was ‘a lot’ in terms of the number of people harmed. A valid comment was made that even ONE death was one too many.

Whilst the numbers involved are insufficient to draw any statistically significant conclusions, these free-text responses did suggest the types of incidents that respondents felt were catastrophic.

A break-down of the categories of incidents is given in Table 7.1. There were a number of additional non-construction incidents identified but these are not recorded here. Many of the incidents involved railway work (10) and bridges (3), but there were also other transportation, building, civil engineering, nuclear, refurbishment and demolition projects. Excavation works (8) and works associated with disturbance of underground services such as electricity and gas (8) were also featured as were fires (3). 23 examples were provided where there had been a failure of temporary works, including falsework or formwork. Failure of permanent works was identified in seven cases and one demolition example. Five examples of tunnel collapses were included, and a further thirteen projects involved complete or partial collapse of buildings or structures. Examples involving cranes (5) and plant & equipment (4) mainly covered collapse or overturning. These incident types map well across the case study examples featured in Section 8.

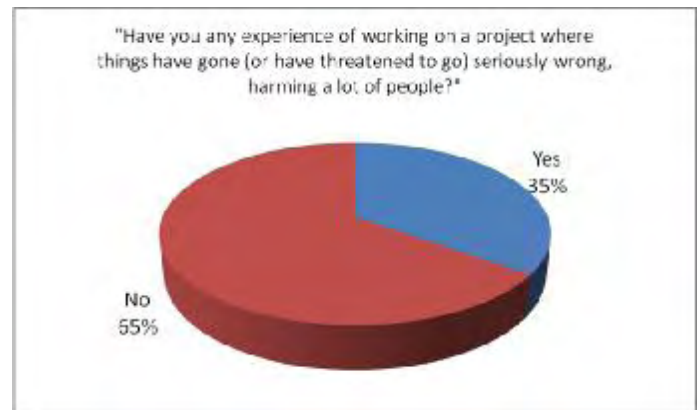


Figure 7.1. Experience of major hazard events

**Table 7:1 Types of catastrophic events witnessed by respondents (free text responses)**

Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse
1	Construction of bridge abutment adjacent to railway where method statements are general in nature - do not recognise hazardous situations, relying upon people on site without the requisite information	X	X												
2	Working on a disused rail track doing maintenance work which caused a road bridge to collapse only by luck no one was hurt.	X	X												X
3	Damage to a bridge over railway lines	X	X												
4	Temporary structure failing with potential of collapsing onto a railway.	X				X									X
5	A week after I left the railways as a recently chartered engineer <i>in my mid twenties</i> , three members of the track gang who had been 'protecting me' in my last week of employment were <u>hit by a train</u> and killed when working on the same completely open straight length of track to where I'd been in my last week. <i>It seems clear that the look-out lost concentration and the men stopped looking out for themselves</i> as well... A lesson I learnt was to make sure I looked after myself at all times and also tried to look after others I work with.	X													
6	A bridge on temporary bearings dropped a few inches, dropping concrete planks onto a <u>railway</u> below almost causing a derailment and stranding several trains	X													X
7	Involved with collapse of railway tunnel	X								X					X
8	Part of newly constructed station platform collapsing on three individuals.	X													X
9	My previous experience in rail industry included 4 major rail disasters. I also initiated the Safety Risk Model to formally analyse such incidents, including Fault and Event tree modelling of potential rail "major hazards"	X													
10	DLR blowout on the Isle of Dogs	X													
11	Striking underground services: 1. Unmarked and in a different field to the one we were told they were in; i.e. poor Utility records. 2. Temporary site cables not shown on the 'current' site services drawing quickly enough; i.e. speed of recording new services too slow. 3. Digging without permission; i.e. ignorance of dangers because of inadequate site induction.			X	X										

<sup>1</sup> These were events that the respondents considered were major hazard events – they have not been evaluated against specific criteria

Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse
12	Inadequate <b>trench support system</b> used by a contractor in deep open cut works in heavy clay, leading to punching of acrow props into baulk timbers. Resolved by use of trench boxes			X											
13	<b>Excavation</b> at foot of natural slope failed to take account of overall slope instability - at root of a dam. Continuation by contractor in face of evident partial collapse (and designer refusal to reconsider the design calculations / assumptions) could have caused total dam failure. The geotechnical investigation was limited to immediate area of new build, ignored wider landscape features upslope.			X											X
14	I was involved in a construction project where a large embankment slipped. No one was injured but potentially they could have been.			X											X
15	<b>Fire</b> in refuelling, storage area. Stores person hospitalised due to constricted means of escape													X	
16	Fire dampers and fire stopping very improperly installed by supposedly competent contractors, and the problems "missed" by designers, inspectors & Building Control (has happened on two recent projects)													X	
17	Large scale <b>fire</b> at power station, investigation unable to determine cause, but likely to be smoking in unauthorised areas and poor housekeeping.													X	
18	Gas main strike on busy site				X										
19	A HP gas main running close to a school was ruptured because it was not where shown on record drawings			X	X										
20	Hitting of a major gas main by an excavator, which lead to the evacuation of several adjoining buildings to the site.			X	X				X						
21	Gas explosion and collapse of a building				X										X
22	Tipper truck backed into overhead power line				X				X						
23	Live electrical cable cut (luckily containing very minor current) because of communication problem and belief electricity was switched off.				X										
24	The damage of critical electrical services to a specialist unit in a hospital.				X										
25	collapse of a <b>temporary walkway</b> on a <b>bridge</b> project. No one was seriously hurt but in different circumstance could have caused many injuries.		X			X									X
26	Flooding of roundabout where client had allowed a culture of allowing the contractor to work at risk outwith the agreement. Similarly at collapse of a bridge temporary works which the contractor refuted as a major incident under RIDDOR until into next reporting year.		X			X									X
27	<b>Bridge collapse, 1967</b>		X												X
28	Potential <b>bridge collapse</b> due to failure of critical element of the structure caused by poor quality material. Too much focus on "safety" not enough on "quality". The two are intrinsically linked		X												X

Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse	
29	Various structural collapses (permanent and temporary works) resulting in multiple fatalities and injuries.					X										X
30	Temp works during auger bore under a river					X										
31	Temporary works designers & Cat 3 checkers did not consider how permanent shuttering to precast beams over railway could be installed under temporary cross bracing. Positive location of stability bracing totally inadequate. Agent took designers advice re using large shallow hardwood wedges which compensated for poor TW design.	X				X										
32	As a forensic investigator for <u>shoring and scaffold collapses</u> involving injury and death.					X										X
33	We have had several failures of temp works or partially completed permanent works that could have led to multiple fatalities					X	X									
34	<p>On a site where <i>precast concrete</i> units were being used as a permanent formwork for a floor there were two incidents in which a <i>precast unit</i> collapsed. Luckily no one was injured.</p> <p>The first incident was due to unauthorised removal of some props the night before an early morning pour was to take place. Some electricians working late needed to get some fairly heavy equipment into place on the floor that was being used to prop the precast slabs, and removed and displaced slabs at one location to take a dumper through; the props were not put back in their original positions afterward. The propping had been checked by the contractor and then myself the evening before and all props were correctly positioned. The slab collapsed when everyone was at the breakfast break.</p> <p>The second precast unit that collapsed was in a section where I had pointed out significant deficiencies in the fixing of timber lattice beams supporting the units above a ramp between floor levels. Wedging of the lattice girders in the u-heads of the props was totally inadequate in both directions and the wedges had not been nailed in place. Vibration caused one or two wedges to fall out. A lattice beam became unrestrained and twisted in the u-heads sufficiently to cause a large section of slab to fall onto the ramp below. The contractor thought that he had fixed the lattice beams adequately and proceeded to concrete without asking me to carry out a re-check. Again the collapse happened at break time and there were no casualties. The investigation found that three carpenters had been working on the ramp below as the pour was proceeding. As a result of these incidents the contractor took the decision never to use this type of permanent formwork on any future work. In completing the remaining work the contractor introduced another early morning check for displaced props if checks had been carried out the previous afternoon. He also had a carpenter stationed on the level below the pour to ensure that no one passed under the pour area, which had been taped off.</p> <p>For the second incident the contractor did not have a signed check sheet, and so did not follow procedures. Too often contractors believe that method statements are only to comply with the regulations, but do not need to be followed.</p>					X									X	

Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse
35	Girder launching gantry for concrete segmental construction collapsed, since responsible party arrogantly ignored manufacturer's recommended use manual and installation procedures. In another instance, improper concrete anchors were approved for use, resulting in death of motorist from fallen object in tunnel					X							X		X
36	Near miss major birdcage scaffold falsework failure					X									X
37	Lack of site understanding temporary works concepts.					X									
38	Failure of temporary works on a major and complex roof structure requiring the evacuation of over 4000 site workers.					X									
39	Contractor undertaking major alterations didn't put props in place as required on the drawings. Fortunately I was near the site so popped by to have a look. Client sacked the contractor the following day.					X									
40	Formwork failure on 12m high wall casting					X									
41	Concrete shutter collapsed during concrete pour at weekend because of rushing (time pressures) and inadequate supervision/ checking of shuttering joiner.					X									X
42	3 people injured 500Kg slab fell on operatives following removal of temporary props.					X									X
43	A building collapse. The structural integrity of the building was not sound and could not have been built to specification at the outset. The client, having been in receipt of expert reports suggesting this to be case, commissioned a separate report summarising the previous reports. This, unsurprisingly, failed to highlight the problems. The proposed temporary propping system between the floors - which then appeared over engineered - was then questioned by our temporary works team and the clients expert advisers accepted an alternative proposal. The building - in a city centre location - partially collapsed during demolition as the columns punched through the floor slabs. There was insufficient tie-in between the column heads and individual floor slabs. Fortunately no-one was killed - though several people were either working on the uppermost floor slabs, or within the building at the time.					X									X
44	I have had to stop works for scaffolding being incomplete, guardrails missing and trestle systems not being erected correctly which were overloaded.					X									
45	Failure of a major scaffold by display banners being attached without calcs on wind loading. Fell over footpath in major town. No injury to public.					X							X		
46	The undermining of a sheet pile cofferdam by over-excavation. Staff were evacuated from the excavation just prior to the sheet piles failing.			X		X									
47	Precast framework of buildings collapsed due to improper support or design in the erection process					X	X								X

Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse	
48	I was involved in the structural design of a 4 storey office block. The structural frame was a reinforced concrete flat slab, with no column heads. We had detailed loose reinforcement throughout the slabs with the exception of the shear reinforcement to the columns, where we had specified the shear hoop prefabricated reinforcement, on a separate drawing (which was fully referenced on the loose bar reinforcement drawings). This scheme was being constructed by a well respected contractor and was a D&B contract. By chance myself and a colleague were on site shortly before the first section for the first upper floor slab was going to be cast. My colleague happened to notice that <b>none of the shear hoops had been placed</b> , which we quickly brought to the attention of the site staff. The shear reinforcement was essential for the slab design and if the slab had been cast without this reinforcement it is very likely that catastrophic failure would (at some point) have occurred. I believe that this error (which had the potential to cause catastrophic collapse) would not have happened if there had been an RE on site. The main contractor claimed that they had quality procedures in place, and as such should have been checking for such fundamental errors as this (they clearly did not).						X									X
49	Major structural elements not designed or detailed correctly.						X									
50	<u>Crane collapse</u> and an <u>uncontrolled earth collapse near a busy street</u> .			X				X					X			X
51	Falling of <u>crane</u> in to tunnel							X		X						X
52	I am a loss adjuster involved in a number of crane related incidents on sites in UK & Europe.							X								
53	Crane collapse							X								X
54	One operative dead due to falling formwork when tower crane knocked column.					X		X								
55	A number of <u>piling</u> projects where either rigs have nearly fallen or have fallen but luck has prevented serious injury or fatality.								X							
56	A high rise <u>mast climber</u> fell to ground with two men on board. The men survived but were seriously injured. The report by HSE was confidential, but cause is believed to be lack of servicing to the motor and breaking mechanism.								X							
57	<u>Tunnel collapsed</u> during construction (with no injuries), due to failure of arch during backfilling.									X						X
58	Tunnel collapse where engineering structure was not strong enough and where effects of trying to recover time where not risk reviewed									X						X
59	urban tunnelling work where adequate control of face stability has been lost									X						
60	Flying rock fragments from blasting work due to excessive muck at the toe of the slope.									X						

Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse
61	I have worked on a project where some major items would have been unstable (and would probably have collapsed) during erection. It was an oversight, which was picked up due to <u>final review</u> of the design within the design team, and was corrected before the situation arose - but it was a near miss.						X								X
62	On a number of projects I have worked on, things have threatened to go seriously wrong, fortunately each time the hazard was identified at the last minute and controlled. Hazards have included: lack of stability during construction, very low concrete strength in piles, design requirements not communicated to subcontractor's designers, design concepts not able to be safely constructed when detailed.														X
63	During a demolition process we had a substantial unplanned collapse due to unforeseen inadequate building techniques used on the structure - re-bar in the original building was missing and incorrectly positioned leading to an inherent weakness in the structure										X				X
64	Old retaining walls collapsed allowing cliff section above the works to slide into site taking part of a public road with it. By chance no buses or public on road, no one on site (out of hours) and no injuries.			X									X		X
65	Failure to control public access to a site on a University campus												X		
66	Public access through a city centre development												X		
67	In renovation work not everything is found to be constructed as it should be ie rot problems or walls tied together											X			
68	Wet concrete poured into a confined space containing operatives.														
69	The drilling of a third party Hazardous Underground Oil Pipeline														
70	Refurb of building built in 18 <sup>th</sup> Century. Wall was opened up for a shop front on ground floor. Whilst opening was open (waiting for correct steel), water board made a hole through the basement right under the pier supporting the corner of the building (ancient rubble masonry). Building was quickly shored.											X			
71 <sup>1</sup>	8.6 billion transportation project with ??? poor oversight, poor design, and owner pushing time over safety														
72	Nuclear 1999 HSE report highlighting 133 recommendations														
73	Design change not carried fully through. Lack of checking.														
74	The design of extensions to schools where pressures of time and budget led to inadequate checking and led to poor designs.														

<sup>1</sup> Events 71-80 provided little or no detail to enable them to be categorised – However, they are retained as they refer to causal factors which are drawn out in table 7.3.



Ref	Catastrophic events witnessed by respondents (free text responses) <sup>1</sup>	Rail Sector	Bridge	Excavation	Gas Electric	Temp Works	Perm Works	Crane	Plant	Tunnel	Demo	Refurb	Public	Fire	Collapse
75	Have been involved on projects where fatalities have occurred due to risk taking and others a detailed method statement not being considered, reviewed and implemented														
76	Design change not carried fully through. Lack of checking.														
77	Client bullying post award of contract (small structural project); Request for design changes post contract award - lack of understanding by client and contractor of design process and time pressures to produce revised information.														
78	As HSE Manager I have had to deal with a number of situations. I would generalise that poor design and incompetent supervision are the two biggest areas of concern.														
79	Lift engineer killed when testing a lift														
80	client wanting things done to speed things up														

## 7.4 WHAT CAUSES CATASTROPHIC EVENTS IN CONSTRUCTION?

### 7.4.1 Ranking of pre-selected causal factors

Although hazard events may be attributable to a complex interplay of factors, the consultation exercise and preliminary research had identified a range of 23 causal factors (a to w) influencing construction catastrophic events and survey respondents were asked to assess the significance of these pre-chosen factors in turn. See Appendix C for the list of factors.

Respondents were asked to rate each factor as having a high, medium, low or zero significance to major hazard events. Table 7.2 presents the 23 identified factors and indicates: the number of respondents registering a complete response (n) for each factor; the computed total score assigned to the factor<sup>1</sup> (s); the mean score value ( $m = s / n$ ); and the rank.

It is important to consider the ranking carefully, to prevent misunderstanding and over-simplification. By calculating and then comparing the relative significance of the score values, five tiers of factors were identified. The research demonstrated that *a failure to recognise hazardous scenarios and influencing factors* was the highest ranked factor in major hazard events (tier one).

**‘Failure to recognise hazardous scenarios and influencing factors’ was the most significant factor in major hazard events.**

The following 15 ranked factors were much closer to each other and therefore can be considered together as a second tier group, with a slight increased importance the higher they are in the list:

- § Lack of site control
- § Interface problems between the various parties
- § Lack of checking and of competent reviewing
- § Lack of involvement on site by designers
- § Designers working in boxes; no-one responsible for providing overview
- § Design which didn't consider/explain how construction could be done
- § Ignorance, incompetence
- § Unreasonable time pressures
- § Poor team-working
- § Lack of experience
- § Drawings not clear
- § Design process
- § Lack of proper change control
- § Conscious risk taking
- § Inappropriate maintenance or modification

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<sup>1</sup> Respondents were asked to rate the factors as High, Medium, Low or Zero Low impact. Scores of 3, 2, 1 & 0 respectively were allocated. The score in table 7.4 is the sum of these individual scores

**Table 7.2 Factors affecting Catastrophic Events in construction**

Tier	Factor	Number of responses (n)	Total Score (s)	Mean (M=s/n)	Rank	Significance <sup>1</sup>
1	Failure to recognise hazardous scenarios and influencing factors (b)	320	771	2.409	1	0.000
2	Lack of site control (j)	320	702	2.194	2	0.216
	Interface problems between the various parties (g)	322	692	2.149	3	0.045
	Lack of checking and of competent reviewing (e)	318	672	2.113	4	0.036
	Lack of involvement on site by designers (w)	319	672	2.107	5	0.007
	Designers working in boxes; no-one responsible for providing overview (r)	318	664	2.088	6	0.019
	Design which didn't consider/explain how construction could be done (v)	320	668	2.088	7	0.001
	Ignorance, incompetence (c)	319	652	2.044	8	0.044
	Unreasonable time pressures (p)	320	645	2.016	9	0.028
	Poor team-working (i)	324	649	2.003	10	0.013
	Lack of experience (h)	319	621	1.947	11	0.056
	Drawings not clear, significant risks not apparent or highlighted (s)	318	615	1.934	12	0.013
	Design process not effective, not coordinated (q)	320	618	1.931	13	0.003
	Lack of proper change control (n)	318	611	1.921	14	0.010
	Conscious risk-taking (k)	319	605	1.897	15	0.025
	Inappropriate maintenance and/or modification of a structure (m)	317	600	1.893	16	0.004
3	Underlying lack of "robustness" (a)	306	547	1.788	17	0.105
	Over-complex procurement with unclear responsibilities (t)	318	568	1.786	18	0.001
	Error (by people who are competent) (d)	322	574	1.783	19	0.004
4	Underfunding (l)	315	505	1.603	20	0.179
	Over-reliance on software analysis which cannot be easily verified (u)	319	461	1.445	21	0.158
	Over-reliance on codes (f)	316	421	1.332	22	0.113
5	Vandalism or malicious act (o)	315	299	0.949	23	0.383

A third tier is then: *underlying lack of robustness; over-complex procurement with unclear responsibilities; and error by people who are competent.*

A fourth tier is *underfunding* followed by *over-reliance on software analysis* and *over-reliance on codes*. Finally, *vandalism and malicious acts* was considerably lower placed as the least significant factor in tier five.

The fact that *failure to recognise hazardous scenarios* (b) emerged as a main contributing factor requires some comment. Construction professionals should have the skills to recognise hazards,

<sup>1</sup>These data use a statistical method of determining the significance between ranked items – the larger the figure the more significant the difference between the mean scores.

estimate or calculate the consequences of a failure and act to eliminate a hazard or mitigate the risk and its final impact. Difficulty in recognising hazards and reducing their consequence was therefore nevertheless. There are both subjective and objective reasons for this situation, a detailed discussion of which exceeds the scope of the current section but will be assessed in the case study analysis and subsequent discussions.

*Lack of site control* as the second contributing factor raises serious concerns about how construction projects are managed. Success from the project management's viewpoint is achieving the highest quality, with no major project disruption. This means bringing all disciplines in a coordinated manner to limit liabilities of cost, schedule, quality, safety, labour productivity, materials consumption and waste as well as managing safety, so good site control should improve management generally as well as managing safety risks.

*Interface problems*, identified as the third most significant factor, recognises that in any project, especially a construction project, many different and sometimes conflicting interests must be considered. Having identified the main responsibilities on a project, various disciplines must communicate effectively to facilitate project success. Interface or communication problems can severely obstruct the implementation of the construction process. Such communication problems will cause cost overruns and exceeded time schedules due to conflicts and controversies concerning project design (e, w, r and v) and implementation, and could also lead to catastrophic hazard events.

#### **7.4.2 Respondents' free text opinions on causal factors**

Respondents offered their opinions regarding causal factors on around half of the incidents (Table 7.3). These opinions have not been independently tested and therefore must be considered in that light. The various causal factors<sup>1</sup> raised were as follows, where frequency of a topic being mentioned is shown in brackets:

- § Inappropriate action or inaction by the client or client's advisor (4)
- § Pressure from time or money (6)
- § Inadequate design or (late) design changes of permanent or temporary works<sup>2</sup> (12)
- § Incorrect as-built drawings and information (2)
- § Inappropriate or generic method statements (3)
- § Problems with materials or equipment (3)
- § Poor communication (2) and coordination (2)
- § Ignoring information, guidance or 'tell-tale' signs of an imminent problem (3) and breaking rules / failing to follow agreed procedures (4)
- § Lack of, or inadequate checking or review (9)
- § Lack of competence (3)
- § Poor housekeeping (1)
- § Poor supervision (4)
- § Poor work quality (10)
- § Lack of concentration (1)

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<sup>1</sup> It should be noted that many of these incidents may have involved a number of these causal factors, but each has only been noted where it was specifically raised.

<sup>2</sup> Note that Temporary Works design is typically the responsibility of the contractor

**Table 7:3 Suggested causal factors in catastrophic events witnessed by respondents (where indicated) (free text)**

Ref	Suggested causal factors in catastrophic events witnessed by respondents (where indicated) (free text)  (NOTE: Judgement as to the significance of these events was made by the respondents)	Client/advisor problems	Time & money	Design & changes	As-built drawings	Method Statements	Poor Materials or Equipment	Poor Communication	Poor Coordination	Ignore signs, info, guidance	Poor Checking or Review	Lack of Competence	Poor Housekeeping	Poor Supervision	Poor Work quality	Poor Concentration	Breaking rules
71	8.6 billion transportation project with <i>VERY</i> poor oversight, poor design, and owner pushing time over safety	X	X	X										X			
77	Client bullying post award of contract (small structural project); Request for design changes post contract award - lack of understanding by client and contractor of design process and time pressures to produce revised information.	X	X	X													
80	<i>An example of when the client wanting things done to speed things up</i>	X	X														
43	A building collapse. The structural integrity of the building was not sound and could not have been built to specification at the outset. The client, having been in receipt of expert reports suggesting this to be case, commissioned a separate report summarising the previous reports. This, unsurprisingly, failed to highlight the problems. The proposed temporary propping system between the floors - which then appeared over engineered - was then questioned by our temporary works team and the client's expert advisers accepted an alternative proposal. The building - in a city centre location - partially collapsed during demolition as the columns punched through the floor slabs. There was insufficient tie-in between the column heads and individual floor slabs. Fortunately no-one was killed - though several people were either working on the uppermost floor slabs, or within the building at the time.	X		X													
41	Concrete shutter collapsed during concrete pour at weekend because of rushing (time pressures) and inadequate supervision/ checking of shuttering joiner.		X					X			X			X			
58	Tunnel collapse where <i>the</i> engineering structure was not strong enough and where effects of trying to recover time where not risk reviewed		X	X							X				X		
74	The design of extensions to schools where pressures of time and budget led to inadequate checking and led to poor designs.		X	X							X						
45	Failure of a major scaffold by display banners being attached without calcs on wind loading. Fell over footpath in major town. No injury to public.			X													
47	Precast framework of buildings collapsed due to improper support or design in the erection process			X													

Ref	Suggested causal factors in catastrophic events witnessed by respondents (where indicated) (free text)  (NOTE: Judgement as to the significance of these events was made by the respondents)	Client/advisor problems	Time & money	Design & changes	As-built drawings	Method Statements	Poor Materials or Equipment	Poor Communication	Poor Coordination	Ignore signs, info, guidance	Poor Checking or Review	Lack of Competence	Poor Housekeeping	Poor Supervision	Poor Work quality	Poor Concentration	Breaking rules
49	Major structural elements not designed or detailed correctly.			X													
62	On a number of projects I have worked on, things have threatened to go seriously wrong, fortunately each time the hazard was identified at the last minute and controlled. Hazards have included: lack of stability during construction, very low concrete strength in piles, design requirements not communicated to subcontractor's designers, design concepts not able to be safely constructed when detailed.			X				X							X		
72	Design change not carried fully through. Lack of checking.			X													
78	As an HSE Manager I have had to deal with a number of situations. I would generalise that poor design and incompetent supervision are the two biggest areas of concern.			X								X		X			
31	Temporary works designers & Cat 3 checkers did not consider how permanent shuttering to precast beams over railway could be installed under temporary cross bracing. Positive location of stability bracing totally inadequate. Agent took designers advice re using large shallow hardwood wedges which compensated for poor TW design.			X							X						
11	Striking underground services: 1. Unmarked and in a different field to the one we were told they were in; i.e. poor Utility records. 2. Temporary site cables not shown on the 'current' site services drawing quickly enough; i.e. speed of recording new services too slow. 3. Digging without permission; i.e. ignorance of dangers because of inadequate site induction.				X												X
19	A HP gas main running close to a school was ruptured because it was not where shown on record drawings				X												
67	In renovation work not everything is found to be constructed as it should be ie rot problems or walls tied together				X			X							X		
34	<i>Precast concrete</i> units were being used as a permanent formwork for a floor there were two incidents in which a <i>precast unit</i> collapsed. Luckily no one was injured. The first incident was due to unauthorised removal of some props the night before an early morning pour. Some electricians working late needed to get some fairly heavy equipment into place on the floor that was being used to prop the <i>precast</i> slabs, and <i>removed and displaced slabs</i> at one location to take a dumper through; the props were not put back in there original positions afterward. The propping had been checked by the contractor and then myself the evening before and all props were correctly positioned. The slab collapsed when everyone was at breakfast.					X					X						

Ref	Suggested causal factors in catastrophic events witnessed by respondents (where indicated) (free text)  (NOTE: Judgement as to the significance of these events was made by the respondents)	Client/advisor problems	Time & money	Design & changes	As-built drawings	Method Statements	Poor Materials or Equipment	Poor Communication	Poor Coordination	Ignore signs, info, guidance	Poor Checking or Review	Lack of Competence	Poor Housekeeping	Poor Supervision	Poor Work quality	Poor Concentration	Breaking rules	
	<p>The second <i>precast unit</i> that collapsed was in a section where I had pointed out significant deficiencies in the fixing of timber lattice beams supporting the <i>units</i> above a ramp between floor levels. Wedging of the lattice girders in the u-heads of the props was totally inadequate in both directions and the wedges had not been nailed in place. Vibration caused one or two wedges to fall out. A lattice beam became unrestrained and twisted in the u-heads sufficiently to cause a large section of slab to fall onto the ramp below. The contractor thought that he had fixed the lattice beams adequately and proceeded to concrete without asking me to carry out a re-check. Again the collapse happened at break time and there were no casualties.</p> <p>The investigation found that 3 carpenters had been working on the ramp below as the pour was proceeding. As a result of these incidents the contractor <i>decided</i> never to use <i>this type</i> of permanent formwork <i>again</i>. In completing the remaining work the contractor introduced another early morning check for displaced props if checks had been carried out the previous afternoon. He also had a carpenter stationed below the pour to ensure that no one passed under the pour area, which had been taped off.</p> <p>For the second incident the contractor did not have a signed check sheet, and so did not follow procedures. Too often contractors believe that method statements are only to comply with the regulations, but do not need to be followed.</p>																	
1	Construction of bridge abutment adjacent to railway where method statements are general in nature - do not recognise hazardous situations, relying upon people on site without the requisite information					X												
75	Have been involved on projects where fatalities have occurred due to risk taking and others a detailed method statement not being considered, reviewed and implemented					X					X							X
12	Inadequate trench support system used by a contractor in deep open cut works in heavy clay, leading to punching of acrow props into baulk timbers. Resolved by use of trench boxes						X											
35	Girder launching gantry for concrete segmental construction collapsed, since responsible party arrogantly ignored manufacturer's recommended use manual and installation procedures. In another instance, improper concrete anchors were approved for use, resulting in death of motorist from fallen object in tunnel						X			X								
28	Potential bridge collapse due to failure of critical element of the structure caused by poor quality material. Too much focus on "safety" not enough on "quality". The two are intrinsically linked						X								X			

Ref	Suggested causal factors in catastrophic events witnessed by respondents (where indicated) (free text)  (NOTE: Judgement as to the significance of these events was made by the respondents)	Client/advisor problems	Time & money	Design & changes	As-built drawings	Method Statements	Poor Materials or Equipment	Poor Communication	Poor Coordination	Ignore signs, info, guidance	Poor Checking or Review	Lack of Competence	Poor Housekeeping	Poor Supervision	Poor Work quality	Poor Concentration	Breaking rules
70	Refurb of building built in 18 <sup>th</sup> Century. Wall was opened up for a shop front on ground floor. Whilst opening was open (waiting for correct steel), water board made a hole through the basement right under the pier supporting the corner of the building (ancient rubble masonry). Building was quickly shored.								X								
13	Excavation at foot of natural slope failed to take account of overall slope instability - at root of a dam. Continuation by contractor in face of evident partial collapse (and designer refusal to reconsider the design calculations / assumptions) could have caused total dam failure. The geotechnical investigation was limited to immediate area of new build, <u>ignored wider landscape</u> features upslope.									X							
39	Contractor undertaking major alterations didn't put props in place as required on the drawings. Fortunately I was near the site so popped by to have a look. Client sacked the contractor the following day.									X					X		
16	Fire dampers and fire stopping very improperly installed by supposedly competent contractors, and the problems "missed" by designers, inspectors & Building Control (has happened on two recent projects)										X	X					
48	I was involved in the structural design of a 4 storey office block . The structural frame was a reinforced concrete flat slab, with no column heads. We had detailed loose reinforcement throughout the slabs with the exception of the shear reinforcement to the columns, where we had specified the shear hoop prefabricated reinforcement, on a separate drawing (which was fully referenced on the loose bar reinforcement drawings). This scheme was being constructed by a well respected contractor and was a D&B contract. By chance myself and a colleague were on site shortly before the first section of the first upper floor slab was going to be cast. My colleague happened to notice that none of the shear hoops had been placed, which we quickly brought to the attention of the site staff. The shear reinforcement was essential for the slab design and if the slab had been cast without this reinforcement it is very likely that catastrophic failure would (at some point) have occurred. I believe that this error (which had the potential to cause catastrophic collapse) would not have happened if there had been an RE on site. The main contractor claimed that they had quality procedures in place, and as such should have been checking for such fundamental errors as this (they clearly did not).										X				X		
61	I have worked on a project where some major items would have been unstable (and would probably have collapsed) during erection. It was an oversight, which was picked up due to final review of the design within the design team, and was corrected before the situation arose - but it was a near miss.										X						



Ref	Suggested causal factors in catastrophic events witnessed by respondents (where indicated) (free text)  (NOTE: Judgement as to the significance of these events was made by the respondents)	Client/advisor problems	Time & money	Design & changes	As-built drawings	Method Statements	Poor Materials or Equipment	Poor Communication	Poor Coordination	Ignore signs, info, guidance	Poor Checking or Review	Lack of Competence	Poor Housekeeping	Poor Supervision	Poor Work quality	Poor Concentration	Breaking rules
37	Lack of site understanding temporary works concepts.											X					
17	Large scale fire at power station, investigation unable to determine cause, but likely to be smoking in unauthorised areas and poor housekeeping.												X				X
65	Failure to control public access to a site on a University campus													X			
44	I have had to stop works for scaffolding being incomplete, guardrails missing and trestle systems not being erected correctly which were overloaded.														X		
56	A high rise mast climber fell to ground with two men on board. The men survived but were seriously injured. The report by HSE was confidential, but cause is believed to be lack of servicing to the motor and breaking mechanism.														X		
63	During a demolition process we had a substantial unplanned collapse due to unforeseen inadequate building techniques used on the structure - re-bar in the original building was missing and incorrectly positioned leading to an inherent weakness in the structure														X		
59	Urban tunnelling work where adequate control of face stability has been lost														X		
5	A week after I left the railways as a recently chartered engineer <i>in my mid twenties</i> , three members of the track gang who had been 'protecting me' in my last week of employment were hit by a train and killed when working on the same completely open straight length of track to where I'd been in my last week. <i>It seems clear that</i> the look-out lost concentration and the men stopped looking out for themselves as well... A lesson I learnt was to make sure I looked after myself at all times and also tried to look after others I work with.															X	
26	Flooding of roundabout where client had allowed a culture of allowing the contractor to work at risk outwith the agreement. Similarly at collapse of bridge temporary works which the contractor refuted as a major incident under RIDDOR until into next reporting year.																X

### 7.4.3 Comparison of pre-set and respondents' experience on incident causality

Drawing together the data regarding the causes of catastrophic events, it is interesting to note the significant overlap between responses to these fixed options with the free text responses to particular events that had been witnessed by the respondents (Table 7.4).

**Table 7.4 Comparison of pre-selected causal factors and factors identified from respondents' experience**

Pre-selected factors based on previous research	Factors identified from respondents own experience of events
<b>Client &amp; Procurement issues</b>	
Over-complex procurement with unclear responsibilities Unreasonable time pressures Underfunding	Pressure from time or money Inappropriate action or inaction by the client or client's advisor
<b>Overall Management issues</b>	
Failure to recognise hazardous scenarios and influencing factors Interface problems between the various parties Lack of proper change control	Poor communication and coordination Ignoring information, guidance or 'tell-tale' signs of an imminent problem
<b>Design issues (Temporary and Permanent Works)</b>	
Underlying lack of "robustness" Lack of involvement on site by designers Designers working in boxes; no-one responsible for providing overview Design which didn't consider/explain how construction could be done Drawings not clear, significant risks not apparent or highlighted Design process not effective, not coordinated Over-reliance on software analysis which cannot be easily verified Over-reliance on codes	Inadequate design or (late) design changes of permanent or temporary works Incorrect as-built drawings and information
<b>Checking &amp; Review issues</b>	
Lack of checking and of competent reviewing	Lack of, or inadequate checking or review
<b>Competence, Experience, Training &amp; Education issues</b>	
Ignorance, incompetence Poor team-working Lack of experience Error (by people who are competent)	Lack of competence
<b>Site Management &amp; Worker issues</b>	
Lack of site control Conscious risk-taking	Poor supervision breaking rules / failing to follow agreed procedures Inappropriate or generic method statements Problems with materials or equipment Poor housekeeping Poor work quality Lack of concentration
<b>Miscellaneous</b>	
Inappropriate maintenance and/or modification of a structure Vandalism or malicious act	

## 7.5 WHAT CAN BE DONE TO PREVENT CATASTROPHIC EVENTS?

### 7.5.1 Ranking the effectiveness of pre-selected control factors

When asked “How effective do you think the following "controls" are in reducing extreme risks?” respondents were asked their opinion on the formal construction process and how effectively this was managed in a wider context. The control options offered were based on the preliminary research.

Table 7.5 presents the 17 identified controls a to q (see Appendix C) and indicates: the number of respondent registering a complete response (n); the relative total computed score assigned to the factor (s); the mean score value (average score:  $m = s / n$ ); and the rank.

Significantly highest amongst control failures was *having good people involved and available* which points to issues such as recruitment, training and risk management abilities of key construction personnel i.e. competence.

As a second tier, there was a close relative ranking of the next four control failures which were: *managed interfaces, communication and cooperation; Thinking deeply individually and as a team about hazards; having adequate resources* relative to controls; then *checking of detail on site*.

*Considering risks consciously* was in a third tier.

*Sensible programmes, well managed* was considered significantly less important to the second tier controls; and a further fourth tier was established of the next four factors that included: *Good management of information; adequate access to knowledge* (especially records); *good change management*; and *sensible programmes well managed*.

*Following good practice for normal situations* was in a fifth tier.

Once again, it is important to consider the ranking carefully, to prevent misunderstanding and over-simplification. By calculating the relative significance of the score values, the research was able to demonstrate that *having good people involved and available* was the highest ranked control in reducing major hazard events and was considered to be significantly more important than the other controls.

**‘Having good people involved and available’ was the most significant control in reducing major hazard events.**

The finding here reinforces some widely held views amongst industry commentators that people management issues remain a concern to the industry. Managing the human resource component on projects is vital to any project but also keeping people inspired and involved is vital for project success.

**Table 7.5 The effectiveness of controls in reducing catastrophic events**

Tier	Controls	Number of responses (n)	Total Score (s)	Mean (m=s/n)	Rank	Significance (see note below)
1	Having good people involved and available (h)	301	789	2.621	1	0.000
2	Managed interfaces, communication and cooperation (i)	301	755	2.508	2	0.113
	Thinking deeply individually and as a team about hazards (e)	299	749	2.51	3	0.003
	Adequate resource (j)	302	744	2.464	4	0.041
	Checking of detail on site (p)	301	737	2.449	5	0.015
3	Considering risks <i>consciously</i> (f)	301	731	2.429	6	0.020
4	Sensible programmes, well-managed (l)	301	703	2.336	7	0.093
	Good management of information (m)	301	685	2.276	8	0.060
	Adequate access to knowledge (especially records) (k)	300	675	2.250	9	0.026
	Good change management (q)	300	662	2.207	10	0.043
5	Following good practice for normal situations (d)	300	656	2.187	11	0.020
6	Checking of concepts (n)	297	609	2.051	12	0.136
	Checking of calculation (o)	299	612	2.047	13	0.004
7	Independent review and checking of design within the team (b)	299	605	2.023	14	0.023
8	Applying CDM 2007 principles for risk management (g)	298	560	1.879	15	0.144
9	Independent certification (c)	294	520	1.769	16	0.110
10	Our legislative framework (a)	296	495	1.672	17	0.096

NOTE: These data use a statistical method of determining the significance between ranked items – the larger the figure the more significant the difference between the mean scores.

It should be noted that there were a number of factors that were linked to checking, review and certification:

- § checking of detail on site
- § checking of concepts
- § checking of calculation
- § Independent review and checking of design within the team
- § independent certification

It may be that, by including these several items, the relevant scores for each of them may have been adversely affected with some respondents not being able to distinguish completely between them. Notwithstanding, the overall significance of the views that checking and review are currently a problem and improvement would be of significant benefit is evident.

**Improvement of in-house and independent checking and review during both design and construction would be a significant factor in helping to reduce catastrophic events.**

Once again none of the control failures outlined in the study were seen to have zero impact and score values suggest all control failures outlined did have a medium level of impact on major hazard events (in order of least impact). The lowest five control measures were:

- § Checking of calculation (o)
- § Independent review and checking of design within the team (b)
- § Applying CDM 2007 principles for risk management (g)
- § Independent certification (c)
- § Our legislative framework (a)

Of the lowest control failures there were significant differences amongst respondent scores for the lowest three which were: *our legislative framework*; *independent certification*; and *applying CDM 2007*, although *independent review and checking of design within the team* and *checking of calculations* had little significant difference between them.

## **7.5.2 Respondents' views on what more could be done to prevent catastrophic events**

In addition to the closed question discussed previously, 299 respondents answered the question: "When construction involves a major risk such as a risk to lots of people, should extra precautions be taken?" and 106 offered more details and comments on their answer. The key comments have been grouped by content and presented in Table 7.6<sup>1</sup> The groups are not precise nor mutually exclusive and in some cases a complex comment has been split between different groups to reduce unnecessary repetition. As the question was asking for 'problems' or 'solutions to problems' it is not surprising that almost all of the comments were negative. A number of reassuring statements that much was being done were also offered. It should also be noted that a number of these comments are very pointed and dogmatic – they are, of course, the views of individuals and should be interpreted in that light. Notwithstanding, they do reflect some of the views held by people in the industry.

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<sup>1</sup> Italicised text has been added to aid comprehension

The main thrust of these comments are summarised as follows<sup>1</sup>:

Accidents have **multiple causes** and cannot be treated simplistically. We need to be **better at recognising the hazards** in the first place and we need to **deal with unusual hazards**. Whenever possible, we should **eliminate the hazard**, especially during the design and pre-construction phases. It was acknowledged that, at times this was difficult but that this must still be the primary aim – there was considerable feeling that this was not being done well at the moment. Several respondents argued that using **engineering judgement** and **compliance with existing codes and advice** is important, but it was noted that more advice needed and so some **subjective decisions may still be necessary**.

**Removing one hazard may create others** and **things will change** so we still need to **manage the residual risk** and we still need **good supervision**. Many respondents stressed the need to **check that things are actually done by review and monitoring** both during design and construction. The importance of independence in such reviews was emphasised. We also need **better teamwork, coordination and communication**

In assessing and managing the risk we must **beware of just ‘ticking the boxes’** and we should **beware missing the ‘big picture’ by concentrating only on ‘everyday’ risk management**. We should **beware complacency** and not accept that we can do something just because it is ‘the way we have always done it’.

**Competence and experience** of all involved is essential and currently lacking in many quarters. Respondents argued that **clients need to fulfil their role effectively**. There was considerable strong feeling that **some designers don’t do as much as is needed**.

We need to **face the challenges from other project priorities** such as time, cost, quality and aesthetics. It was agreed that **small projects** and small organisations **have some special challenges**. We need to **address complications with the supply chain** and procurement methods, particularly **dealing with sub & sub-subcontracting and interfaces**.

Some respondents claim that **we are generally doing ok – but it is patchy**. Finally, all people involved in the process need to **take responsibility**.

**Table 7.6 Respondents’ examples of what more could be done to prevent catastrophic events - categorised free text**

Examples of what more could be done to prevent catastrophic events
<b>Accidents have multiple causes</b>
Very rarely was a failure down to a single factor
They try, sometimes they underestimate the magnitude of them or changes to the planned circumstances affect the controls and it passes un noticed.
A risk identified and planned for normally is no longer a risk of any magnitude--accidents occur because of a particular combination and/or a risk not recognised as a risk.
<b>We need to be better at recognising the hazards in the first place</b>
They would <i>do something</i> if they recognised the <i>hazards</i> ! Many don't recognise the hazard
<i>People will take action</i> only if they are made aware of the <i>hazards</i> and they can be convinced that even if the likelihood is low the severity could be catastrophic.

<sup>1</sup> The style here is intentionally in the first person to reflect the fact that many people have taken the time to make personal contributions.

<i>They will only identify the ones they know, or that have been pointed out to them.</i>
Not many project teams start by seriously analysing and understanding the hazards associated with the job
In my experience people are not aware of what hazards are!
You cannot consciously eliminate a hazard unless you have identified it. Too many people have blinkers on.
Once designers recognise a risk, they then usually try to eliminate or reduce the risk.
We are not good at seeing the hazards especially at change points
<b>We need to deal with unusual hazards</b>
Current focus seems to be on eliminating those hazards unusual and infrequent nature they can difficult to account that are less obvious, as per CDM 2007, however, due to their nature they are difficult to design out. we still find that the majority of hazards are posed by users i.e. the unfamiliar, and that such hazards can be dealt with through good design and residual risk management.
For major works, hazards are considered - the lower the perceived risk the less they look at hazard reduction
People look at hazards, but do not recognise the hazardous situations that can result - especially when there are unusual initiating factors.
<b>We should eliminate the hazard wherever possible</b>
Hazard notification and reduction seem to occur far more often than hazard elimination
People try and put mitigation measures in place rather than eliminate hazards, often wasting time and money when it would have been easier to eliminate something
Generally people, particularly designers, are too reliant on a last resort such as 'access must be by trained personnel with appropriate PPE with suitably erected scaffold', rather than trying to eliminate a hazard at source
The attitude is that hazard elimination is not possible, because we have always done it this way and it would be too expensive / time consuming.
Yes a lot of people do try to eliminate, but I do think do a lot more could be done at design stage - this is best time to eliminate and we don't do enough
Identify hazards and eliminate it is prime response of all Engineers in construction
You will never eliminate human error, but having alert, experienced staff reviewing what is happening minimises the risks.
Elimination at design stage by designer
Hazards are usually identified and mitigation measures considered
Certainly in contracting we spend a lot of time considering and trying to eliminate hazards
<i>We need to reduce the risk of their occurrence, eliminating hazards is not practicable.</i>
Hazards generally need to be eliminated early in the design stage and it is often this element that is missing
Elimination is usually done for reasons other than CDM.
<i>People generally apply precautions to lower the risk but do not remove the source</i>
Traditional approaches still prevail in the industry and consideration of elimination of hazards is rare.
<i>The correct choice of design solution can eliminate hazards</i>
You cannot start a design with hazard elimination being the main driver otherwise all buildings would be a single storey box. I think hazard elimination only starts properly after stage C by which time some of the key irreversible hazards are in place.
Particularly at the design stage, hazard removal is infrequently utilised
Eliminating hazards is not yet fully embedded into the design culture. It is often an add-on at a too late stage in projects.
I think those involved in the management and supervision actively try to eliminate hazards as far as they can.
This is something we are addressing through our Zero Harm programme, which requires elimination of risk of serious injury/fatality.
Elimination of hazards is the first part of design that any design should consider.
The hierarchy of control is not always followed fully
<b>Using engineering judgement and compliance with existing codes and advice is important</b>
It is down to 'engineering judgment'
There are few projects which contain 'problems' that lie outside accepted 'best practice' on these situations then the input from suitably experienced engineers is essential.
It would be good if we all simply complied with existing guidance / requirements from Standards, Codes etc. I suggest that most of our construction accidents are a failure to comply with the present clear industry best practice.
If existing procedures eg BS5975 are applied rigorously & conscientiously, risk of accidents is vastly reduced
<b>More advice is needed</b>
There is very poor advice on what is 'acceptable risk' and 'un-acceptable risk'.
<b>Subjective decisions may still be necessary</b>

Quantifiable data is hard to come by
<b>Removing one hazard may create others and things will change</b>
...they are replaced by something else
It is often the case that eliminating one hazard will only introduce another. While eliminating hazards is an admirable goal, efforts should be focussed on reducing and managing the residual risks.
Late changes both design and especially construction sequence/programme, time pressures all reduce the actual effectiveness of the hazard elimination.
The hazards may change from those foreseen at the design stage but a new review of hazards is not then carried out because the Team haven't recognised the extent of the differences or because they have 'no time' to do so.
<b>We still need to manage the residual risk</b>
Elimination is usually done for reasons other than CDM. Managing the hazard and risk is the big challenge and should be where concentration of effort is focussed.
<b>We still need good supervision</b>
Too much reliance on briefings and not direct supervision. As workforce will take the easiest quickest option if unsupervised.
<i>Time pressure on workers</i> means close management and supervision is needed at all times to ensure the detail and big picture are kept in mind by all concerned.
<b>We need to check that things are actually done – Review &amp; Monitoring</b>
Many hazards "dealt with" by use of standard phrases in risk assessments, e.g. use a banksman, but who checks whether these processes are followed?
We are always looking to reduce risks as team. We go over scenarios repeatedly and then monitor in site that things are going as planned.
Far too often designers follow 'codes' for 'their specialism' and are reluctant to allow 'third party questioning'
Planning always needs to be re-checked throughout the construction process
Paperwork exercises are carried out to make it appear things have been done but <u>these are rarely communicated and implemented</u>
Formal risk analysis is rarely conducted. Though, even if it were, the majority of failures I've investigated were caused by the lack of proper execution of routine operations, which would probably go below the radar of most risk analyses.
Too often a lack of checking takes place, eg has the best method of construction been used, have all the hazards been covered, is rigorous checking being carried out both at design and construction stages.
You will never eliminate human error, but having alert, experienced staff reviewing what is happening minimises the risks.
Very rarely was a failure down to a single factor - <i>this</i> led to my paying great attention to specific aspects of work in which I was involved, particularly the design and site checking of falsework.
The major problem is that engineering has become a "JOB", a 9am to 5pm occupation; the extra work of checking is avoided and covered with contract disclaimers
Usually down to common sense or at least the designer (of the permanent or temporary works) being given the opportunity to see that the contractor has interpreted the design properly
The formal risk process needs independent review by an experienced team who have no direct involvement in the project.
The hazards may change from those foreseen at the design stage but a new <u>review</u> of hazards is not then carried out because the Team haven't recognised the extent of the differences or because they have 'no time' to do so.
<b>We need better teamwork, coordination and communication</b>
No-one co-ordinates the process effectively (including the CDM-C who is often not involved in such deliberations)
Paperwork exercises are carried out to make it appear things have been done but <u>these are rarely communicated and implemented</u>
Hazards identified are evaluated in a team approach, in most instances
Early involvement of contractors is paramount.
<b>We must beware of just 'ticking the boxes'</b>
It appears to be tick box exercise.
Many hazards "dealt with" by use of standard phrases in risk assessments, e.g. use a banksman,
Too much emphasis on design risk assessments, often numeric, done too little too late.
<i>People</i> often only apply procedural or administrative controls
Paperwork exercises are carried out to make it appear things have been done but these are rarely communicated and implemented
<i>We try an</i> informal way. Formal ways seem to be tick box situations of paperwork only.



Procedures (beyond a certain minimum level) just dull the senses.
People tick boxes but we need to instil conscious awareness
Some people do not know why they are doing it, they just go through the motions because they have to.
There is a great deal of emphasis on box-ticking type procedures that distract rather than concentrate attention on relevant factors.
Risk assessment becomes superficial and serves only as a prerequisite paperwork before construction starts.
<b>We should beware missing the 'big picture' by concentrating only on 'everyday' risk management</b>
They worry too much about the well known risks and miss the big picture (for major accidents)
Numeric risk assessments do not adequately address low probability, high consequence events (Parallels with e.g. petrochem where e.g. BP Texas City were too busy with relatively minor consequences and <i>took their</i> eye off the <u>process</u> safety ball)
We tend focus on the common hazards and miss the less popular ones
All of the risk assessment processes I've been involved with focus on 'manageable' risks (i.e. on site processes) rather than issues of structural safety for instance (it is almost a given that the structural engineer will deal with this independently).
It is important that major hazards are identified in the first place - there can be too much dependence on identifying and addressing the 'good housekeeping hazards' and not enough real in depth thought on the project specific hazards.
<b>We should beware complacency – 'the way we have always done it'</b>
Traditional approaches still prevail in the industry
In my experience it is rare for accidents - especially major accidents - to happen where the personnel involved have not been aware of the hazards and risks ..They invariably believe they are in control and that an incident will not happen. (e.g. the team know an underground service is in the immediate vicinity but will use an excavator to try to clear as much material away from the area - and as close to the service as they think they can 'get away with' - before proceeding with hand digging.
Some people have their own way of doing things and it's hard to change when you don't stand over them 24 hours a day
The workers do not think like that ( <i>i.e. about risk</i> )
We have done it this way before and we did not have an accident
<b>Competence and experience of all involved is essential and currently lacking</b>
Unfortunately, not everyone has a high degree of competence in this, which creates additional risks in itself.
Designers do not have the competence or drive to take this forward.
<i>People only do things as far as their experience permits</i>
It depends on the character/knowledge of the team involved and their experience.
<i>It's usually down to common sense</i>
If aware, hazards are reduced, its ignorance that creates hazards
PPE is generally considered first because of cost and a <u>lack of understanding</u> .
Hazards <i>are</i> easily perpetuated in designs without appropriate depth of site experience
The major challenge is to make sure individuals are competent to do the job they are employed to do.
Computers seem to have overtaken the lateral thinking process that used to be put in during the process, when we used to do hand calculations in respect of structural design. Some of the younger generation are too much reliant on computers and have very little experience of actual site works or the practicalities of how the actual construction works will take place of their proposed design. In other words, designing something without knowing/imagining how it will be actually achieved on site.
CDM 2007 is great in principal, but where is the policing of this. Far too many designers have little or no knowledge of what is required from them.
<b>We need clients to fulfil their role effectively</b>
Basically people do try to eliminate risk but its clients who hold the final say
<i>Action only occurs</i> when driven by Client or his representative
In my most recent experience, the designers & contractor have not adequately considered the risks and have had to be guided/forced to do so by the Client.
As a contractor, clients appear to be very weak (in my view) at actively managing <i>the</i> permanent works design process to eliminate hazards.
Of course, depends on the project-- some clients get it, a lot don't
If there's insufficient time & resources people will take the risk. Project owner should allow realistic timeframe & budget to do the work in a good practice <i>manner</i> .
<b>Some designers don't do as much as is needed</b>
Designers tend to still think risk should be Contractor's problem

Some people try; some don't even think about it; few identify why they have eliminated a hazard and fail to pass that information to others (e.g. clients, others in the design team and constructors).
Architects do not consider how a building is to be constructed when producing designs. They are more concerned with the aesthetic than safety. Design risks are passed to the Constructor. CDM has not changed this fundamental problem.
Workers at the "face" will attempt to reduce them. There is however often lack of appreciation of these by office based designers despite CDM
Far too often designers follow 'codes' for 'their specialism' and are reluctant to allow 'third party questioning'
Much design will still resort to an entry in the designer's risk assessment as "by competent contractor" Many Contractor Designed Portion elements within the procurement framework present such a risk interface.
Designers generally do not understand their duties. Architects are very bad.
What a designer considers to be a positive measure is not always seen as such by some contractors.
Many designers do not appear to value hazard analysis.
Sometimes there simply seems to be a lack of imagination amongst engineers, it might be rare but if it can go wrong eventually it probably will.
We try to deliver good design in everything we do. The idea of separately identifying risk reduction can sometimes seem contrived.
I have requested that a school building be moved 3m west to avoid conflict with services. The architect understood that this was a significant risk that could be eliminated and so moved the building (post planning, pre detailed design).
Some designers more driven by design quality than risk elimination
<i>On the whole, most people endeavour to eliminate hazards</i>
Designers still need educating and training to consider the significant risks (and passing on relevant information) and stop extolling about small risks and telling competent Contractors what they should do.
<b>We need to face the challenges from other project priorities</b>
Small construction projects are often very cost driven
Unfortunately, there is still the issue of time and money that those at the 'coal face' sometimes allow to cloud their judgement
Cheapest, quickest solution – we have always done it like this
Eliminating hazards is considered but is secondary to producing a cost effective design for the Client.
Risks are taken when time and/or money is severely restricted.
Time constraints seem to be more important
PPE is generally considered first because of <u>cost</u> and a lack of understanding.
Procedures may be in place but commercial/time/resource pressures induce short cuts
We must also recognise that the industry is reliant on individual operatives being paid for production.
In my experience, the greatest number of "potential" major accidents/incidents are due to experienced people rushing to get started or finished in possession works - and this allows problems to occur as available important safety critical information is sometimes overlooked due to the pressurised activity in hand. This means close management and supervision is needed at all times to ensure the detail and big picture are kept in mind by all concerned. Example: live overhead cable, details briefed to all on site, but the gang gets carried away with the rush to start or finish the works that materials or tools are raised above head height without thinking. Equally, when there is a change to the planned works, the change is not always fully understood and therefore not properly acted upon by each individual. For example, we work for 3 nights with isolation of <i>the services</i> , then due to operational difficulties elsewhere, we cannot have an isolation on the 4th night - so we devise a safe way of working without an isolation. The briefing is not understood by and individual or in the rush to get things done quickly, an individual raises tools/materials above head height - as they are still in the mind set of the previous 3 nights' work and have not taken cognisance of the potential impact of the briefed change.
Designers are quite often expected to work under tight budgets and thus often forget to consider H&S or possible hazards during construction.
Late changes both design and especially construction sequence/programme, time pressures all reduce the actual effectiveness of the hazard elimination. The hazards may change from those foreseen at the design stage but a new review of hazards is not then carried out because the Team haven't recognised the extent of the differences or because they have 'no time' to do so.
Costs tend to conflict with H & S.
<b>Small projects have some special challenges</b>
<i>It is very much dependant on the industry sector we are considering e.g small construction projects are often very cost driven</i>
Probably this depends on the size and 'reputation'(culture) of the organisation and size of the project including resources

<b>We need to address complications with supply chain – sub &amp; sub-subcontracting and interfaces</b>
The majority of incidents / hazards creation occur when the planning / appointment of labour (mainly subbies) process has been by passed / not adhered to
The modern tendency to package work into boxes reduces hazards to secondary considerations rather than primary.
There are hazards presented further down the supply chain i.e. a subcontractor to a subcontractor etc.
<b>Some claim that we are generally doing ok – but it is patchy</b>
Method of works and how we achieve them are always considered in a safe way.
<b>If appropriate procedures are employed the risks are identified and addressed prior to any works commencing on site or even identified at design stage</b>
We apply a rigorous process of risk management and evaluation throughout the life of a project
Risks are continually assessed on our sites. Risk management is an endemic process within our business
It is getting better but still work to be done
Extent of trying can vary
Some people try; some don't even think about it;
Improvement is needed
Most projects have good quality management teams and good liaison with the Principal Contractor
I work in the nuclear industry with has a very strong focus on health and safety.
<i>The Civil Engineering industry is behind the Energy sector – Risk management in Civils is very inconsistent - polarised even</i>
<b>People need to take responsibility</b>
But most often I see people regard the duty to reduce or manage the hazard as someone else's responsibility
People may see hazards but do not accept the reality of risk. Do do so is not macho.
Most hazards are accepted as part of the risk in doing the job.
<i>This is not dealt with sufficiently. There is an acceptance of hazards as part of work</i>
<i>People try to underplay the hazards if it causes them problems elsewhere</i>
<i>This IS done, but not always and reluctantly if it effects their design considerably</i>

### 7.5.3 Respondents' views on key priorities for reducing catastrophic events

Respondents were asked: "What do you think that (above all else) should be done to prevent catastrophes in construction?" 230 people responded, some mentioning more than one priority (see Table 7.7). A number of focus areas were identified as follows:

§ Safety risk management	29
§ Think 'worse case'	7
§ Overview essential	4
§ Leadership	7
§ Accountable 'designated' persons	11
§ Culture	10
§ Client issues & procurement	19
§ Resources - Time	20
§ Resources – Money	10
§ Planning	22
§ Design	27
§ Manage change	4
§ Collaboration / coordination	9
§ Communication	7
§ Checking / detail	4
§ Independent review	3

§ Independent site inspections	1
§ Training	8
§ Education / universities	5
§ Feedback / learning	3
§ Competence	9
§ Regulation / HSE / Campaigns	9
§ Supervision / site control	8
§ Site management systems	6
§ Misc	2

**Table 7.7 What do you think (above all else should be done to prevent catastrophes in construction?)**

Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worse case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
Number of mentions	29	7	4	7	11	10	19	20	10	22	27	4	9	7	4	3	1	8	5	3	9	9	8	6	2
Need to consider the biggest "what if" and work back from that.	X	X																							
Robust risk assessment process that focuses on identifying hazardous situations and the lines of defence that are being relied upon.	X	X																							
Promotion of a culture of systematic hazard recognition and risk management. A lot of lip service is paid to risk assessment but very few project teams really use risk management techniques as a tool to control work.	X					X																			
Adequate hazard and risk management at design and construction stages.	X																								
Awareness identification and involvement of all construction people at all levels.	X																								
Design out hazards, communicate out residual hazards, then supervise, control, monitor site.	X													X	X								X		
Detailed critical risk management procedures with the introduction of 'hold points'.	X																								
Effective assessment and management of risks on site	X																								
Identification and awareness of any residual hazards	X																								
Proper well thought through risk assessments.	X																								
Robust assessment of risks and effective arrangements to manage/communicate significant risks to others.	X																								
Thorough planning, risk assessment, information and adequate resources.	X						X			X				X											
Design competence is crucial in every aspect, and being able to interpret designs is of equal importance. Value engineering often is the root cause of failures where designs are not re-evaluated, simple altered, and construction needs to pay more attention.	X								X		X										X				

Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worse case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
Assess and manage the risk.	X																								
There should always be a systematic and formalised assessment and management of risk on construction projects.	X																								
Awareness of risks by open and frequent discussion. Don't ever think processes or legislation will prevent them.	X																								
Consistent application of policies and procedures adopted to ensure that sensible safety is being applied to every operation that is undertaken during all construction activities.	X																						X	X	
Greater degree of risk management and commitment to same by all parties.	X																								
Ban codes of practices, allow engineers to think creatively and identify all risks that arise from their design and proper mitigation procedures.	X																								
Encourage a balanced approach to hazard control. Good engineering practice and controls are paramount to ensuring safety. By concentrating on "safety" alone another element causes the accident to happen.	X																								
People on the whole recognise risks and don't want others to get injured, however people's threshold of what is an acceptable risk and response to it varies a great deal. Risk registers should always be compiled by the team to cater for the varied views.	X												X												
Keep assessing risks, keep advertising safety campaigns, employ good safety professionals at planning stages.	X									X											X	X			
Stand back - take advice - speak to the designer.	X										X														
Coordination and proper risk analysis.	X												X												
Clients need to appreciate the whole process from cradle to grave and not just appoint duty holders because they have to by regulation. There needs to be a better understanding of hazard evaluation and risk reduction. The project team needs to review designs.	X		X				X				X					X									

Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worst case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
Allow time for competent designers to consider effectively risks and remove processes which hinder that ie many that are generated through the CDM Regs and CDM-C in particular.	X							X			X														
Provide appropriate experienced staff with sufficient time to work as a team, with all parties, to identify risks and then be allowed to fully consider implications.	X							X																	
Early risk assessment and involvement of insurance people (who have more knowledge about losses than anyone else) at an early stage in the construction process and then all the way through.	X																								
Don't take risks. Fully assess what they are, and plan them out.	X									X															
A no fault system of reporting near misses should be used. Knowledge of what could go wrong and has gone wrong on other projects should be widely disseminated so we all learn from it.		X																		X					
Education. Firstly to students as a safety module as an integral subject at University. Secondly to ICE Graduates/Members as Case studies of significant failures. Unfortunately there is only a limited number of researched case studies available.		X																X	X						
Teach people to think what can possibly go wrong with my project/design/concept.		X																X	X						
Design Teams and site management should work closely together on site to highlight potential hazards.		X										X													
Greater level of formal communication between project team members on a "What if" basis, endorsed by the client.		X											X												
Have an experienced person within the organisation who has the responsibility to take an overview and the authority to intervene when necessary.			X		X																				
Follow procedures but understand the intent.			X																					X	

Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worse case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
In my experience the design of a structure has to be turned around as soon as possible as the fees for the structural engineering process keep getting lowered. This does not leave a massive amount of time to take a step back and consider all aspects with regards to safety. I do not think the design and build system lends itself to this either.			X					X	X																
Single person designation - not all in it together with none named. Serious problem in lack of support or interest from high level management				X	X																				
Empowering those at most risk. Hold senior staff accountable.				X	X																				
Adequate planning and engaged visible leadership				X						X															
A culture set from the top which sees learning from every near miss as an opportunity not a problem				X																X					
Good safety leadership, ensuring every employee is not only aware of hazards and risks but looking for them and avoiding them, a proper chain of responsibility where managers are watching their staff.				X										X							X				
Management and leadership.				X																					
Make the client responsible and in line for prosecution if it is their pressure that has caused the accident				X			X																		
Design out risk. On large projects, consider the Temporary Works Co-ordinator role as stand-alone rather than as a tack-on to other significant duties.					X						X														
Place responsibility on a single professional, with adequate authority and require that that person assure that adequate care, experience and education be brought to bear. (No harm shall be allow to occur for lack of knowledge, effort and care					X													X	X						
Single point of responsibility in each organisation involved in the design, procurement and construction process - "safety coordinator." Ideally similar to the SER system of design certification, where the individual is personally <i>responsible</i> .					X																				



Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worse case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
Hold people personally responsible-- for every major injury, owners/managers/supers should face criminal charges with real jail time.					X																				
Greater awareness of potential prosecution and accountability within the design/construction team.					X																	X			
Individuals should be held accountable for their actions.					X																	X			
Communication and joint working between all parties on projects, with a commitment to individual and collective responsibility for safety.					X									X											
Define responsibilities clearly (instead of trying to make everybody responsible) and have one level of independent scrutiny.					X																				
Develop a caring awareness that we are an industry that provides a service to people.						X																			
I have been on sites worldwide with 7 deaths generally due to bravado. I was a H&S consultant for 4 years - CDM was ineffective with no backup and lots on board for no intelligence money making. Real lateral thinking using experience is needed on all projects.						X																			
Reiterate personal responsibility and the need for common sense. A receptive environment for people to report concerns.						X																			
Good procedures will resolve such issues ahead of such occurrences. Much though depends on the attitude of the contractor. The exercise must look at the tier of building being undertaken by companies with an annual turnover below £100m						X																			X
Always work safely.						X																			
There is no single thing - in my experience it is the culture of people always being aware and thinking about H&S that prevents catastrophes. This culture exists because of the sum of all the individual things that promote health and safety - so it's important						X																			
Culture change at workforce level.						X																			

Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worse case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
A better understanding from ALL parties on site, of their roles, responsibilities and risks before carrying out an operation. A change of mindset that taking a risk to get the job done isn't worth it.						X																		X	
Shared learning / better publicise the incidents which do occur. Encourage a questioning approach. Chartered Institutions should discipline practitioners who will not acknowledge mistakes can be made.						X														X					
Set realistic time frames for projects that allow proper planning and re-consider areas such as L & AD's, pain and gain clauses that can put unreasonable pressure on contractors to take unacceptable risks.							X	X		X															
Good, thought through design having eliminated risk - combined with a detailed conceptual plan of how the structure will be constructed. Once this has been produced, a fair contractor appointment process that ensures sufficient funding has been built into the process for a safe time to construct, safe methods to be employed and training for all those involved in the construction process on site - ensuring only competent personnel are employed to undertake tasks on site.							X				X														
Impress on Client Organisations that irrational programming looks great on paper but carries serious safety consequences.							X																		
Use forms of contract where contractor and specialists involved at a very early stage in order that all parties can identify and eliminate hazards and risks.							X																		
Promote a 2 stage tendering process to Clients to allow experienced contractors into the design team at an early opportunity.							X																		
procurement methods that allow collaborative working so that all can share information and address risk.							X																		
Procurement routes by clients need to take account of the type of project and focus on many aspects. There tends to be an emphasis on cost over other differentiators.							X																		
Educate people continuously and remove safety costs from the assessment of tenders.							X											X							

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Joint training courses. i.e. architects, designers, constructors share at least part of their courses together and more site visits. Better representation from clients i.e. clients too powerful forcing prices down and shortening programmes.							X												X						
APPROPRIATE FUNDING, TRAINING AND REGISTRATION OF SUBCONTRACTORS (NOT cscs)							X											X							
H&S should be legally established as a separate % budget set for all tenderers, divorced of the technical submission ie. say a minimum of 2-5% of the project value, calculated on the basis of risk assessment by the Client. Tender bids would then be only completing on technical ability and commercial aspects of this in the reassurance that H & S is already adequately budgeted for. Also more accountability on Clients, Designers CDMC's and Delivery Partners needs to happen.							X															X			
Severe consequences that can really be applied would, I believe, drive improvements in independent oversight of the entire process: Budgeting, Tendering, Design, Planning, Resourcing, Execution.							X									X									
Clients taking proper responsibility for their actions. I have not yet seen a client prosecuted under CDM 2007.							X																X		
All projects should be collaborative, starting with meaningful client briefings and knowledge sharing. Client must take advice and not assume that he knows best.							X																		
Clients should fully understand the implications of their projects and should ensure the budget, programme and contract strategy reflects the demands/significance of the project.							X																		
Client expect work to be completed far too quickly often with little time for proper consultation and design consideration.							X																		
Competent management, with adequate resources, including time.								X	X													X			
Adequate time, money and resources available.								X	X																

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Reduce overburdening time and money pressures on design staff created by senior management striving for commercial success on the slimmest of margins.								X	X																
Sensible time periods both for design and construction. Experienced, competent people carrying out the work. Right price for the project to avoid cutting corners to save money.								X	X												X				
A better balance between programmes, cost and checking.								X	X						X										
Take more time to think carefully.								X		X															
Allow sufficient time at each stage of the project.								X																	
Allow sufficient time to consider the risks and engage knowledgeable qualified persons to review.								X							X										
The right people with adequate knowledge and time is the key ingredient to ensuring effective management.								X													X				
Ensuring people have sufficient time to do the job, whether the design, or the construction.								X																	
Having competent, well resourced and managed staff who have the time to undertake the task they are being asked to do.								X													X				
jobs should be slowed down as the rush of programmes and deadlines cause more problems and accidents than anything else.								X																	
More attention given to ensuring a realistic and therefore safer time window for all contractors working on a construction site.								X																	
Realistic timescales both at design stage and post contract award.								X																	
Safety is of high importance. But time scale often drives the risk of cutting corners.								X																	
Sensible timescales at the design and construction phases of a project.								X																	

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Construction Managers for all contractors should be incentivised for safety above all other motivators; i.e. profit should be weighted below safety in the actual rewards system. In most companies profit is 'king' and this is reflected in behaviours.									X																
Adequate resources to manage all aspects of the site team.									X																
In my opinion the underlying cause will always go back to financial constraints.									X																
Better Planning										X															
Better planning, cooperation and pre-task inspections.										X			X										X		
Considering appropriate means of escape. Better procedures & better designed storage area.										X													X		
Detailed planning of works should be undertaken which involves those directly undertaking the works. Where this is not practical (in many cases it won't be) there should at least be a detailed briefing with those undertaking the works.										X															X
Better planning and preparation to realistic timescales.										X															
Good site prelim discussions with clear duties allocated.										X															
Good well thought out planning.										X															
Plan more										X															
Plan, gather information, evaluate risks and make sure the information reaches the right people.										X				X											
Planning										X															
Planning and resourcing reviews with others outside the project team prior to high risk operations.										X															
Proper and timely planning and assessment by experienced personnel followed by strict management protocols undertaken during site process.										X														X	

Above all else, what should be done to prevent catastrophes in construction?	safety risk management	Think 'worse case'	Overview essential	Leadership	Accountable 'designated' persons	Culture	Client issues & Procurement	Resources - Time	Resources - Money	Planning	Design	Manage change	Collaboration / coordination	Communication	Checking / detail	Independent review	Independent site inspections	training	Education / universities	Feedback / learning	Competence	Regulation / HSE / Campaigns	Supervision / site control	Site management systems	Misc
The seven P's always! Proper preparation and planning prevents pp performance!										X															
Robust Planning and control of sub contractors. Behavioural attitude training. Management adhering to the systems which are in place.										X													X	X	
Those in the industry planning and managing construction works.										X													X		
Detailed prior planning.										X															
Designers considering the constructability and installation of equipment and the structure.											X														
Good design and frequent site inspections by experienced personnel.											X						X								
Have robust buildable designs that reduce risk upfront.											X														
Designers should be more aware of the temporary supports and arrangements necessary for construction rather than focussing purely upon the finished design and leaving 'temporary works design' to the contractor. Ad-hoc on site design/method statement change											X													X	
Client to pay for evaluation of design principles through design teams and again prior to starting construction on site to ensure designs a robust and risks fully identified											X														
Site briefing by designers.											X														
Proper design resources, independent checking of design (other than very minor structures), proper independent supervision on site.											X				X								X		
More design reviews											X														
All designers should have a fundamental knowledge of how buildings are constructed and should fully appreciate the impact of their designs on the safety of people. This knowledge should begin at the very start of the designer's education.											X								X						

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Better training of site management team and most importantly better understanding by designers of the CDM Regs.											X							X							
Training, Training and more training for designers.											X							X							
Full implementation of CDM 2007 regs.											X														
More frequent site visits & inspections by HSE & BCO, and more in-depth scrutiny of the designers actions in reducing or removing hazards.											X											X			
Overhaul CDM regs, give more power to the CDM-C, take more enforcement action against designers, better regulation processes that are more likely to give risk to major catastrophes.											X	X										X			
The CDM 2007 Regulations with regard to designers responsibilities should be more fully implemented and more aggressively checked and actioned by HSE.											X	X										X			
Client, CDMC and Designer responsibilities for design enforced.											X	X													
It should become law that a project does not commence on site without a fully coordinated and integrated design which has been verified by building regs (properly).The procurement world is driving a culture that makes our industry start on site with 80% of the design still to be done by subcontractors. This is wrong.											X											X			
An experienced person should review and take responsibility for the design.											X										X				
Principal Contractor & Designers to take more responsibility for safety during construction. Frequently lip service is paid to this by both parties, often this is due to unrealistic programming.											X												X		
For some types of important temporary works there should be a register of approved Temporary Works designers.											X														
Clear communication of design intent to site team and ensure everyone involved understands risks and limitations of the design.											X		X												

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Behaviours in project teams should change so that all proposed changes to a design for temporary works are properly checked and approved.												X													
More training. Higher quality personal development project. More apprentices - gain experience. Improved and clearly identified communication links and responsibilities. STRONG CHANGE MANAGEMENT PROCEDURES.												X						X			X				
Clarity and agreement on how we manage changes to the work, and when the rules do not fit- ie the gap between work as imagined and work as performed.												X													
If a hold is enforced when something unplanned occurs however insignificant it may appear to be then we may eliminate the majority of failures.												X													
Mandatory site co-ordination, checking and tool box talks involving the construction specialists in conjunction with the designers to ensure the operatives fully understand the risks and control measures that must be implemented.													X		X										
Better collaboration between parties without fear of litigation or claims for extra payment.													X												
Assistance. Never one individual to blame. Sites need more supports, no one is an expert in everything.													X												
Training and communication are vital														X				X							
Industry wide Lessons Learnt detailing previous incidents so we can all learn from them and avoid it happening on our projects.														X						X					
Close supervision and genuine communication between supervisors/workers about the real risks involved and their consequences.														X									X		
Good management undertaken by experienced people, communicating with whole project team.														X							X				
Clear lines of communication to ensure risk are understood and actioned/controlled.														X											



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Communication and planning, working in proper sequence of work														X										X	
Communication is vital, now that verbal communication with workers can be impaired, due to difficulty with language														X											X
Everything we do is about effective communication between all parties. If communication breaks down then inevitably there will be problems.														X											
Improvements in sharing of information on outcomes and future prevention control														X						X					
Better communication by ALL parties														X											
Proper handover is required (never happens in my experience) between the design team and the contractors (and subbies) so that the reasoning behind design is understood on site. That way people wouldn't endanger themselves by thinking that there is a cheaper way, when in reality it was discounted on H&S grounds. Working at height seems to be the main issue but I have no idea how we can mitigate that without reducing the height of buildings..														X											
Appropriate Commitment by all parties within Construction Industry including signing up to a Charter which outlines individual authority to stop work at any time to review decisions already processed so the risks can be evaluated.															X	X	X								X
Independent inspection allowance to be identified and ring-fenced by all clients, which must be used to allow interrogation of design teams /contractors and work practices.															X	X	X								
Supervision and inherent checking (i.e. not just as a procedure one has to do) at all stages in the conception, design, tendering and construction.															X								X		
Checking criteria and assumptions.															X										
Design compatible with actual conditions and integrated management.															X										

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Formal checking design reports & drawings in design office and on site.															X										
The only sure means to prevent construction catastrophes is to prevent construction -- which is not an option. To reduce construction risks, I believe that diligent checks of design and field work by qualified people both prior to and during operations is essential.															X								X		
Competent site managers checking work															X						X		X		
DETAILED Method Statements, fully reviewed.															X									X	
Promote the need for 'technical competence and attention to detail throughout the project process.															X										X
'Peer' review of designs / method statements / similar by trained and experienced competent personnel who are independent of the design process - a fresh pair of eyes.																X	X								
Checking of designs/site works by competent persons i.e. chartered/ experienced designers, etc should become a formal legal requirement with drawings/reports signed off.																X	X								
For items that are identified as being high significance have independent review.																X									
Independent body must be included in design stage.																X									
Place emphasis on peer review type procedures and away from box-ticking and form-filling which human nature turns into rubber-stamping.																X									
Core supervision on site through independent bodies.																	X						X		
Supervision on site by independent bodies on a regular basis.																	X						X		
There should be a hierarchy of Chartered Engineers ON SITE with clearly stated responsibilities in a chain of command to ensure the design is safely and appropriately implemented.																	X								

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Education for all levels of personnel involved																		X	X						
Inclusion of Modules of Construction Risks in all training courses. Mandatory training of CDM all levels in industry.																		X	X						
Increase the awareness of those involved in construction of the risk of major catastrophe and provide them with the motivation and skills to limit the risks.																		X	X						
More emphasis on education throughout the industry.																		X	X						
Much better awareness of the risks.																		X	X						
Better training for individuals including a required standard (set by industry &/or legislation) of general HSE training for all operatives.																		X							
Adequate training and supervision. Adherence to site best practices and providing the necessary safety equipment at all times.																		X					X	X	
Better investment in training.																		X							
Training on site and control of personnel allowed to work on site.																		X			X				
Better training throughout industry - more practically minded.																		X							
Ensure that there is sufficient adequately trained staff to successfully carry out the task/project																		X			X				
More supervisor training.																		X							
Need to upskill the industry and better retain competent people. This needs increased application of initiatives such as "Respect for People." The industry must get much better at sharing lessons learned from incidents. Some progress in the work the work of the UK Contractors Group .																		X		X					
Trained & Experienced managers.																		X			X				
Trained and competent people following the processes.																		X			X				

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Get rid of the numerous money making schemes such as CSCS passport for safety and replace with one scheme.																		X			X				
Education in cause and effect. Case studies etc.																				X					
Experienced but, most importantly, well educated site teams.																				X	X				
Improve the communication link between parties in this industry and the universities.																				X					
Reduce the reliance on People with Degrees as they are no match for experience Degree or not.																				X	X				
Honest reporting on Near Misses in Blame Free Culture.																					X				
Better corporate knowledge sharing, training and instruction.																					X				
Educating people with construction responsibilities by examining past failures.																					X				
Learn from the past and learn ' there but for the grace of God! Be aware it really can happen.																					X				
A corporate conscience and memory; learn the lessons of the past.																					X				
Share information so that lessons can be learned from the experiences of others and continuously update the lessons.																					X				
Having engineers in charge of design and construction activities not technicians or accountants.																						X			X
Competence remains the main criteria to ensure people have the option of making the right choice.																					X				
Ensure competent people are employed at all levels form designers to operatives. Ensure operatives are well briefed on risk and method statements prior to commencing a task.																					X				
Have people carrying out jobs which they are competent to complete.																					X				
Improve competence in all levels of supervision and management.																					X				

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Improve people competence.																						X				
Consolidation of the various competence certification schemes.																						X				
Clear accountability and competence of those accountable people.																						X				
Good Management.																						X				
Having competent people involved (Designers & Contractors).																						X				
Thinking, challenging, employ competent people.																						X				
Solid experience on project management.																						X				
Stricter controls.																							X	X		
Improve funding to HSE, more enforcement action required to ensure compliance with current Regulation.																							X			
Legislation to be made clearer although not in a prescriptive way as people won't think.																							X			
Enforcement of regulations!!																							X			
Strengthening of CDM Regulations.																							X			
Clear direct supervision at ground level upwards.																								X		
Ensuring good management.																								X		
Reduce paperwork on site to allow more time for adequate supervision of the works.																								X		
Sensible programming and good site management with relevant experience.																								X		
Statutory maintenance plans of site plants .																										X
A Principal Contractor 100% responsible needs to be appointed.																										X
Do not be complacent.																										X

## 7.5.4 Comparison of control factors to reduce catastrophic events

A comparison of the data gathered from the ranking of the 17 prescribed control factors (Table 7.5) and the free text replies shown in tables 7.6 and 7.7 is shown in Table 7.8.

This leads to ten summary themes, namely:

1. People
2. Interfaces, teamwork and coordination
3. Hazard and risk management
4. Design and preconstruction planning
5. Checking and review
6. Change management
7. Project management, procurement and resources
8. Site management and supervision
9. Information and communication
10. Legislation and codes

### *People*

Having good people (i.e. competent, motivated people) involved and available was the first ranked control factor to reduce or prevent catastrophic events, rated considerably more important than the other factors.

‘Having engineers in charge of design and construction activities not technicians or accountants’

‘Competence remains the main criteria to ensure people have the option of making the right choice’.

‘Improve competence in all levels of supervision and management’.

‘Have people carrying out jobs which they are competent to complete’.

The need for leadership was stressed and skills such as making good quality subjective decisions rather than just blindly applying the rules were identified.

‘Good safety leadership, ensuring every employee is not only aware of hazards and risks but looking for them and avoiding them, a proper chain of responsibility where managers are watching their staff’.

The length of time that a person has worked in the industry (see Section 5) did not seem to have a large impact on how individuals viewed factors influencing catastrophic events, although an analysis was conducted and general differences assessed. The 11-20 year experience group rated the risks highest (average answer of 2.039) while the 6-10 year group rated them the lowest (2.215)

**Table 7.8 Controls to reduce catastrophic events – comparison of prescribed option ranking and open responses**

Effectiveness of controls – prescribed options - ranked (Table 7.4)	What can be done – open response (Table 7.6)	Above all else, what can be done – open response (Table 7.7)
<b>People</b>		
Having good people involved and available (1 <sup>st</sup> tier)	Competence and experience of all involved is essential and currently lacking People need to take responsibility Subjective decisions may still be necessary	Leadership (7) Accountable 'designated' persons (11) Competence (9)
<b>Interfaces, teamwork &amp; coordination</b>		
Managed interfaces, communication and cooperation (2 <sup>nd</sup> tier)	Accidents have multiple causes We need better teamwork, coordination and communication We need to address complications with supply chain – sub & sub-contracting and interfaces	Collaboration / coordination (9)
<b>Hazard &amp; risk management</b>		
Thinking deeply individually and as a team about hazards (2 <sup>nd</sup> tier) Considering risks <i>consciously</i> (3 <sup>rd</sup> tier)	We need to be better at recognising the hazards in the first place We need to deal with unusual hazards We should eliminate the hazard wherever possible We should beware complacency – 'the way we have always done it' We must beware of just 'ticking the boxes' We still need to manage the residual risk We should beware missing the 'big picture' by concentrating only on 'everyday' risk management	Think 'worse case' (7) Overview essential (3) Safety risk management (29)
<b>Design and pre-construction planning</b>		
Applying CDM 2007 principles for risk management (8 <sup>th</sup> tier)	Some designers don't do as much as is needed	Planning (22) Design (27)
<b>Checking and review</b>		
Checking of detail on site (2 <sup>nd</sup> tier) Checking of concepts (6 <sup>th</sup> tier) Checking of calculation (6 <sup>th</sup> tier) Independent review and checking of design within the team (7 <sup>th</sup> tier) Independent certification (9 <sup>th</sup> tier)	We need to check that things are actually done – Review & Monitoring	Checking / detail (4) Independent review (3) Independent site inspections (1)

Effectiveness of controls – prescribed options - ranked (Table 7.4)	What can be done – open response (Table 7.6)	Above all else, what can be done – open response (Table 7.7)
<b>Change management</b>		
Good change management (4 <sup>th</sup> tier)	Removing one hazard may create others and things will change	Manage change (4)
<b>Project management, procurement, resources</b>		
Adequate resource (2 <sup>nd</sup> tier) Sensible programmes, well-managed (4 <sup>th</sup> tier)	We need to face the challenges from other project priorities	Resources – Time (20) Resources – Money (9)
<b>Site management and supervision</b>		
<i>Sensible programmes, well-managed (4<sup>th</sup> tier)</i>	We still need good supervision	Supervision / site control (8) Site management systems (6)
<b>Information and communication</b>		
Managed interfaces, communication and cooperation (2 <sup>nd</sup> tier) Good management of information (4 <sup>th</sup> tier) Adequate access to knowledge (especially records) (4 <sup>th</sup> tier)	More advice is needed We need better teamwork, coordination and communication	Communication (7) Feedback / learning (3)
<b>Legislation and codes</b>		
Our legislative framework (10 <sup>th</sup> tier)	Using engineering judgement and compliance with existing codes and advice is important	Regulation / HSE / Campaigns (9)
<b>Miscellaneous</b>		
Following good practice for normal situations (5 <sup>th</sup> tier)	<i>Not specifically identified</i>	<i>Not specifically identified</i>
<i>Miscellaneous (Not in pre-chosen list)</i>	We need clients to fulfil their role effectively	Client issues & procurement (19)
<i>Miscellaneous (Not in pre-chosen list)</i>	Small projects have some special challenges	<i>Not specifically identified</i>
<i>Miscellaneous (Not in pre-chosen list)</i>	<i>Not specifically identified</i>	Culture (10)
<i>Miscellaneous (Not in pre-chosen list)</i>	<i>Not specifically identified</i>	Training (8) Education / universities (5)



There were subtle differences amongst the lowest represented groups. When the job type factor was analysed, interestingly, clients (1.997) and operatives (1.957) viewed the risks as most severe while the insurance sector (2.217) viewed it as least severe.

While the differences were relatively small, more experience seems to result in more respect for the controls in place to reduce risk with the 20+ group scoring the controls highest (1.757).

Once again analysing for the job type factor yielded some interesting results as the insurance respondents scored the controls as least effective (1.857). Operatives scored the controls as most effective (1.510). These two results take on more significance with the knowledge that the other groups all scored the controls between 1.723 and 1.796.

### ***Interfaces, teamwork and coordination***

Many projects are complex, requiring effective teamwork, careful management and coordination of the interfaces between organisations and cooperation between all parties. The culture of sub and sub-subcontracting must be understood and the challenges addressed.

*‘Mandatory site co-ordination, checking and tool box talks involving the construction specialists in conjunction with the designers to ensure the operatives fully understand the risks and control measures that must be implemented’*

### ***Hazard and risk management***

Many of the respondents’ comments can be summarised as effective safety risk management - the promotion of a culture of systematic hazard recognition and risk management. The application of a risk hierarchy of eliminate first was evident. But there was also a particular emphasis on the need for an overview and to consider what is the worst thing that could happen.

The online survey asked respondents several questions related to the general consideration of risk throughout the industry, and whether they knew of organisations that seek to actively raise awareness of risk management issues. Respondents were first asked: “Do the risks of major accidents get considered by a formal hazard elimination and risk reduction process?” Response options were always, sometimes or never.

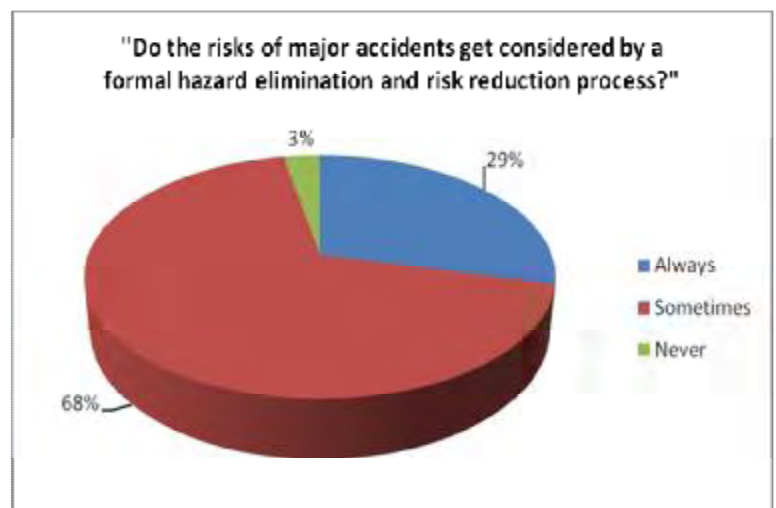


Figure 7.2. Formal hazard elimination and risk reduction process

Figure 7.2 shows that of the 299 active responses, very few considered that the risk of major accidents was *never* considered, with most claiming sometimes (68%) or always (29%) When further asked whether “people actually try to *eliminate* hazards?” around three quarters of the sample (216) considered that people did; and an overwhelming majority (279 of 299) suggested that when construction involves a major risk such as a risk to lots of people, that extra precautions should be taken.

‘There should always be a systematic and formalised assessment and management of risk on construction projects’

‘Awareness of risks by open and frequent discussion. Don't ever think processes or legislation will prevent them’

### ***Design and preconstruction planning***

Surprisingly, applying CDM 2007 principles for risk management was only ranked 15<sup>th</sup>, however, there were 27 mentions of design and 22 of planning actions identified as priorities for controls to reduce catastrophic events. Surprisingly, applying CDM 2007 principles for risk management was only ranked 15<sup>th</sup>, however, there were 27 mentions of design and 22 of planning actions identified as priorities for controls to reduce catastrophic events. Checking of designs and design reviews were also identified. Design included temporary as well as permanent works.

‘Design competence is crucial in every aspect, and being able to interpret designs is of equal importance. Value engineering often is the root cause of failures where designs are not re-evaluated, simple altered, and construction needs to pay more attention’

Design out risk. On large projects, consider the Temporary Works Co-ordinator role as stand-alone rather than as a tack-on to other significant duties’

Good, thought through design having eliminated risk - combined with a detailed conceptual plan of how the structure will be constructed. Once this has been produced, a fair contractor appointment process that ensures sufficient funding has been built into’.

### ***Checking and review***

Checking and review activities were included in several of the prescribed optional controls in the on-line survey. Full reviews as well as more limited scope checks were deemed essential, both those by in-house teams as well as those by independent inspectors. The lack of independent reviewing seemed to be a particular point of concern for many respondents.

### ***Change management***

Part of the complexity of construction projects is because things are often changing, sometimes due to circumstances beyond the control of all the project stakeholders and sometimes caused by brief changes, design adjustments or incorrect work done on site. Effective management of change was seen as essential, because, as details and methods change so do the hazards.

*‘Behaviours in project teams should change so that all proposed changes to a design for temporary works are properly checked and approved’.*

*‘Clarity and agreement on how we manage changes to the work, and when the rules do not fit- ie the gap between work as imagined and work as performed’.*

### ***Project management, procurement and resources***

The need for adequate resources, such as time and money were frequently cited as essential components in reducing major hazards. It was felt that project teams need to face the challenges of conflicting project priorities.

*‘Realistic timescales both at design stage and post contract award’.*

‘Jobs should be slowed down as the rush of programmes and deadlines cause more problems and accidents than anything else’

‘More attention should be given to ensuring a realistic and therefore safer time window for all contractors working on a construction site’

‘Having competent, well resourced and managed staff that have the time to undertake the task they are being asked to do’.

### ***Site management and supervision***

Even if all the previous controls are in place, respondents argued that good site management and supervision was still required. There was also considerable overlap here with the checking theme.

‘Close supervision and genuine communication between supervisors/workers about the real risks involved and their consequences’.

‘Clear direct supervision at ground level upwards’.

### ***Information and communication***

The on-line survey showed that communication was key to improving the effectiveness of controls. But it was also emphasised that the information that was communicated and its management were also crucial. Respondents argued that more advice was needed; access to the knowledge should be improved and we should ensure that we learn from our mistakes through feedback from real incidents and near misses<sup>1</sup>.

‘Industry wide Lessons Learnt detailing previous incidents so we can all learn from them and avoid it happening on our projects’

This aspect was picked up in additional questions regarding SCOSS<sup>2</sup> and CROSS<sup>3</sup>. Respondents were asked: “Are you aware of the work of SCOSS (Standing Committee on Structural Safety)?” and “Are you aware of the work of CROSS (Confidential Reporting on Structural Safety)?” (Figure 7.3).

It was notable that a high proportion of respondents had no knowledge of either SCOSS (54%) or CROSS (62%) with only a small proportion having a detailed knowledge of either organisation.

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<sup>1</sup> ‘Near miss’ should in the context of this report perhaps be ‘near hit’ or ‘near accident’.

<sup>2</sup> SCOSS - the Standing Committee on Structural Safety - is an independent body established in 1976. It is supported by the Institution of Civil Engineers, the Institution of Structural Engineers and the Health and Safety Executive to maintain a continuing review of building and civil engineering matters affecting the safety of structures.

<sup>3</sup> CROSS (Confidential Reporting on Structural Safety), a more formal system to obtain additional data on trends in failures (and potential failures) was launched in 2005. In a similar vein to SCOSS, CROSS aims to improve structural safety and reduce failures by using confidential reports to highlight lessons that have been learnt, to generate feedback and to influence change

Incident reporting is a central strategy for improving safety in the construction industry. Incident reporting schemes are socio-technical systems and every such scheme is different in implementation and use. SCOSS and CROSS use reports on the concerns of engineers and other industry professionals for the benefit of the public and practitioners in the construction industry.

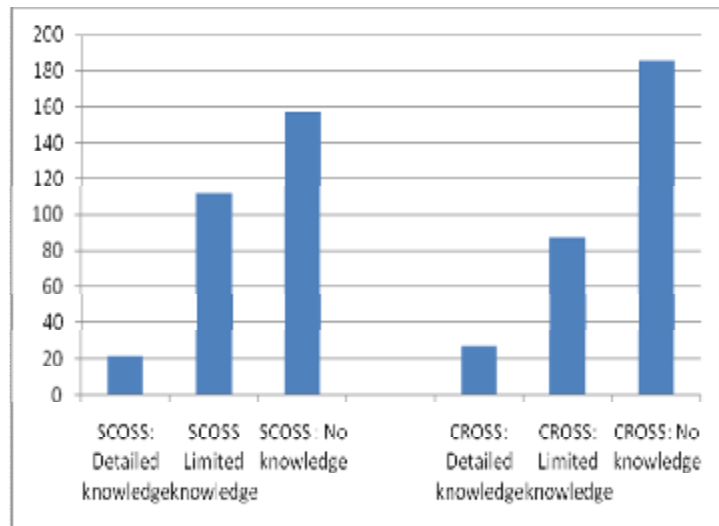


Figure 7.3. Recognition of the work of SCOSS and CROSS

The lack of incident reporting systems, particularly the lack of definition regarding the scope and nature, is a major barrier to extrapolating meaningful data at a national level. Without the recognition provided by reporting systems such as CROSS (see Glossary), hazard potentials can be overlooked.

### *Legislation and codes*

The legislative framework was ranked as least important as a control factor. However, generally, the need to be aware of and work to the appropriate codes and requirements was raised and there were a number of mentions of the role of the HSE.

‘Improve funding to HSE, more enforcement action required to ensure compliance with current Regulation’

‘Legislation to be made clearer although not in a prescriptive way as people won't think’.

## 7.6 SUMMARY

The Industry Survey was successful in attracting approximately 700 respondents. Although 350 completions give an active response rate of 50%, which is reasonable, there are concerns about the groups with low response (client, insurance sector and operatives). However the sample were well qualified in experience with a majority (55%) having more than 21 years experience in the industry.

In considering the results, it should be noted that role and length of experience were not of major significance; hence, results are mainly presented for the totality of respondents, although some differences are highlighted.

The most significant factor in major hazard events was the *failure to recognize hazardous scenarios and influencing events*. Other important factors included: lack of site control, interface problems between the various parties, lack of checking and competent reviewing and a lack of designers’ involvement on site.

Most of the factors considered were seen as having a significant impact, although there was somewhat less concern about: over-reliance on codes; underfunding; vandalism or malicious act; over-reliance on software analysis which cannot be easily verified – and legislative framework.

Client and operative response gave a higher average level of concern and insurance lower than average, but the size of sample for these groups is too small to rely on this result.

The most effective control in reducing catastrophic events was ***having good people involved and available***. Other significant controls were: deeply thinking as an individual and as a team about hazards; managed interfaces, communication and cooperation; adequate resources; and checking of detail on site. Most of the controls considered were seen as having a significant part to play, although 'legislative framework' was seen as less effective than other controls.

Although few respondents (3%) considered that the risk of major accidents was *never* considered, a high proportion (68%) said that they are only *sometimes* considered. However, 72% of respondents said that people do *try* to eliminate hazards. There was overwhelming support (93%) for the proposition that, where construction involves a major risk such as risk to lots of people, extra precautions should be taken.

Whilst learning from incidents and the need for better communication was identified, it was notable that a high proportion of respondents had no knowledge of either SCOSS or CROSS and their work in collating and making such lessons available.

The respondents' view on causal factors for catastrophic events can be grouped as

- § Client and procurement issues
- § Overall management issues
- § Design issues (permanent and temporary works)
- § Checking and review issues
- § Site management and worker issues

Key control factors to prevent or reduce catastrophic events can be grouped under the following headings:

- § People
- § Interfaces, teamwork & coordination
- § Hazard & risk management
- § Design & pre-construction planning
- § Checking and review
- § Project management, procurement and resources
- § Site management and supervision
- § Information and communication
- § Legislation and codes

## 8. Case Study Analysis

### 8.1 INTRODUCTION

This section introduces the analysis of 62 case studies. It explores potential and actual catastrophic incidents using a case study method and examines the impact, key causative factors and control failures. The research instrument was based around 67 structured questions (two open-ended) which were completed in relation to each case study event.

The analysis focused on critical factors, controls (regulated and management process), additional features (such as whether the work was innovative/complexity/unusual) and how these variables may have influenced the major hazard events or catastrophes encountered. Typically this involved the analysis of the actions of individuals, the system of actions and communication interfaces between groups of people. The individual cases studied were selected based on the availability of access to the levels of information to conduct a thorough assessment of particular incidents; particularly focusing on issues that were fundamental to risk and hazard understanding. This section presents the descriptive statistical findings along with more detailed content analysis of the 62 case studies. The data forms a phase of the inquiry and considers the evidence gleaned from: a review of recent HSE reports; accounts of HSE investigators; firsthand accounts from project teams; and media archives. It complements the online survey (section 7) which evidenced individual perceptions of the construction industry, factors, controls and risk management in relation to major hazard events.

### 8.2 CASE STUDY KEY POINTS

#### **Key points from the statistical data gathered from case studies were:**

The top five causative factors of major hazard events and catastrophes by rank order:

- § Failure to recognise hazardous scenarios
- § Lack of site control
- § Shared ignorance
- § Competence of Principal Contractors
- § Communication and interface problems

The top five control failures which were the most significant were:

- § Deeply thinking as an individual and as a team about hazards
- § Having good people involved and available
- § Managed interfaces, communication and cooperation
- § Adequate resources
- § Checking of detail on site

#### **Key emerging Issues by way of content analysis were:**

**Major Hazard Potentials and Catastrophic events** – The potential for major hazards and catastrophic events warrants conscious consideration as part of the safety risk management process.

**Multiple Causality**– case studies point substantially to a multi-cause model, whereby several failures in the construction process contribute either directly or indirectly to the event. Major accidents potential is increased within practice areas that are highly process dependent and reliant on numerous individuals and organisations (eg scaffolding, see below). As such this increased the propensity for error at any point in the process. Conversely, inherently hazardous activities such

as tunnelling are less disparate; there are fewer interactions between organisations so there are fewer opportunities for multiple causes.

**Failure to recognise hazardous scenarios** – There is a fundamental failure to recognise potential for a catastrophic event, due to the lack of competence of personnel (education, training and experience). This may be due to the lack of understanding that conjoint events (fairly minor triggers) may lead to major hazardous events (multiple causality) coupled with the low probabilities. There are implications at all levels of the industry (top down) from client, designers, Principal Contractors, Main Contractors, subcontractors and site personnel. Where there is ignorance about risk this is often shared throughout the project (shared ignorance).

**Lack of site control (reviewing and checking)** – Risk could have been mitigated for if competent reviewing and checking procedures had been in place. The absence of specific regulations (in the construction industry) specifically drawing attention to the need to address the threat of catastrophic events influences a culture where there is a fundamental lack of checking and review procedures that could encourage the recognition and acceptance of hazardous scenarios.

**Complexity Communication and Interface** – Where hazards had been identified prior to catastrophes, they were often not communicated to other disciplines or organisations within the projects. Construction projects cannot be considered as simple sequential processes and the case study projects featured complex processes operating in highly parallel systems. In recognising complexity, it is vital that effective communication and interfaces between disciplines are managed well.

**People Process Product Factors** – The case studies indicate that no single focus on people, process or product will guarantee the identification and management of major hazards. Where events were seen as attributable to defective products, an underlying link was found in the management or processing of checking procedures and the action of people associated with various tasks. Having good people involved and available, having good processes for checking detail on site and checking the quality and use of products has the potential to eliminate major hazard risks.

### 8.3 INTERROGATION OF CASE STUDIES

Data were collected from several sources including: HSE reports, independent accident reviews, first hand individual accounts of incidents, accounts from HSE investigations; and media accounts from selected industry publications. The information was detailed using a case study interrogation document, which used a series of 67 structured questions to examine each case study in detail (Appendix 8.1). The questioning process assessed the general project details, the hazard event and underlying causes, technical issues and the effectiveness of regulation and control. A series of open ended questions were also used to capture any unique features of the incident.

The broad range of questions included:

§ **Project details**

- Brief description of the project

§ **What happened?**

- Brief description events

§ **Is the actual technical reason for the problem known?**

- Brief description technical reasons

§ **Are key underlying reasons known?**

- Brief description underlying reasons leading to the event

- § **What impact did the triggers have to make this a potential or actual ‘major hazard’ scenario?**
- § **What were the key causative factors?**
- § **What controls *should* have operated but *didn’t*?**
- § **How much did any of the following failures influence the event?**
  - Client deficiencies; failure of the integrated design process; failure of the team; hazards and risks; failure to have experienced personnel; failure of site team; and late design changes
- § **What impact did the following have on the event?**
  - People, process and products

## **8.4 CASE STUDIES BY PRACTICE AREAS AND GROUPS**

Of an initial outline of 120 incidents, enquiries were made for 87 case studies, of which meaningful scrutiny was given to 62. These case studies were then grouped into five broad practice areas for further analysis (*structural collapse of permanent structures; collapse of temporary works; cranes, mobile plant & equipment; sub-terrain activities; and fire*). Table 8.1 shows the number of cases by practice area and group.

Due to the disproportion of case study categories, no statistical significance could be assumed across the case study practice areas. However, a simple measure of central tendency (mean/average) was calculated by assigning numerical values to “High”, “Medium”, “Low”, or “Zero” responses awarded to each question field in order to generate raw score data (High=3; Medium=2; Low=1; Zero=0 respectively).



**Table 8.1: Featured case studies and group frequencies**

Case Study Groups by Practice Area	Number of cases [N:62]	
	By Area (n)	Group Total (n)
Structural collapse of permanent structures		14
Bridges	3	
Buildings	4	
Structural collapse during demolition (including refurbishment)	7	
Collapse of temporary works		16
Formwork, falsework, launch gantries, shoring, propping	6	
Scaffolding	10	
Cranes, mobile plant and equipment		9
Tower cranes	7	
Free-standing cranes, piling rigs and other plant inc large MEWPs	2	
Associated sub-terrain activities		16
Tunnelling and groundwork's	10	
Disruption of underground services	3	
Excavations and earthworks	3	
Fire		8

### 8.4.1 Major Hazard Events by Practice Area and Group

A calculation was made of all interrogation questions to determine the distribution and significance of events by practice area and group. Table 8.2 shows the rank order by category and gives the raw score values for the number of causal factors<sup>1</sup>. It was identified that *scaffolding* (n:10) had the greatest number of causal factors in relation to catastrophic events (ranking highest) with *tower cranes* having the lowest causative contributors. Interestingly, a comparison of *scaffolding* (rank 1) and *tunnelling and groundwork* (rank 10) which were practice areas with an equal number of case study assessments (10), revealed a significant difference in the amount of factors contributing to their relative events. The greater number of factors does not equate to

<sup>1</sup> Questions were scored along a Likert scale (a psychometric scale) which is the most widely used scale in survey research. When responding to a Likert question item, respondents state their level of agreement to the specified statements (Appendix E). In the calculations responses were awarded: High=3; Medium=2; Low=1; and Zero=0. The score is the sum of responses divided by the number of respondents.

equate to the practice area being more hazardous, but suggests that the underlying causality was more complex.

Table 8.2: Outline of case study groups, frequency, score and average values

Case Study Category [N:62]		Causal Factors Total Score	Causal Factors Average	Rank by number of causal factors
Scaffolding	10	833	83	1
Disruption of underground services	3	246	82	2
Excavation	3	237	79	3
Bridges	3	199	66	4
Buildings	4	236	59	5
Demolition	7	409	58	6
Formwork/Falsework	6	340	57	7
Fire	8	356	45=	8=
Free standing cranes & equipment	2	90	45=	8=
Tunnelling and groundworks	10	365	37	10
Tower cranes	7	254	36	11

Several cases involving *scaffolding* attributed problems to new scaffold systems. The cases showed that, notwithstanding the advancements attained in scaffold fabrication, the control over scaffold execution using conventional tube-and-fitting techniques is highly process dependent and reliant on numerous individuals. As such this increased the propensity for error at any point in the process. Conversely, hazardous activities such as groundwork and tunnelling reflected a greater emphasis on the task (i.e. the actual construction) as a major hazard. Sub-terrain activity was more prone to influence from the environment (adjacent buildings and infrastructure) and hazards arising from the environment (ground and or weather conditions). Evidence from the case studies points to the activities themselves being hazardous, inducing varying degrees of ground movement, which caused damage to temporary work structures and/or equipment. An essential element to minimise possible detrimental effects in these cases was the ability to predict the ground settlement profile; as opposed to cases of scaffold activity which relied heavily on abilities to control and manage human processes; and communicate the controls to the different discipline groups.

Examples outlining the complex array of the underlying causes of some incidents include:

***Case study example of Scaffold Collapse*** - During building work two sections of a scaffold loading bay tower approximately 20 meters in height collapsed. The loading bay tower collapsed as a pallet of building blocks weighing one tonne was loaded onto it. The scaffold was a 3 bay

20metre high with a loading bay tower. There was no design for the loading bay tower and the scaffold system was not fit for purpose. The scaffolding was then overloaded. There was insufficient plan bracing and the outer bay was carrying approximately 10 tons of concrete blocks immediately prior to the collapse. The structure had been severely overloaded although a number of factors contributed to the final collapse. The primary factors were failure to appreciate that such a structure would require to be designed; a failure to provide information on the safe loading for this structure; and, a failure to control the loading of material onto the structure.

**Case study exemplifying Tunnelling & Groundwork** - An extension was being made to a city Metro system where the construction was in clay marl which the drawing indicated was “with sand lenses”. Above this level to the road was waterlogged gravel with a high level water-table. The tunnel construction was by the NATM method using spray concrete, with the tunnel diameter of 7m. An additional permanent lining would be put in place inside the NATM construction. The contract drawing clearly showed two things – (a) that the clay marl through which the tunnel was to be constructed did contain “Sand Lenses”, and (b) the contract drawing required a minimum of 1.5m of this clay above the top of the construction profile.

Miners onsite realised that the face being excavated was becoming increasingly unstable and it reached a point at which they had to leave the site. A collapse occurred at the ground level and a bus sank below the groundwater. One worker and three passengers were drowned.

A technical committee found that the primary cause of the instability and subsequent collapse was the transfer of water above the construction works into the face of the tunnel construction. This was attributed to:

- § Lack of risk management – no response when sand/water started to rush in - freezing would have been expensive of course....
- § Designed with low cover; contractor possibly took on the risk without talking about it.
- § No good risk assessment by both designer and contractor. Must have been incompetent people involved to take the risks they did.

Although case studies involving tower crane incidents had a wide range of identified causes, these incidents (*tower cranes n: 7*) ranked lowest of the identified groups in terms of the variety of linked causal factors contributing to the individual hazard event. This suggests that each individual case studied had a limited number of causal factors.

When considered at the grouped level (as Table 8.1), *collapses to temporary works* had the most causative factors along with *sub-terrain activities* as a whole. The areas of practice which fell under the *structural collapse of permanent works* were ranked third; with *cranes* and *fire* ranked lowest out of the groups. Some outline findings are discussed below although the group and practice areas are investigated further later in this section in relation to the individual interrogation questions:

## 8.4.2 Structural collapse of permanent structures

- **Bridges:** Interface problems were a significant factor in bridge failures and added to problems caused by lack of competent review (see Glossary). Thinking deeply as individual and as a team as well as better interface management would make significant improvements to the construction process.
- **Buildings:** Lack of robustness and failure to recognise root causes caused most problems here while better review of design would contribute towards safety on site.
- **Structural collapse during demolition:** Heightened danger led to increased recognition of the fact that the task itself was hazardous. Ignorance, error and failure to recognise hazardous scenarios and influencing factors caused most problems in this group.

### 8.4.3 Collapse of temporary works

- **Formwork, falsework, bridge launching gantries, shoring, propping etc:** Lack of site control and conscious risk taking seemed to be problems here. While there was recognition of the dangerous nature of the task by those involved, it was found that independent review and checking of design within the team, certification of design and construction by an official organisation and better communication and cooperation would all have provided a more effective degree of control.
- **Scaffolding:** Failure to recognise hazardous scenarios was the greatest risk here and played a part in all incidents involving all case study events. Ignorance, error and a lack of competent reviewing also played a significant role. Failing to follow good practice was an important control failure in this category. Considering risks consciously, applying the CDM 2007 regulations and having the good people involved were sufficient controls.

### 8.4.4 Cranes, mobile plant and equipment

- **Tower cranes:** Here there was recognition of a higher level of skill needed to properly execute the task. It was also important to consider the CDM 2007 regulations in more detail and ensure that the equipment is thoroughly examined by a competent person.
- **Free-standing cranes, piling rigs and other plant, including large MEWPs:** Here it was important that good practice and the CDM 2007 regulations were followed as closely as possible.

### 8.4.5 Sub-terrain activities

- **Excavations and earthworks:** The case studies revealed that the checking of calculations was of primary importance in reducing the risk of operations in this area.
- **Tunnelling and groundwork:** Interestingly, there was a certain level of risk that seemed 'acceptable' or, at least, did not seem to be able to be remedied as most causal factors were given a low rating. The controls in place were likewise generally seen to be effective as few were seen as being able to have made a significant difference to the level of risk. This implies that the industry has a challenging risk profile; this conclusion requires further debate.

### 8.4.6 Fire

- **Fire:** Failure to recognise hazardous scenarios was the primary risk leading to fire incidents while underlying lack of robustness also caused problems. Considering risks consciously would have the biggest impact on risk, while correct application of CDM 2007 could have contributed significantly to safety.

## 8.5 WHAT MADE THE CASE STUDIES ACTUAL OR POTENTIAL ‘CATASTROPHIC EVENTS’

The individual cases were assessed to determine the impact of the events and how these contributed to making the incident a potential or actual ‘catastrophic event’ – i.e. Why did interviewees think that these incidents were ‘catastrophic’? Table 8.3 shows the average score<sup>1</sup> for the 62 case studies; and Figure 8.1 shows the percentage of case studies to which each impact was attributed.

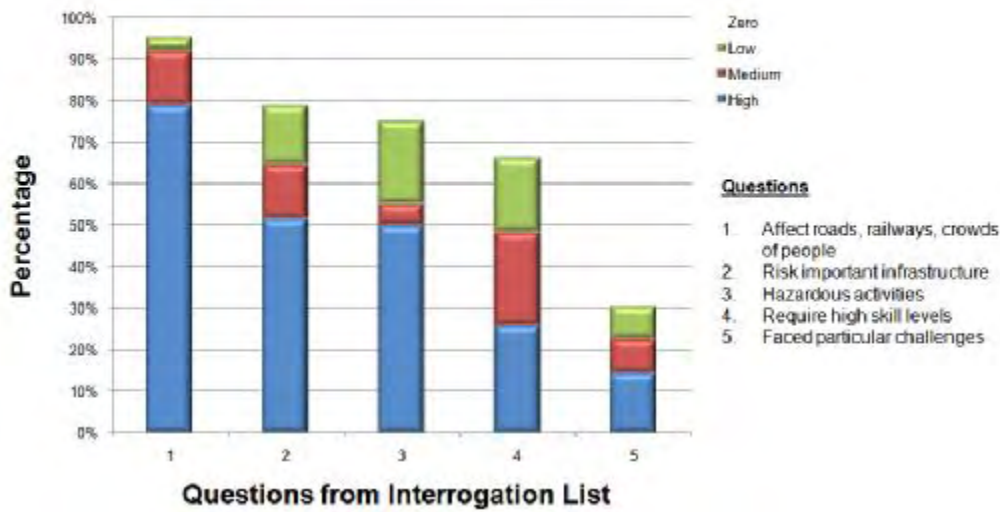
The majority of case studies were seen to be catastrophic when the event involved multiple workers on site or the general public. It was also determined that when an event involved a potential impact on important infrastructure the incident would be elevated to ‘major hazard’ status. These two factors scored significantly higher than the incidents that were considered to involve activities which are recognised as particularly hazardous such as demolition (ranked 3<sup>rd</sup>) and where cases were deemed to require higher levels of skills (ranked 4<sup>th</sup>). In 15% of cases it was seen that the impact of the event was due in particular to the job challenges. Particular construction challenges due to difficult access, soil conditions or weather were considered to be of least impact when determining whether hazards were major or not; although in case studies involving tunnelling and groundwork these challenges were seen to be more apparent. This is unsurprising as factors related to geotechnical conditions often cause of significant time and cost overruns on both large and small scale construction projects.

**Table 8.3: Average scores measuring impact of events**

	H	M	L	Z	Score	Average score
Clearly might affect a public road, railway, crowds of people etc	49	8	2	3	165	2.66
Put at risk important infrastructure or working facilities	32	8	9	13	121	1.95
Involved activities which are recognised as particularly hazardous (such as demolition)	30	3	12	15	108	1.74
Clearly required higher levels of skill than normal	16	14	11	21	87	1.40
Faced particular challenges such as difficult access/soils/water/weather	9	5	5	43	42	0.68

<sup>1</sup> Questions were scored along a Likert scale (a psychometric scale) which is the most widely used scale in survey research. When responding to a Likert question item, respondents specify their level of agreement to the specified statements (Appendix E). In the calculations responses were awarded: High=3; Medium=2; Low=1; and Zero=0. The score is the sum of responses divided by the number of respondents.

### What impact did the triggers have to make this a potential or actual 'major hazard' scenario?



## 8.6 FACTORS AFFECTING CATASTROPHIC EVENTS IN CONSTRUCTION

Case studies were assessed to determine the key causative factors of each event. Table 8.4 and Figure 8.2 show the key scores<sup>1</sup> from the case studies and the relative percentages attributed to the range of causal factors identified.

Table 8.4 shows the rank order of factors. **Failure to recognise hazardous scenarios and influencing factors stands out as a major influence.** In 85% of cases this factor was scored high as a contributor (Figure 8.2).

<sup>1</sup> Questions were scored along a Likert scale (a psychometric scale) which is the most widely used scale in survey research. When responding to a Likert question item, respondents specify their level of agreement to the specified statements (Appendix E). In the calculations responses were awarded: High=3; Medium=2; Low=1; and Zero=0. The score is the sum of responses divided by the number of respondents.

**Table 8.4: Causative factors in case study events**

What were the key causative factors?	H	M	L	Z	Score	Average value
Failure to recognise hazardous scenarios and influencing factors	156	6	1	6	163	2.63
Ignorance, incompetence	114	20	6	8	140	2.26
Lack of checking and of competent reviewing	117	6	0	20	123	1.98
Underlying lack of robustness	99	12	3	20	114	1.84
Error (by people who are competent)	90	22	1	20	113	1.82
Lack of site control	84	18	5	20	107	1.73
Interface problems	69	22	1	26	92	1.48
Poor team-working	66	22	4	25	92	1.48
Lack of experience	51	32	2	27	85	1.37
Design process not effective, not coordinated	63	8	0	36	71	1.15
Drawings not clear, hazards not apparent or highlighted	51	14	4	34	69	1.11
People working in boxes, no-one clearly responsible for providing design overview	42	18	3	36	63	1.02
Conscious risk-taking	30	10	12	35	52	0.84
Ad hoc on-site changes to planned build procedures	45	0	3	44	48	0.77
Design didn't consider/explain how construction could be done	30	16	1	43	47	0.76
Poor management of late changes in build procedures	33	8	2	44	43	0.69
Over-complex procurement with unclear responsibilities	12	12	3	49	27	0.44
Inappropriate maintenance and/or modification of a structure	9	8	6	49	23	0.37
Poor management of late design changes	21	0	2	53	23	0.37
Unreasonable time pressures	6	8	4	52	18	0.29
Underfunding	12	4	1	55	17	0.27
Criminality	6	6	0	57	12	0.19
Over-reliance on codes	6	4	1	57	11	0.18
Over-reliance on software analysis which cannot be easily verified	9	0	1	58	10	0.16
Vandalism or malicious act	6	0	0	60	6	0.10

## What were the key causative factors?

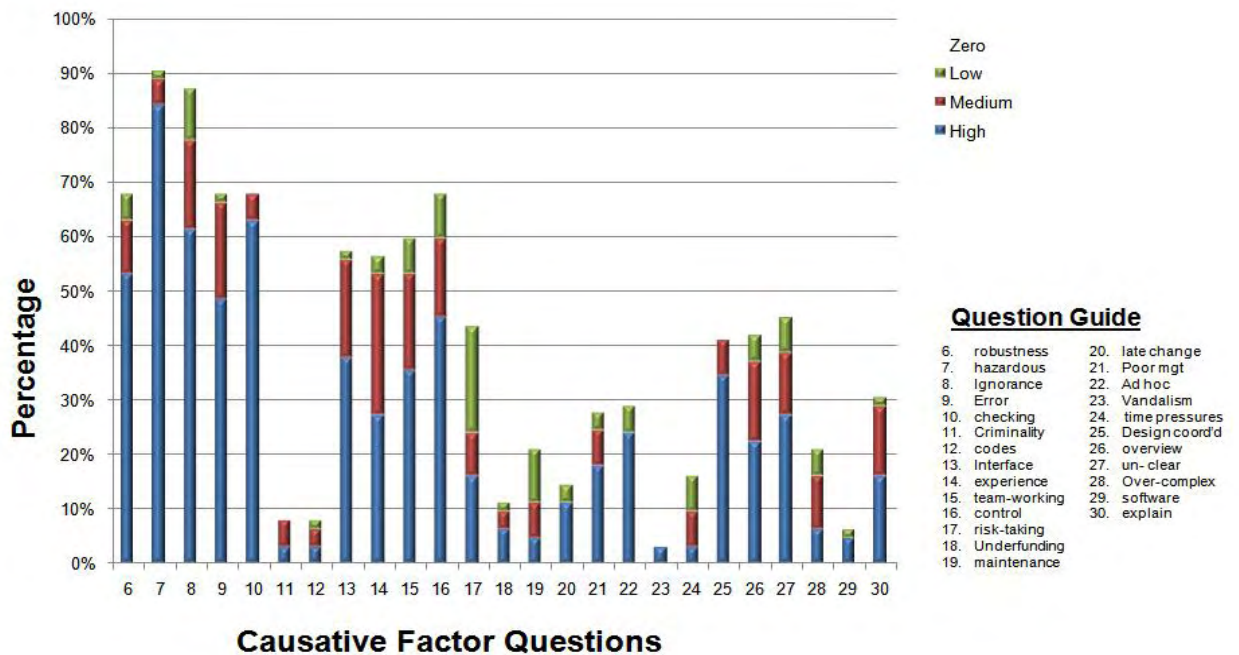


Figure 8.2: Responses to causative factor questions

### 8.6.1 Failure to recognise hazardous scenarios

In 90% of case studies, *failure to recognise hazardous scenarios* was identified as a causative factor, 84% of which were considered to be of high significance to the event. This featured most prominently in cases involving: cranes (both mobile and static); excavation; demolition; formwork and falsework; scaffolding; fire; and disruption of underground services.

**Case studies exemplifying failure to recognise a hazardous situation** - This was evidenced in an excavation at street level for access to break down piles and install shutters for pile cap construction. As part of the process, cables were diverted (offset) in an open excavation by manually displacing them a specified distance out of the way from the proposed pile structure. The offset distance should have been based on the location of the pile cap but instead was based on the pile position. Hence in the excavation for the pile cap there was insufficient work space. The cables were further forced back to allow working space. An explosion of the cables occurred which killed one of the workers in the excavation and could have killed more workers or members of the public.

Moving services, particularly electricity cables, is common practice. However, nobody on site recognised that the cable was already stretched to near breaking point and would not stretch further.

### 8.6.2 Ignorance / incompetence

In almost 90% of cases *ignorance* and/or *incompetence* was identified as a causative factor ranked as of high significance in 60% of cases. This was most significant amongst cases involving excavation, although it also featured highly amongst demolition, falsework, formwork and bridges.



### **Example of ‘ignorance and incompetence’**

In terms of ignorance and incompetence, a particular case study example details where joiners were given responsibility for demolition work and had received no proper training.

In addition to this, the case study identified:

- § Poor weather conditions
- § No proper planning or design for the demolition work
- § Lack of full supervision
- § Worker was not issued with full or proper instruction
- § No proper exclusion area which would contain material

As an outcome of this, a worker later walked into the cordoned-off demolition zone thinking this was part of the worksite and further believing that exclusions were for members of the public. As a consequence a worker was badly injured with possible permanent disabilities.

Specifically, one of the emerging issues that emanates from the case studies is that of *shared ignorance* or ignorance shared among co-workers or between disciplines. This shared ignorance may result from their misinterpretations of data specific to the project, changing work roles or inability to integrate different sets of on the job information into the specific task. The ability to recognise the mistakes made by individuals and rectify them seems to flow through several of the cases studied.

### **Case study exemplifying ‘shared ignorance’**

This was evidenced in a case where a prohibition notice was served during a gas mains renewal works when HSE inspectors noted that there was a lack of adequate support during excavation works. It was adjudged that there were clear potential risks to road users and multi injury potential as plastic trench sheets were used with only two adjustable props to support the excavation mid span. On investigation there was found to be:

- § No client or design level checks
- § No clear design process in place by the contractors
- § Supervisors failed to provide suitable guidance to operators
- § Supervisors and site engineers failed to monitor and control the works
- § Lack of experienced engineers

The evidence drawn from several examples in the case studies suggests that when an individual or project stakeholder (designer, engineer etc.) is unaware of the ignorance they tend not to recognise the liabilities associated with the acquisition of knowledge as the failure evolves. On one particular project the work was relatively routine and was not beyond the capabilities of competent professionals; however the issues of *shared incompetence* were raised as there was a marked failure to recognise obvious signs. Both shared knowledge and shared ignorance (at individual, site and project levels) are representations of what exists and does not exist from past experiences (i.e. in shared memory).

## **8.6.3 Lack of checking and of competent reviewing**

The depth of the implementation of comprehensive reviews and checking procedures (process) was examined in the case studies with a view to making determinations of how these factors may have contributed to events. In the case studies, checking and reviewing covered a wide scope and related to: regulations, technical standards and specifications; design documents for construction drawings; structural safety; and safety in the public interest. 68% of all cases featured *lack of checking and of competent reviewing* as contributing to the range of causative factors. These range of factors were extremely prominent in cases involving *bridges, excavation, scaffolding and disruption of underground services*; however they were also high in cases involving *demolition, building, formwork and falsework, tower cranes and free standing cranes*. In cases involving *tunnelling*, failures of checking and reviewing rarely featured and rarer still in cases involving *fire*.

From this the research could assert that, by group, *collapse of temporary works* ranked highest of cases where *lack of checking and of competent reviewing* contributed to events. *Associated sub-terrain activities* was ranked 2<sup>nd</sup> and *structural collapses of permanent structures* was ranked 3<sup>rd</sup>; *cranes and mobile equipment* 4<sup>th</sup>; and *fire* 5<sup>th</sup>.

#### **Case study exemplifying lack of checking and of competent reviewing**

A case study example described events during the construction of a multi auditoria leisure complex. The event involved the collapse of a false ceiling which was not adequately secured, causing 200 square metres of ceiling (which held the lights and the fire preventing sprinkler system) to collapse in one of the auditoria.

The heavy ceiling was suspended by drop rods fixed to a U section channel system attached to the underside of a composite steel deck and in-situ concrete slab. The design was for each rod to be connected to a nut with a washer over a pre-formed hole in bottom of the channel. In practice the washers were too small; one (or more) pulled through its hole, initiating a progressive collapse of the whole ceiling. The design was considered “unworkable” which resulted in late design changes which were unauthorised.

No one was inside the complex and so there were no injuries although the theatre had the capacity to hold 500 people; and the incident happened only days before the complex was due to open to the public. During subsequent investigations there was no evidence of inspection or supervision of the installation.

### **8.6.4 Underlying Lack of Robustness**

Robustness used in a structural context has a defined meaning. BS EN 1991-1-7 provides one definition of robustness as “the ability of a structure to withstand events like fire, explosions, impact or the consequences of human error without being damaged to an extent disproportionate to the original cause”. In the case study examples “*robustness*” was indeed generally related to robustness as a property of structural systems (stability of structures) that may lead to physical failures. In 68% of cases, underlying lack of robustness was featured as a causative factor to the event, of which 53% were highly significant.

However, it appears that many interviewees typically understood a broader interpretation of the term, especially where they were not from an engineering background. Further examinations uncovered that interviewees used the term robustness to relate to the strength of different regulatory mechanisms and further still to the robustness of procedures, as a framework for management or planning process.

A lack of structural robustness was most prominent in the group of tower crane cases although it also featured highly in cases relating to formwork and falsework, scaffolding and disruption of underground services. Taken from case studies, examples of robustness as a measure of stability were given as:

*“All practicable steps had not been taken to prevent danger of collapse of the excavation and the excavation was not sufficiently supported to prevent danger and suitable steps had not been taken to prevent persons or vehicles falling into the excavation.”*

*“Position of diverted cable not questioned or challenged – contractor self assurance.”*

*“Several failures and under calculations made, which meant that the scaffold system was not tied adequately to the adjacent building.”*

Conversely, in the following case study involving a luffing jib tower crane, robustness related to a system or process was raised:

### **Example of a robustness issue**

Cranes were being used in the construction of the building. The cranes were tied to the building structure and were being extended, by climbing, as the structure increased in height.

As the last tower section was being climbed into the tower of one of the cranes, the climbing frame collapsed with the crane top and three members of the erection team were killed as a result of the 120m fall. Debris from the crane was spread over a wide area although there were few members of the public in the vicinity.

Although in this case study a definitive cause of the failure was not established, various potential contributory factors were found including: inadequate planning and not following manufacturer's instructions. The lack of robustness in question was given as "*lack of effective planning; lack of adequate assessment at product design stage*". These are issues that could be managed on the project if effective design and management processes are in place.

## **8.6.5 Communication and Interface**

Assessed through the interrogation questions, 50% of all case studies featured *interface problems* and *managed interfaces, communication* and *cooperation* between project stakeholders (client, designers, principle contractors, CDM-Coordination, contractors, sub-contractors and workers) as a main contributor to case study events. However on reviewing the qualitative commentary from the open-ended section of the interrogation sheets, the majority of cases had an aspect of *interface* and *communication* which could be cited as an influencing factor. The design and construction process needs to be integrated with several internal processes; it is also dependent on many external stakeholders and their specific activities and demands. In this environment, with short lead times and parallel processes, it is obvious that construction is a highly complex process. It is equally clear that the process is frequently an uncertain process. Furthermore, the current trend towards outsourcing and subcontracting makes this process more complex in terms of design coordination and the construction process itself. Interfaces between the differing organisations and groups of stakeholders are crucial to this process. The case studies uncovered several incidents where a communication and/or interface problem was cited amongst factors.

It is widely accepted that the majority of cost associated with a project is determined during the early phases of the design process. However, during these early phases, the designer may have limited knowledge regarding problems that will be encountered during the construction phase. Thus, the goal is to learn as much as possible about the evolving project as early as possible in the design process, as changes are least expensive during this stage.

The basic decisions concerning stakeholders, requirements, functions and product concepts are made during the early phases of the development process. Thus, a huge amount of information about the evolving project should be generated and must be shared, structured and communicated. It is important to share information between stakeholders about their requirements. However, it is only beneficial if the information is used effectively: within the case studies this was not found to be a straightforward task. The many challenges that were encountered involved getting people from different backgrounds and disciplines to produce and share a common view of the project and the varying risks and hazards. Interpretation of sometimes imprecise information was found to be a challenge for the design team, as too was the understanding of the clients' true requirements and the particular in-situ challenges encountered by Principal Contractors. In addition, the requirements from different stakeholders were sometimes in conflict. These requirements need to be negotiated and product concepts balanced in order to eliminate or mitigate any risks.

### **Case study example of Communication and Interface Problems**

One particular case involved the partial collapse of a rubble retaining wall due to nearby excavation work. During the excavation there was a plan to create a "toe" (that was to be installed) however the structural engineers decided the wall was being undermined in places because the foundations were not as good as first imagined. There was a cracking on the road side which was of concern to the client and engineer, so they had started discussions by telephone regarding shoring of this part of the excavation.

No sufficient risk assessment or method statement had been formulated. Information was not properly communicated to the relevant parties. The interviewee stressed that the above should be undertaken under the direction of a suitably qualified structural engineer.

The foundations of the wall were explored and they were deemed good enough not to sheet pile but, on uncovering the wall, it was discovered that the wall was undermined in areas and the plan to put in the toe was put in place. The client representative and Principal Contractor had been in discussions about putting in shoring to this section because of concerns over the cracking on the roadside. However, the site manager and contracts manager for the groundworks' subcontractors were unaware of any talk of supports being required..

In this particular case, there was a marked failure by the Principal Contractor to communicate with the site manager and the contracts manager.

In order to develop a well-balanced strategy, it is necessary to consider not only the client, but also all the other stakeholders throughout the project life cycle. In all reported cases, a holistic view was needed in order to manage all criteria, considering as many perspectives and interests as possible. A common understanding for stakeholders must be developed, together with the requirements, functions and sub-systems of the project. In this particular case, these were found to be lacking. This had implications on subsequent decision making processes. The interfaces between the client, designer and other groups were not clearly managed in order to balance the varied interests and the related functions.

### **8.6.6 A Note on 'Criminality'**

It is interesting to note that through the case study investigations the issue of *criminality* and an associated item concerned with *vandalism or malicious acts* did not feature highly among responses, being ranked 22<sup>nd</sup> and 25<sup>th</sup> respectively. However, on closer inspection, in half of the case studies there is mention of prosecution (by HSE), and in several cases where there is no explicit mention of an actual prosecution, it would be reasonable to assume that there would be implications for legal recourse (particularly where there had been a fatality). The HSE enforces health and safety legislation for most industry sectors in Great Britain and prosecutes both companies and individuals for breaches of health and safety law. Breaches of legislation on construction sites are legally enforceable and thus by definition can be considered to involve criminality. In this particular study the assumptions (when devising the interrogation instrument) was that *criminality* would be associated with conscious illegal activity such as arson, which accounts for the low ranking as there were few cases of illegality under this definition.

## **8.7 CONTROL FACTORS CONTRIBUTING TO CASE STUDY EVENTS**

The complexity and diversity of construction projects requires control systems to support management and workers within their roles and to increase the efficiency of decisions made at the expense of hazards affecting people (workers and the general public) and the environment. The failure of any construction related controls was examined within the case studies by posing the interrogation question: "What controls should have operated but didn't?" Table 8.5 and Figure 8.3 display the descriptive statistical data gathered.

While score values<sup>1</sup> did not determine that any of the featured controls failures was significantly high, *thinking deeply individually and as a team about hazards, considering risks consciously, having good people involved and available (knowledgeable, trained, etc), following good practice for normal situations, applying CDM 2007 principles for risk management; and managed interfaces, communication and cooperation*, featured prominently amongst this series of interrogations.

*Considering risk consciously* had the highest overall percentage of 83% compared to *thinking deeply individually and as a team about hazards* which had 81%, the latter had 72% scoring as a “High” failure compared to the former which had 62%.

Lowest amongst these interrogations were: *adequate resources; management of late changes in build procedures; management of late design changes; and our legislative framework*.

### 8.7.1 Thinking Deeply as a Team

There are many physical, organisational and interpersonal interfaces on most construction projects, requiring teams of individuals to combine and integrate their input. Therefore it is important that mechanisms for effective communication between disciplines and teams are established so that risks and hazards can be indentified and addressed in a suitably ‘joined up’ manner.

*Thinking deeply and as a team about hazards* was a prominent control failure in 71% of all cases, with 61% being at a high level. Amongst this series of interrogations, areas that featured prominently were: *bridges; demolition; excavation; and fire*, with all cases within the group given a “High” in terms of control failures.

#### **Case study exemplifying failure to ‘Think Deeply as a Team’**

Reports into the collapse of a bridge attributed the failure to two causes; the structural design by designers and an unusual method of erection by the contractors. On the day of the collapse there was a difference in camber of 11.4cm between two half girders at middle of the span which needed to be joined. It was proposed that the higher one be weighted down with 10 concrete blocks, each 8 tonnes, which were located on site. The weight of these blocks caused the flange to buckle, which was a sign of structural failure. The longitudinal joining of the half girders was partially complete when orders came through to remove the buckle. As the bolts were removed the bridge collapsed.

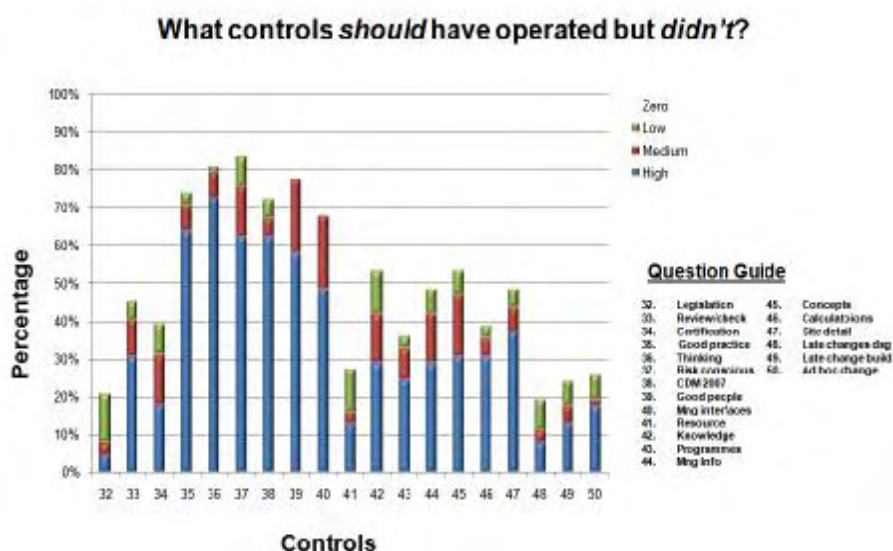
There was no sudden onslaught of natural forces, no unexpected failure of new or untested material. The reasons for the collapse were identified in the failures of the teams who designed and built the bridge which was considered to be of a new and highly sophisticated design. The various companies who supplied the materials used were not shown to be in any way at fault. However, among those engaged in the design and construction there were mistakes, miscalculations, errors of judgement, failures in communication and general inefficiency. It was adjudged that to a greater or lesser extent, the designers and the contractors, engaged in the work were all at fault.

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<sup>1</sup> Questions were scored along a Likert scale (a psychometric scale) which is the most widely used scale in survey research. When responding to a Likert question item, respondents specify their level of agreement to the specified statements (Appendix E). In the calculations responses were awarded: High=3; Medium=2; Low=1; and Zero=0. The score is the sum of responses divided by the number of respondents.

**Table 8.5: Controls failures contributing to catastrophic events**

<b>What controls <i>should</i> have operated but <i>didn't</i>?</b>	<b>H</b>	<b>M</b>	<b>L</b>	<b>Z</b>	<b>Score</b>	<b>Average value</b>
Thinking deeply individually and as a team about hazards	135	8	1	12	144	2.32
Considering risks consciously	114	16	5	10	135	2.18
Having good people involved and available (knowledgeable, trained, etc)	108	24	0	14	132	2.13
Following good practice for normal situations	117	8	2	16	127	2.05
Applying CDM 2007 principles for risk management	114	6	3	17	123	1.98
Managed interfaces, communication and cooperation	90	24	0	20	114	1.84
Checking of concepts	57	20	4	29	81	1.31
Checking of detail on site	69	8	3	32	80	1.29
Adequate access to knowledge (esp. records)	54	16	7	29	77	1.24
Good management of information	54	16	4	32	74	1.19
Independent review and checking of design within the team	57	12	3	34	72	1.16
Checking of calculation	57	6	2	38	65	1.05
Sensible programmes, well-managed	45	10	2	39	57	0.92
Independent certification of design and construction by an official body	33	16	5	37	54	0.87
Prevention of ad hoc on-site changes to planned build procedures	33	2	4	46	39	0.63
Adequate resource	24	4	7	45	35	0.56
Management of late changes in build procedures	24	6	4	47	34	0.55
Management of late design changes	15	4	5	50	24	0.39
Our legislative framework (if so, why?)	9	4	8	49	21	0.34



**Figure 8.3: Failure of control systems contributing to catastrophic events**

## 8.7.2 Considering Risk Consciously

The case studies highlighted that success on construction projects was enhanced when all involved on a projects were aware of the risks which existed and acted accordingly. Where individuals and organisations had planned for major hazards, the likelihood was that hazards would be eliminated or the risks mitigated.

The research identifies that major hazard events are often considered to be a low probability even though the inevitable consequences are high. On many of the case studies, risks were not mitigated in advance even when there were clear risk indicators. 82% of cases identified *considering risk consciously* as an issue. *Fire, excavation and disruption of underground services* featured prominently in these interrogations although *demolition, scaffold, and formwork/falsework* featured moderately.

**Case study exemplifying *Considering Risk Consciously*** – This comprised the construction of five new blocks of timber framed apartments and retail units but also refurbishment to existing buildings. A fire originated on two of the newly constructed buildings but spread to the refurbishment areas, completely destroying all new blocks and damaging all surrounding buildings. Despite previous well publicised incidents involving timber framed buildings, the work programme appears to have ignored the high fire hazard. It is suspected that the fire was caused by the careless disposal of smoking materials in an area of highly flammable waste materials. Although this was considered to be the fault of operatives on site and their failure to consider the risk of fire, there were several flaws established in the overall consideration of risk by designers, Principal Contractor and other contractors.

The risk of fire development (rapid spread) was not considered consciously as the designs should have incorporated a degree of fire containment by compartmentation. Verbatim comments emphasised the following flaws:

*“Lack of compartmentation between completed stairwells and flammability of construction materials.”*

*“Risk Assessment was in place - however, it proved to be neither suitable nor sufficient”*

*“Lack of appreciation of the vulnerability of the building at that stage of construction and lack of control of ignition sources”*

This incident appears to highlight the need for recognition of the major hazards and proactive management in order to encourage risk reduction.

In the majority of these cases it was reported that individuals on construction projects only considered risks consciously when explicitly made aware of hazards. These case studies also suggest that hazard identification and reduction occur far more often than hazard elimination; which involves informal engineering judgement where there are no specific instructions issued at the design stage. In this respect risk assessment becomes more of a formal “tick box exercise” although many individuals do not have the explicit competence to make informal risk assessments or to drive preventative measures forward.

### 8.7.3 Having good people involved and available (knowledgeable, trained, etc.)

In 78% of cases it was considered that having good people involved on the project and available at the time of construction was an important control for avoiding incidents. This concerned the presence on site of knowledgeable, fully qualified, trained and competent individuals who could recognise and act upon any hazards (and their attendant risks) involved in the various construction practices. The range of issues was considered most prominent in cases involving *demolition, scaffolding, excavation, and tower cranes*. The most prominent issues amongst this range of cases were, lack of *effective planning, including contingency planning*, lack of *qualified personnel on-site*, having *inexperienced people involved* and *training of personnel to follow manufacturer’s instruction*.

These issues were found at a moderate level where cases involved *formwork and falsework, free standing cranes, building work and tunnelling and groundwork*; although they were identified much less frequently in cases involving *fire, disruption of underground services and bridges*.

**Case study exemplifying having good people involved and available (knowledgeable, trained, etc)** - During the construction of a school, two tower cranes had been erected on site. A crew of three from the tower crane supplier were carrying out work on one of the tower cranes in preparation for dismantling, which was due to start on the following day. The erection supervisor had called in sick; however the contractor had no outlined contingency planning for sickness. Two experienced erectors were working on the front jib of the crane removing the trolley rope whilst a third untrained man was loosening the tower bolts. This was achieved by slewing the counterweight of the crane over one side of the tower to compress the joint and make it easier to loosen the bolts. Unfortunately the third man, instead of just reducing the preload in the bolts, undid the bolts until just two or three bolt threads were engaged with the nuts. When the counterweight was slewed through 180° all the movement was taken by the remaining bolts. These failed through overload and the crane collapsed, striking the jib of the remaining tower crane. The two men on the front jib were killed, whilst the third man in the tower was injured. Fortunately the crane collapsed at a time when most of the site personnel were taking their morning tea break so there were no more casualties.

There was also a lack of understanding by the third man (due to inexperience) and he had been ineffectively briefed as to the risks involved. In this particular case the main causes of the incident were considered to be a lack of contingency planning (having good people involved and available); and inadequate planning, inadequate training and supervision. This case study suggests causal factors including the erection supervisor being off sick and the remainder of erection team left to get on with the job

Examples in the case studies point to annual leave, sickness or *leaving the site early*. Contingency plans should have existed to minimise the damage when problems do occur. A contingency plan can be formulated by consciously considering the hazards and their attendant risks which might have a negative impact on a construction project. Scheduled annual leave or sickness of key personnel on-site primarily has the potential to impact construction operations either directly or indirectly and, as a result, influence the levels of risk. To compound this, resources may be further stretched as the absence may necessitate other personnel being called



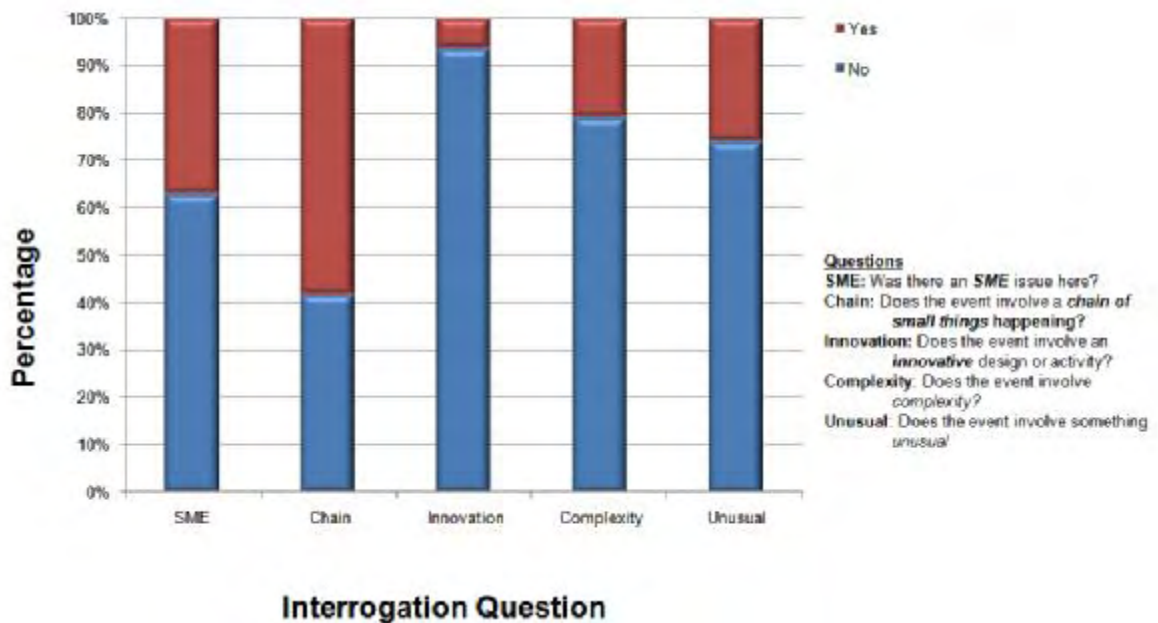
away from their duties in order to provide cover. The indirect impact is that the wider project is affected, resulting in reduced services or withdrawal of services for one or more periods throughout the project. None of the case study examples appeared to have detailed contingency plans to maintain levels of qualified, trained and experienced personnel even when hazardous implications were scheduled to commence.

## 8.8 ADDITIONAL FEATURES CONTRIBUTING TO CATASTROPHIC EVENTS

Emerging features from case study events were examined using five closed questions (yes or no) which included: “Was there an *SME*<sup>1</sup> issue here?”; “Does the event involve a *chain of small things* happening?”; “Does the event involve an *innovative* design or activity?”; “Does the event involve *complexity*?”; and “Does the event involve something *unusual*?”.

While there were no immediate patterns discernable within case groups, the data as a whole yielded some interesting results (Figure 8.4):

- 59% of the time the event involved a chain of small things happening.
- 38% of events involved SMEs.
- 25% involved something unusual.
- 22% of events involved complexity.
- 6% of events involved an innovative design or process. (This low score could be due to the higher level of planning involved in trying cutting edge techniques).



**Figure 8.4: Closed question to determine additional case study features**

Each practice area was assessed against the outlined additional features. Table 8.6 shows the frequency count for each feature; and Figure 8.4 shows these data expressed as a column chart.

<sup>1</sup> SME: Small or Medium Sized Enterprise

**Table 8.6: Frequency counts for "Additional Feature" items**

Case Study Groups	by Practice Area	SME	Chain	Innovation	Complexity	Unusual
<b>Structural collapse of permanent structures</b>	Bridges	0	2	1	2	1
	Buildings	3	1	0	2	1
	Structural Collapse During Demolition (including refurbishment)	4	5	0	1	1
<b>Collapse Of Temporary Works</b>	Formwork, false work, launch gantries, shoring, propping	3	5	1	2	2
	Scaffolding etc	10	9	1	1	4
<b>Cranes</b>	Tower cranes	0	3	0	0	0
	Free-standing cranes, piling rigs and other plant inc large MEWPs	0	1	0	0	0
<b>Associated Sub-terrain activities</b>	Tunnelling and groundwork	1	4	1	4	4
	Disruption of underground services	1	0	0	0	2
	Excavations and earthworks	1	2	0	0	1
<b>Fire</b>	Fire	0	4	0	0	0

### 8.8.1 Chain of small things causing the catastrophic event

In official investigations, examination of the technical details of what failures occurred may tend to look for an overriding and singular root cause. The root cause may be equipment failure or the design and construction decisions that turned out to be inadequate. However the case studies point substantially to a multi-cause model, whereby several failures in the construction process contribute either directly or indirectly to the event. Almost 60% of cases considered that the catastrophic event was caused by a series of smaller events and there was evidence in the remaining cases of a number of different failures that could be seen as contributory.

#### Case study example examining chain of small things

The case study event involved the collapse of a 30 metre scaffold system which was adjacent to an office block development. The development was in a prominent city centre location and caused considerable disruption to a busy city centre. The major cause of the event was put down to a failure to construct in accordance with design although this was found only to be a superficial fault. The access scaffolding collapsed perpendicular to the building construction, leading to one fatality and several major injuries. The initial failure caused the remainder of the access scaffolding to collapse causing collapse of the hoist tower and access platform. The initial collapse was the coincidence of several factors, including: use of non-standard equipment; overloading; and poor design of temporary structure. Overloading had rendered the structure unstable.

The scaffold had not been adequately tied to the building structure and lacked a proper footing which subsequently compromised strength and stability. This was compounded by the temporary removal of adjustment ties and deflection of the scaffold columns from the main structure by a “jacking out” procedure (as the scaffold had collapsed towards the main building). Overloading was due to the loading of building blocks onto three separate lifts. There was a lack of compliance with the design drawings. The specialist scaffolding subcontractor had not ensured that the design of the access scaffold (tie, height and pattern) had adhered to the recommended calculations (no completion or handover certificate). Under strict compliance, overloading would not have occurred if the main contractor had ensured that only two scaffold lifts be worked at any one time. A further catalogue of failures included:

- § Safety critical temporary works were not checked
- § Subcontractor did not ensure compliance with design specification
- § Management sourced and purchased a new (different) scaffold system
- § There were no adequate or detailed designs for the coupling of the system
- § Inadequate software used to design system
- § Lack of training by personnel on the new system
- § Suppliers did not inspect the design
- § Inexperienced site personnel (including graduate design engineer, site engineer; and inexperienced operatives)
- § There were inadequate sole plates to scaffold standard split
- § First line ties were at inadequate heights
- § Inadequate tie positions
- § The scaffold structure had bowed towards building and had then become further compromised by a jacking out procedure
- § There was an un-braced loading tower
- § Goods hoists were not properly tied to building
- § There were too many lifts in consecutive operations (3) and there were excessive loads on the lifts
- § There were no specific instructions for late design changes

It could be suggested that the main failure was in the procurement process, and design of the temporary works, however the incident could have been prevented if there were adequate checking procedures (design specification, software used in the design, the actual placement of ties to the scaffold structure, the number of lifts and overload specifications etc). It is important then to distinguish between direct causal failures and additional indirect failures.

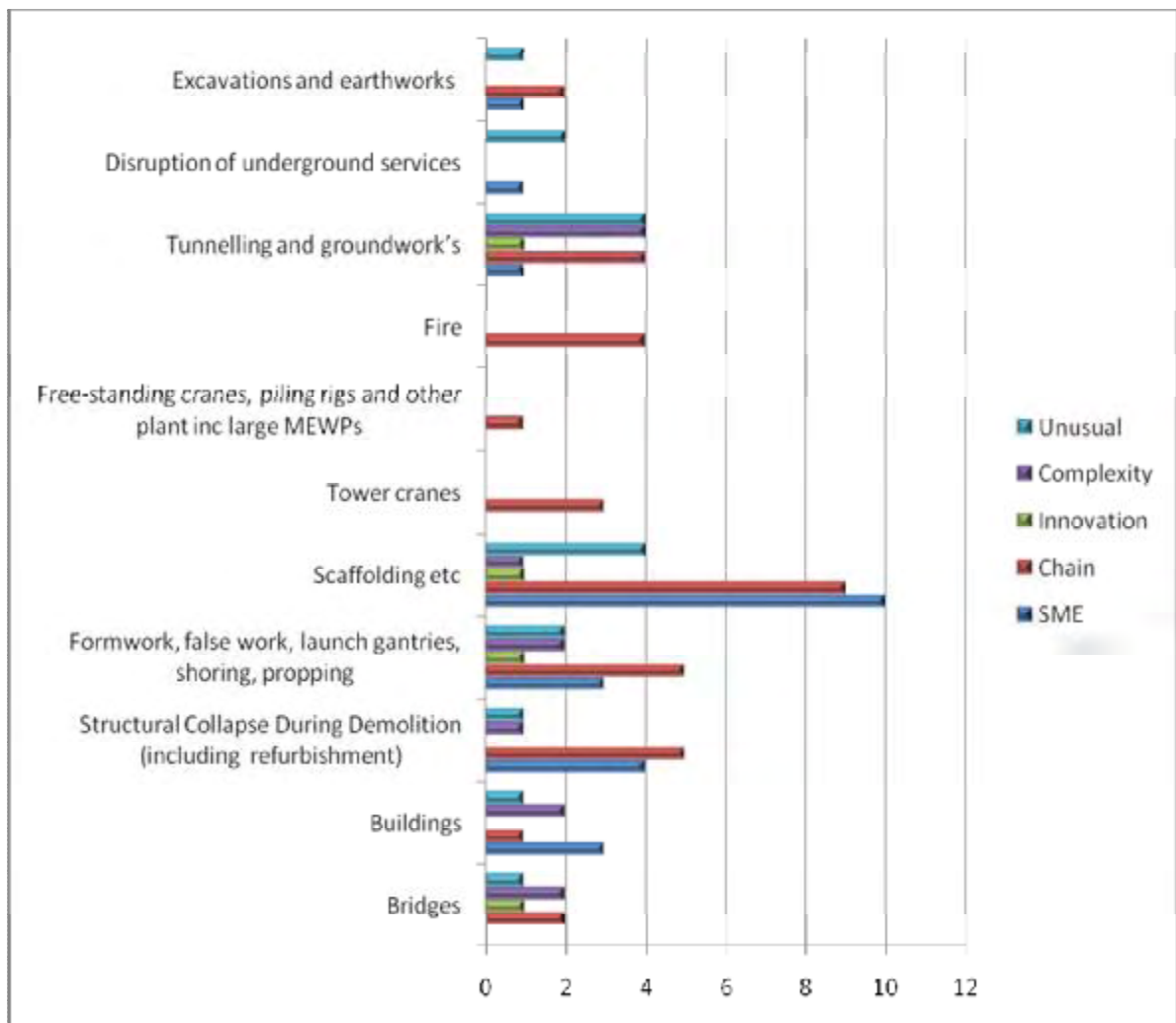
All the checking failures affected the safety of workers and the public. The system required a higher level of competence than was displayed by engineers and the lack of knowledge of codes of practice relating to this equipment was a characteristic feature. As well as design of temporary works, procurement process and checking procedures, the case highlights the need for effective training systems where there is a new or innovative design or teams are working with new equipment. The case also highlights the need for cooperation between parties on site. In this example there was little interface between permanent and temporary design operations. Relatively inexperienced graduate design and site engineers were left to bear responsibility for much of the work but there was no team or network to provide support, additional knowledge and experience despite knowledge of their inexperience, demonstrating a lack of corporate competence.

In common with other case studies, opportunities to eliminate hazards and improve safety were missed at all levels. The causes of failures were human error, including inadequate design checks, errors in design drawings, and poor communication. Although there were adequate product specifications and processes “*Several contributing factors at various hierarchic levels*” produced a causal chain involving lack of personal and corporate competence.

## 8.8.2 Small to Medium Sized Enterprises (SMEs)

Small and Medium-sized Enterprises (SMEs), see Glossary, form a significant portion of the construction industry (and thus SMEs are of significant importance to the successful operation of the construction sector). As a result, it is inevitable that SMEs were involved in a significant portion of the case studies. However, the research reported that SMEs were only seen to be explicitly mentioned as a factor in 38% of catastrophic events. However, it was unclear whether respondents interpreted SMEs specifically as organisations of a certain size or more generically as sub- or sub-subcontractors.

The main impact of SMEs were presented further down the supply chain (mainly sub- contractors and sub, sub-contractors etc.); where recommended processes had been by-passed; procedures had not been strictly adhered to; or where the smaller company had assumed or been given a large amount of project responsibility without having the necessary financial, managerial or technical resources to manage the associated risk. This was particularly true of case study groups falling into the category of *collapse of temporary works* where thirteen such cases were found.



**Figure 8.5: Column Chart displaying frequency counts for additional features**

In particular, *scaffolding* was prominent with ten interrogated case studies, where all cases were deemed to have been influenced by an SME involvement.

Although with far less magnitude, this was also true in case studies involving *structural collapse of permanent structures* where building and demolition was most prominent although there were no cases amongst the practice area of *bridges*. Issues were experienced on refurbishment or

maintenance of buildings, particularly where there were few onsite employees at any one time despite the possible complexity the work.

### **8.8.3 Complexity and Innovation**

Individually as assessment items, neither complexity nor innovation featured prominently amongst case studies. In only 20% of cases events were considered to have been affected by complexity. The very low occurrence of innovation issues (6%) was somewhat surprising, in that the research team expected this to be higher, but see Glossary for discussion. It may be that there was very little innovation involved with these projects, but it is more likely that designs and procedures that are considered to be innovative tend to attract more management effort and closer scrutiny throughout the project process; hence the risks are better managed (but not always).

However, most of the case studies point to complex interactions between the engineering disciplines and the complex nature of the construction process itself. The cases included physical interfaces between materials (i.e. steel, concrete, timber etc.) and social interfaces between management, design and construction. The construction process is never associated with simplicity and, as the majority of construction projects are unique and individual, there will always be a degree of innovation involved. In practice however, much of the risk associated with complexity or innovation can be mitigated by the repetitive nature of construction activity and the incremental way in which innovations in technology or process can be refined and incorporated within standard practice, albeit at the risk of complacency.

The rate of change in many aspects of design and construction has been very dramatic and may add issues of complexity into the delivery of designs. However, from the interrogation of case studies, as a general rule, any 'game-changing' innovations had been successfully integrated into the design and construction process.

Complexity of the catastrophe itself could be linked to the views expressed that most of the events involved a chain of smaller events (see previous section). Also, an element of complexity seems to be linked to unusual or unforeseen events (see following section). However, from the case studies two aspects of complexity emerged: person-focused complexity (complexity of human interaction) and complexity of the management process.

### **8.8.4 Person-focused complexity (complexity of human interaction)**

Based on the size and scope of the case study projects, the large number of individual organisations involved at various stages caused some complexity. While the roles and responsibilities of some organisations or individuals were found to overlap, many tasks were interrelated and interdependent. All featured projects required the involvement of various individuals, although on smaller scale projects (e.g. refurbishment or demolition) some individuals were engaged to perform multiple roles. In the rare event that a project is completely designed, developed, and managed by a single organisation, complexity of people issues should be vastly reduced. However none of the case studies evidenced this and in all events complexity associated with interacting parties was found to be an underlying feature.

### **8.8.5 Management of process complexity**

Generally, construction project management has a tendency to view the project as an ordered, simple and predictable process that may be divided into independently executed phases, activities, work packages, assignments and contracts. The project is also seen as a mainly sequential, assembly-like, linear process which can be planned in a degree of detail through an adequate effort and executed in accordance with the plans. As a consequence, project management seeks to

impose a logical plan but the case studies demonstrated that this aim was often undermined by the complexity involved in the projects. .

### **Case study exemplifying Complexity of Management Process**

A cofferdam method was used during excavation work necessary for the construction of a long culvert. This effectively meant driving metal sheet piles into the ground to form a giant “shoebox,” allowing the interior to be excavated safely. The contractor decided to secure one end of the cofferdam with sandbag bunds to prevent flooding when the tide came in. Subsequently the bund collapsed and two workmen almost drowned as they were trapped in the culvert when water flowed in. The contractor admitted that they had failed to ensure the health and safety of employees who were constructing a culvert as the bunds were not built to the method statement specification. Issues included:

- Insufficient management of hazards
- Workers not briefed
- Not working to method statement
- Inadequate emergency procedures
- Inadequate access/egress

As a result of management staffing issues through holidays, sickness and change in staff, workers did not build the sandbag bunds as per the design on the method statement. There was a failure to communicate sufficient method statement and emergency procedures to staff.

Construction projects cannot be considered as simple sequential processes and the case study projects featured complex processes operating in highly parallel systems. The majority of project activities featured were not independents and were executed in sequences or even simultaneously without any effect on the overall results. While it was often reported that the individual decision making (i.e. chosen methods of conducting activity) led to events, it was uncovered that there was no formal process description provided at higher management levels by the Principal Contractors. Coupled to this was the industry practice of not interfering across contractual boundaries with the way work was to be carried out. In this respect, trade contractors may have their own, different way of executing the job which was found not to be managed at higher levels nor communicated across the project. It was identified that often initial plans and schedules presented an idealised linear picture of what should take place, but not of what was actually taking place. This links closely to interface issues raised earlier in this section.

### **8.8.6 Unusual and unforeseen events**

22% of projects identified unusual aspects as playing a part in the catastrophic events. Most of these were in *tunnelling/ groundwork* and *scaffolding /formwork /falsework*. These areas tend to be more likely to be affected by environmental issues (e.g. weather or ground conditions) which could be considered as unusual from time to time.

Risk management has been an important tool to control safety-related risks. However, while safety practices and preparations for limited emergencies were found to be common activities, in contrast, the vital task of planning for an unforeseen crisis was usually poorly handled. For the majority of cases, construction activities were (to some degree) covered by some form of planning process. For the most part (larger scale projects) the fundamental demand that safety is considered from first principles was evidenced. In many cases there was a suggestion that safety management and assessment tasks had been carried out and were defined as part of a formalised safety management plan. However responsibilities within the organisation for the execution of the plan, the composition and responsibilities for safety review and audit were not clearly established:

### **Case Study exemplifying unusual and unforeseen events**

The launching of a major new bridge over a railway line went well until it was time to lower the bridge onto its bearings. It was realised that the launched end was out of position and needed to be pulled across. This work was carried out by the site team, who had 'done this sort of thing before' and got on with the work with minimal documentation and review by others.

Unfortunately they used temporary bearings which became unstable. The temporary bearings failed and the bridge dropped a short distance onto the abutments, shedding some concrete planks and a large volume of pooled rainwater onto the railway line. After several hours of disruption, the railway line returned to use. The decision had initially been made to attach the planks, but this decision was subsequently reversed. The temporary bearings failed because they were on a slope, two layers of PTFE were used and the resulting forces caused the bearings to be ejected; this issue might well have been spotted by an independent reviewer.

In the above example, the programme was influenced by unforeseen events and the response which ensued fundamentally influenced the safety management process. Such influences in other case studies ranged from poor weather conditions (such as high winds) to unidentified historical features influencing events on site.

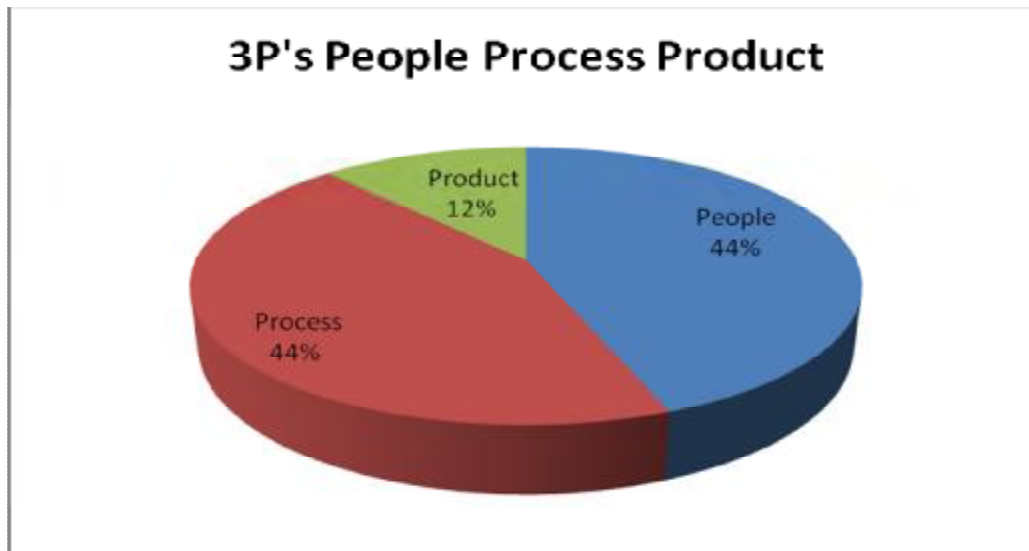
### **Case Study exemplifying unusual and unforeseen events**

One of the case studies referred to the construction of a tunnel under a built-up area. During the project a large crater opened up. It was later suggested that an old well had collapsed underground after the tunnel had been constructed. Local people said that the presence of wells had been known, although the project team had not discovered evidence of any wells while going through historical records. It was argued that the volume of the crater far exceeded the volume of any normal well although there were later suspicions that three wells may have historically existed around the area of the site.

While it is impossible to plan for every unforeseen eventuality, *managing processes in relation to risk and checking of site detail* can minimise the negative effects of such events although this was not managed amongst the case studies which were examined.

## **8.9 PEOPLE PRODUCT PROCESS**

From the questions concerning people, product and process, great importance was placed on the people (44%) and the process (44%) (See figure 8.6) while less emphasis was placed on specific product failures (12%). However the discrete nature of the 3P's as individually attributable to events is less than clear cut and the case studies show that the key to limiting risks on construction projects is to manage and maintain the proper relationships among people, process, and product. This requires the risk management process to control and coordinate routines and subroutines related to people and their use of products in parallel.



**Figure 8.6: Pie chart displaying case study percentage for People, Process, Product**

**Case study exemplifying People-Process-Product** - During the construction of a building, a cantilevered section fell off during the erection which was immediately attributed to the failure of the temporary props (product). However, forensic examination of the case found that the threaded shore adaptors from the supplier were under-strength. It later emerged that the manufacture of the product had been subcontracted (process) but had not been checked by the main supply contractor despite earlier queries. When defects were realised, a recall process was not followed through. Fundamentally, the props should not have been in use although this was not identified. But again site managers (people) and internal systems (processes) failed to follow through. Defective props had been sprayed red. However, the main contractor, as a matter of procedure, sprayed their equipment red (process). Site checks on the products were insufficient (process) although the temporary works designers did not tell site personnel about the use of ‘special’ props (people). Therefore, in this case, what appeared to be a ‘product’ issue, actually turned out to be a complex interrelationship between a number of ‘people’, ‘process’ and ‘product’ failures.

The case studies indicate that no single focus on people, product or process will guarantee success. In all cases where events were seen as attributable to defective products, an underlying link was found in the management or processing of checking procedures and the action of people associated with various tasks. With respect to ‘people’ issues there was found to be a lack of constant or close application or effort or diligence towards risk possibly because “risk can too easily be accepted as a consequence of the construction process”.

## 8.10 SUMMARY

The underlying causes and other significant factors contributing to catastrophic event scenarios on 62 case studies have been assessed using a structured interrogation approach. The findings of descriptive statistical tests and content analysis have been presented to form the basis of further discussions. There is an argument that major hazards should be considered in their own right and demand separate and considered attention due to their high consequence and impact. The majority of case studies were seen to involve major hazards and catastrophic events particularly when the event involved multiple workers on site, the general public and/or disruption to services or adjacent infrastructure. *Failure to recognise hazardous scenarios and influencing factors* stood out as a major influencing factor along with *ignorance, incompetence and lack of checking and competent reviewing*. Significantly, scaffolding has been highlighted as an area of practice where more causative factors have been seen to contribute to events although this did not always determine the nature or a higher level of impact.



The case studies also showed that there were several controls that could have been initiated to reduce risk; in particular, *thinking deeply individually and as a team about hazards, considering risks consciously, having good people involved and available* (knowledgeable, trained, etc.), *following good practice for normal situations*. In all practice areas multiple causalities featured as contributing to events, although this was far less common amongst tower crane incidents.

While people, process and products might be considered as separate issues, where defective products were encountered the management or processing of checking procedures and the action of people were directly linked as a triad. Throughout the case studies the management of processes emerged as a significant consideration, particularly in respect of interfaces between disciplines and communication.

The case studies highlight the complex processes that operate within multiple interacting systems. There is a paradox between the need for highly advanced technical machinery and the need for physical human resource. The result of this unique predicament is that preferences, choices of machinery and technology must be balanced against human behaviour which may be unpredictable. In addition the industry is becoming more complex and multifaceted particularly procurement processes and the subsequent interface problems this creates between the various construction disciplines. Many management (process) decisions are difficult because they are multi-faceted, involve large uncertainty and have important consequences such as impact on quality of outputs, safety of individuals and on allocation of limited resources.

However, while the case study findings add clarity to the understanding of catastrophic events, and provide the basis for further industry consultation, they should not be considered independently. The case study findings are consolidated with data gathered from the on-line survey and considered along with related literature and information gathered from the industry consultation exercises in the following section.

## **9. Consultation**

### **9.1 CONSULTATION ACTIVITY**

#### **9.1.1 Introduction**

This component of the research consisted of meetings with individual industrial contacts to obtain detailed, and confidential, information about individual and institutional experiences of major hazards and catastrophic events in construction. A wide range of individuals were consulted throughout the research including members of the Project Steering Group. It is therefore worth acknowledging that the views presented in this section of the report are the views of the consultees and that they do not necessarily represent the views of the authors of this report or the HSE.

This consultation consisted of 98 individual interviews, discussions and conversations conducted by the research team between October 2009 and April 2010. People in the following areas were consulted:

- § The HSE
- § Building Control Profession
- § Construction work: UK Contractors Group, Specialist Engineering Contractors' Group, Construction Products Association
- § Consultants: Construction Industry Council, Royal Institution of British Architects, Institution of Civil Engineers, Association of Project Safety, Institution of Structural Engineers, Designers Initiative on Health and Safety, Consultants Health and Safety Forum, Royal Academy of Engineers
- § Tunnelling: British Tunnelling Society
- § Piling: Federation of Piling Specialists
- § Scaffolding: National Access and Scaffolding Confederation
- § Fire: Association of Chief Fire Officers, Institute of Fire Engineers, Fire Protection Association, Building Research Establishment
- § Insurance: the Association of British Insurers, Construction Industry Risk Engineering Group
- § Temporary works designers
- § Timber: UK Timber Frame Association
- § Groundworkers
- § Network Rail, Highways Agency, TfL, LUL, BT, RSSB, ODA
- § Achieving Excellence
- § SCOSS (Standing Committee on Structural Safety) and CROSS (Confidential Reporting on Structural Safety).

In addition, three formal events were held, as follows:

- § Two CIRIA CPN (Construction Productivity Network) events during January 2010, in London and Manchester
- § A workshop in London during April 2010

## 9.1.2 Events

The two CPN events were run to the same format; three presentations followed by discussion. The presentations were as follows:

- § Dr Allan Mann of Jacobs examining a series of failures and emphasizing the need for constant vigilance if tragedies are to be avoided
- § John Hodgson of Balfour Beatty explaining how a late change to jacking procedures caused problems during erection of a bridge in London
- § Dr Charles Bradley of DBA Risk Management outlining the way safety risks are managed in the petrochemical industry, under the COMAH legislation

During the discussions a lack of confidence became apparent in some people about how to manage safety risks (a number of these concerns were reiterated during the on-line industry survey).

The follow-up workshop meeting was designed to test particular issues. Delegates used electronic voting buttons to record their opinions in a confidential manner. The majority of the delegates were senior safety managers in large companies. The votes that were recorded during the workshop lead to the following views:

- § There was strong support for the proposition that catastrophic event thinking is relevant to the construction industry
- § Confidence in risk management skills tends to be reduced further down the construction supply chain, with extremely low confidence in the skill of small subcontractors
- § Confidence in the safety risk management skills of designers was also poor
- § It was considered that the education in safety risk management provided (both at universities and at other educational establishments offering HND, BTec and NVQs) should be improved
- § There were no strong views about whether or not people are well-trained by the time they have responsibility for safety risk management; no-one strongly agreed that people were well-trained
- § There was a wide range of views about whether our safety risk management systems work well or not, in a general sense and when catastrophic events were considered, there was no strong support and considerable disquiet about whether they work well
- § The question of whether designers had taken on board the concept of hazard elimination was polled and there was a strong bias against, with no-one strongly agreeing that they have understood and applied the concept
- § We also asked whether, as an industry, our reporting and learning from events works well – being fast and effective - people thought not and the restraint of legal concerns and processes was mentioned
- § On the question of whether modern procurement typically strips away too much independent comment at site, there was a range of views, with a third of delegates expressing concern
- § There was strong support from the proposition that subcontractor safety depends on the efforts of the Principal Contractor
- § When asked what the key was to ensuring a successful project, choosing from a selection of possible issues, there was overwhelming support for the need for a client to appoint a competent team and using a procuring process which facilitates effective communication and cooperation
- § The delegates were asked to choose from a selection of possible features contributing to catastrophic events – over half chose ‘a chain of small things happening’ with some support for ‘lack of resources by SME’, ‘complexity’, and ‘unusual work or events on site’ and little support for ‘innovative design or activity’
- § The delegates were asked to choose from a selection of possible features contributing to the performance of subcontractors, and again ‘effective communication with the

Principal Contractor' was strongly supported, with some support for 'good experience, training and education', for 'effective scheduling, control and management' and 'competent reviewing and checking' – but little support for 'good design processes and activities'

- § The delegates were asked to choose from a selection of possible triggers of major hazards in construction and 'failure in the design process' and 'individual operatives and failings in their supervision' were each strongly supported', with clients not carrying out their CDM duties', 'failings in products' and 'failings in the legislative framework' each receiving little or no support.

Although the replies from the last four questions were not entirely consistent, the messages were clear and it has to be borne in mind that whereas all the choices available might be relevant, only one option could be selected by each delegate.

There was then a period of discussion and the following points were noted:

- § There was agreement that the more competent people who had sight of a situation, the more likely it was that one of them could notice a fatal flaw
- § There was concern that the underlying causes of events were not being uncovered and there was also concern that the industry is failing to learn from experience due to concerns about liability and protracted legal action.

## **9.2 INDUSTRY SECTOR EXPERIENCE OF CATASTROPHIC EVENTS**

### **9.2.1 Introduction**

The sampling of experience which has been undertaken through consultation and case studies is not comprehensive because there is no complete, authoritative database of events. However, during the research advice was received on the issues in various aspects of construction which is recorded here for information and discussion.

### **9.2.2 Failure of permanent structures**

It was considered that permanent works may fail due to either:

- § inherent deficiencies (which might anyway be evidenced later, in service) or due to
- § conditions which exist as a transitional phase during construction, but not subsequently, and which affect their strength or stability

Because of the wide variety of types of structure, there is little commonality – but the failures are generally due to a known weakness which has not been recognised or adequately addressed, on a particular project.

Once new phenomena are recognised, appropriate precautions are normally written into design codes and/or industry guidance, but some complex situations (such as those involving complex ground conditions or fatigue of moving parts etc) will always remain to be dealt with as they arise.

Indication was found of a generally good standard of performance, possibly because most structures are currently designed by or under the supervision of chartered engineers and the techniques used for construction are generally repetitive and well understood.

However, the level of risk is deemed to be high and growing concerns were aired by the consultees about:

- § the move towards design of parts without overall control by a named person
- § use of computers divorcing designers from a real understanding of structural action
- § complexity of modern design codes
- § lack of full design of some temporary works structures

Failure of bridges during construction is thankfully also rare, but where it had occurred it was considered that there were particular mistakes made which were not spotted by those involved. The need for independent review appears particularly strong here as does the need for strong management of risk when there are late changes of plan or unexpected behaviour is noted.

### **9.2.3 Collapse during demolition**

Demolition was considered by the consultees to be inherently dangerous. Although most planned demolition is carried out in a safe manner there are nonetheless many unplanned collapses, particularly during partial demolition for refurbishment and adaptation. Because the collapses are unplanned, workers (and in some cases other people) in or next to a building when it collapses may be killed or injured.

It was perceived by the consultees that many of these events tend to involve smaller, inexperienced clients operating on the fringes of competence and legality, with some of the clients are also acting as designers and/or contractors.

### **9.2.4 Temporary works – general comments**

Various aspects of temporary works were considered and they form a disparate group. However, similarities were found and are grouped here as follows:

- § Temporary works such as formwork, falsework, launching gantries, shoring and propping
- § Temporary works for excavations and groundworks
- § Temporary works – scaffolding
- § Construction plant and equipment including tower cranes, free-standing cranes, piling rigs and MEWPS (mobile elevated working platforms)

The last category (construction plant and equipment) is not normally considered to be temporary works per se but there are interfaces with the construction which require design consideration (such as temporary foundations, hardstandings, tie-backs, construction sequencing etc) which need to be dealt with as part of temporary works.

### **9.2.5 Failure of temporary works, formwork, falsework, launching gantries, shoring, and propping**

After the failure of a complete bridge falsework system (which buckled and collapsed during concreting) at Loddon in 1972, the Bragg Report recommended improvements in practice and a new British Standard for falsework (BS5975) was later prepared. During consultation, concern was expressed that the high standards required are not necessarily being met, due to financial constraints. In particular, the appointment of a Temporary Works Coordinator with time to manage all aspects of temporary works and to visit site sufficiently frequently appears (from comments made during consultation) to be difficult, particularly on smaller projects.

It was felt that there is scope for major hazard events involving temporary works in many projects and the planning, design and execution of these works involves skills which many engineers do not have. There are specialists in this area; traditionally in the UK they have not

cooperated in developing their knowledge and skills but there is currently an initiative to promote improved standards, called the Temporary Works Forum. The intent of this Forum is to offer authoritative advice and guidance on all aspects of temporary works.

## **9.2.6 Failure of tower cranes**

Tower cranes are a vital element in the construction process. During consultation it was said that there are around 1500 cranes in the UK and at any time around 1000 are in use. Whilst some major contractors own their own tower cranes, the majority are hired by contractors from tower crane hire companies.

Tower cranes are often in use on construction sites in urban areas and, although rare, any collapse of the crane could well result in death or serious injury to members of the public outside the boundaries of the site as well as personnel working inside the site. The collapse of tower cranes also presents a risk to adjacent railways and roads. A number of tower crane collapses have occurred in the UK in the last ten years, resulting in eight fatalities, one being a member of the public. Fortunately the UK has not experienced incidents such as the tower crane collapse in Zibo City, China, in 2008, where a tower crane collapsed onto a kindergarten and 5 children were killed. This is not to say that a similar event could not happen in the UK.

Since the collapse of a tower crane at Canary Wharf in May 2000 the industry, including the Plant Safety Group of the Strategic Forum for Construction, in conjunction with the Health and Safety Executive, has analysed the causes of these incidents and produced a significant body of best practice guidance on the erection, maintenance and use of tower cranes and established training course and qualifications for tower crane erection, maintenance and operating personnel. This has included a full revision and expansion of BS 7121-5, *Code of practice for the safe use of cranes – Tower cranes*. HSE have also carried out an ongoing programme of visits to suppliers and users of tower cranes to ensure that best practice guidance is being adopted and implemented.

## **9.2.7 Failure of free-standing cranes, piling rigs, MEWPs etc**

Use of free-standing equipment is in many respects similar to tower cranes, but there is much greater scope for failure due to local ground conditions or hidden/weak structures or due to operator error, due to the mobile nature of the operations.

Again similarly there was a view from the consultees that the lack of a catastrophic event in the UK in recent years was almost certainly simply a matter of luck.

There have been many accidents and ‘product’ (ie the plant) may often be wholly or partly to blame. Recent tower crane collapses in particular have caused concern. It is certain that manufacturers do try to design out hazards once they have been demonstrated by an event, but it is not clear to what extent the problems are actively anticipated and designed out before an incident. Certainly the work of crane erectors requires a high level of skill and application, which when it falls short can have devastating consequences, as events have demonstrated.

There have also been failures due to operation outside the limits set by manufacturers and also due to loss of support arising from a defective working surface or weak covers to underground services. Planning of the work to ensure that these issues are properly dealt with is a crucial activity and working outside the processes developed for safe work, for example in response to an unexpected problem, has to be carefully managed.

## 9.2.8 Failure of scaffolding

Scaffolding collapses into a street were considered to be the prime concern – triggered by for example:

- § Wind loading, particularly where a scaffold is inadequately tied back to an existing structure
- § Overloading with material, either during erection of facades etc or during striking of part of a scaffold
- § Vehicle impact; there appear to be minimal standards laid down that require physical impact protection or traffic calming etc and the scaffold design rarely appears to exhibit sufficient redundancy so that columns can be removed without collapse.

The HSE has advised that scaffolding collapses which could have catastrophic consequences happen regularly and often involve smaller companies working with little control from the Principal Contractor. The leading industry body, the National Access and Scaffolding Confederation (NASC) has prepared solid guidance but the consultees believed that the problem is probably generally with those companies who do not engage.

There are of course also occasions when there is simply a mistake, which could perhaps have been (and often is) spotted by a visit to site of a competent person.

There appears to be scope for tightening up procedures and practice to reduce these risks; lack of a catastrophic event in the UK in recent years is simply a matter of luck. As scaffolding companies will invariably work under the control of a PC (Principal Contractor) or – for smaller projects – Main Contractor, it appears that if the PC takes care that the scaffolding company is competent and aware of the regulations and relevant NASC guidance and operates in a competent manner, risks will inevitably be reduced.

## 9.2.9 Failure of tunnels and groundworks

Tunnelling was considered as being inherently dangerous because of the nature of the activities, the variability of the ground and issues arising from working in a confined space which may become dangerous in various ways. Groundworks are likewise inherently dangerous, for similar reasons.

Whilst knowledge and equipment is constantly improving, it is apparent from consultation (and case studies) that high quality risk management is *essential at all times*. The tunnelling industry in particular has sought to improve communication and activity by fostering closer working between designers and contractors.

The most notable catastrophic event in the UK in recent years was the Heathrow collapse, where massive economic loss was fortunately not accompanied by loss of life.

Those involved in tunnelling and deeper excavations are in general expert in what they do. They are invariably aware of the risks which need to be managed, but the hazards are ever present and have to be taken very seriously.

There have nevertheless been many tunnelling incidents which caused or could have caused a catastrophe. There was a view from the consultees that some of these incidents were due to obvious mistakes, particularly where the risks inherent in the NATM tunnelling method were not rigorously managed.

The UK tunnelling industry appears to work on the issues continuously and insurers take an interest due to the high claims involved and a joint guide has been prepared<sup>1</sup>.

The management of risk once an activity starts to deviate from the expected has been discussed in the literature<sup>2</sup> and the need for Ownership Leadership and Partnership identified (Martin Thurgood, private correspondence). The case studies support the need for rigorous study of potential catastrophic events, independent review (see Glossary), contingency planning, training, avoidance of excessive commercial pressure etc. However, *anecdotally* procurement still tends often to focus upon risk shedding and lowest apparent cost.

The use of the Observational Method to manage risk in tunnelling and groundworks (as mentioned in 2.9 above) is a technique in which risks are closely managed on a continuous basis in support of the design and construction strategy (as opposed to being a simple monitoring process, albeit with 'stop' limits). Remedial actions are prepared for and then put into play as soon as they are required. The role of the client is central to this.

Compared to the problems of deep excavation, there was a view that temporary works for general excavations and groundworks should pose little difficulty, but unusual situations arise and there is often commercial pressure to leave excavated faced unsupported if they 'appear' safe. The consultees felt that potentially catastrophic scenarios can also be posed, as some case studies showed, by issues such as undermining adjacent foundations, if there is inadequate communication, planning and control of the work.

### 9.2.10 Fire

Fire risks need to be considered in two ways: risk of a fire starting and what happens if a fire does start.

Safety risk assessment for fires will need to include consideration of:

- § Use of flammable material
- § Potential sources of ignition
- § Risks of rapid fire spread and loss of control
- § Compartmentation
- § Ease of escape
- § Ease of fire fighting (access, reach etc)
- § Risk to adjacent properties and their inhabitants

Fires during construction mainly start from:

- § Vandalism or careless smoking etc
- § Hot work getting out of control
- § Electrical fault

Once a fire has started the issues are:

- § Detection
- § Fire fighting (workers)
- § Escape of workers and others (alarms, escape routes protection)
- § Reduction of intensity of fire (choice of materials, fire load, stores/rubbish/waste/housekeeping, fire suppression etc)
- § Reduction of area of fire
- § Effect upon adjacent properties
- § Release of poisonous gases and particles
- § Fire fighting (Fire Brigade)
- § Rapid access to reliable information for the fire brigade about hazards, particularly storage of gas cylinders.

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<sup>1</sup> The joint code of practice for risk management of tunnel works in the UK, 2003, Pub. The British Tunnelling Society

<sup>2</sup> The report after Heathrow, Safety in New Austrian Tunnelling Method (NATM) tunnels, 1996, HSE



Under CDM 2007 (together with, in some aspects of construction, the Regulatory Reform (Fire Safety) Order 2005 or 'RRO') these matters should be considered by the Principal Contractor in a Risk Assessment which needs to be continuously updated and used as a management tool on site. There was concern from consultees that this is not being done well on some sites.

Fires during construction have in recent decades caused some loss of life and property but in recent years fires on new-build sites using timber frames have experienced a greater level of economic loss and the size and severity of the fires have alerted the industry to the risk of multiple loss of life of fire-fighters, workers and/or others in the building (particularly where there is phased handover) or in adjacent buildings. The consultees felt that dormant sites appear to be particularly at risk but all sites are at some risk, particularly when unattended.

Designers should (under CDM 2007) be considering hazards such as fire, during construction *and* in-use *and* during maintenance, adaptation, refurbishment and demolition. Bearing in mind the risks during new-build construction referred to above and the risks of fire-spread through breaches in fire protection arising from error or later damage, it is surprising that designers have not (generally) taken steps to eliminate the hazard or to reduce the risks considerably. An appropriate response in some circumstances might be to choose a different form of construction, taking everything into account.

The insurance industry has become increasingly concerned about construction-phase losses in structures using timber framing. Losses during construction can be major because compartmentation may not yet have been installed and fire fighting systems may be lacking. The causes of fires appear to mainly involve arson, accidents during hot work or smoking.

Arrangements for fire service contact with new projects appear to vary and it has been suggested that it should be an explicit requirement that projects with timber frame construction should be notified to the Fire and Rescue Service.

The response of the contracting and specialist supplier parts of the industry to this catastrophic event risk – which can hardly be a surprise – appears to have been slow. However, the industry has now prepared guidance<sup>1</sup> and the HSE is also updating existing guidance<sup>2</sup>. There is debate about the adequacy of the response as a whole, so far, in the light of fires still being experienced.

In particular, designers, specifiers and CDM-coordinators may have been insufficiently involved in managing this safety risk, although the APS (Association for Project Safety) have recently issued guidance<sup>3</sup> discussing the issues.

**This is an example of an issue which needed to be actively and rapidly addressed.**

## 9.2.11 Damage to existing underground services

The New Roads & Street Works Act 1991 replaced the Public Utility Street Works Act (PUSWA) 1950 and came into force on 1 January 1993. Its purpose was to put the duty on Street Authorities in an attempt to co-ordinate all works in the highway and for all those wanting to carry out road work to co-operate in this process. The main objectives of the co-ordination are to:

- ensure safety
- minimise inconvenience to people using the highway, with a specific reference to people with a disability
- protect the structure of the highway and apparatus in it

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<sup>1</sup> *16 Steps to Fire Safety on Timber Frame Construction Sites* prepared by the UK Timber Frame Association (UKTFA) 2008

<sup>2</sup> *Guidance on fire safety on construction sites*, HSG 168.

<sup>3</sup> *Article in Practice Note 2/10*, APS, April 2010

Access to information about existing services (in streets or elsewhere) on a given piece of land appears not to be a seamless exercise, necessitating approaches to large numbers of bodies.

Once information is available, there are many issues, including:

- § information is often not accurate
- § surveying errors
- § services installed incorrectly, at varying depth, have spurs which protrude, have their marking omitted etc
- § use of plastic pipe without a trace-wire system

The consultation exercise suggests that these issues are well understood by the construction industry, particularly where electricity is concerned, although the potential consequences of disrupting a major pipeline are not necessarily so well understood.

This is an area of risk which appeared to have received scant attention and which involved a wide range of poorly documented risks on a day-to-day basis, such as:

- § Cutting into or otherwise disturbing electric cables
- § Disrupting pipes, some of which carry combustible gases or liquids, often under high pressure
- § Disrupting fibre-optic cables carrying enormous volumes of data traffic
- § Penetrating or damaging tunnels, including metro tunnels and service tunnels.

The problems arose through a series of difficulties:

- § Not making the correct enquiries about underground services, as there is no central record and a vital enquiry may be omitted
- § Services not being accurately mapped
- § Services not being declared, for security reasons
- § Difficulty in locating services (for example plastic pipes)
- § Poor working practices
- § Inadequate response to the unexpected, often due to time/money pressures

The UK Contractors Group is known to be active in developing solutions.

**It appeared that this is a construction industry issue where an *acceleration of activity* is required to find solutions, with *industry-wide* participation.**

### 9.3 Summary

The consultation revealed many issues of concern as discussed above. The key message received was that the potential for catastrophic events is (as a concept) appreciated and that there are many ways that the industry could improve its safety risk management performance.

The key issue of competence and the need to build cooperation and communication to overcome the complexities of the industry were appreciated. Safety risk management skills clearly need to be built up through education and training and in-company procedures will often need to be improved, based on experience gained so far.

The importance of the role of the Principal Contractor (or for smaller projects of the Main Contractor) was appreciated.

It was suggested that the chances of failing to get designs right, for the permanent condition and for the temporary condition during erection, would be decreased if a named person was responsible and the role of independent review (see Glossary 'checking and review') was also supported.

There was concern that the industry does not always learn from and respond quickly to problems experienced. Much of the work undertaken in response to issues of concern was carried out by a large number of organisations and it appeared that their central role might be susceptible to better recognised and managed to encourage speedier response to events, involving a wider range of stakeholders.

## **10 Summary of key issues from the literature review; on-line survey; case studies and industry consultation**

Sections 6-9 were reviewed by the research team to establish the key learning points from the literature review; on-line survey; case studies and industry consultation. Most issues were found across all the data sets thus increasing the confidence in the findings. The main points are:

- Catastrophic events are different and complex
- Reducing major hazard risks must be addressed at society, industry, project and site levels
- People, process and product all play their part, both in causing and preventing catastrophic events
- Competent people are the key to success
- Risk identification, assessment and management is essential
- Projects are complex with many interfaces that must be managed effectively
- Gaining and communicating knowledge throughout the team and across industry is crucial

There are practical things that can be done:

- Eliminate risk wherever possible and as early as possible
- Don't let time and cost pressures deflect effort
- Expect change and deal with it
- "Check, check and check again"

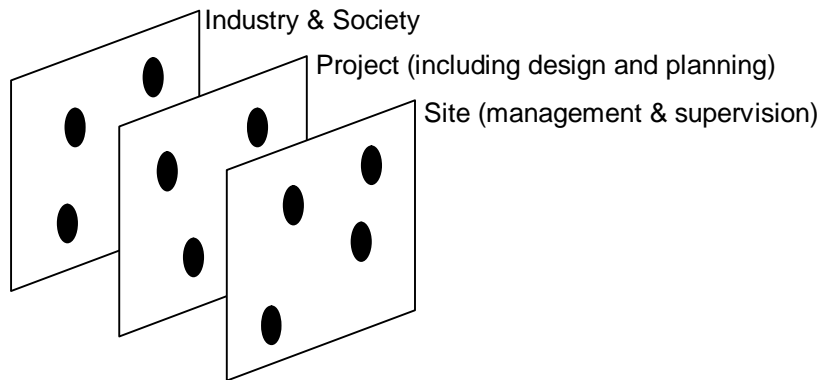
### **10.1 CATASTROPHIC EVENTS ARE DIFFERENT AND COMPLEX**

Whilst there are causal links between catastrophic events and more minor accidents the potential for major hazards and catastrophic events warrants separate appraisal to general risk management and health and safety. The simple question: 'what is the worst thing that could happen?' asked to the right people at the right time with the right resources to take action, would make a significant difference in preventing or reducing catastrophic events.

The case studies point to a multi-cause model, whereby several failures in the construction process contribute either directly or indirectly to the event. Major accident potential is increased within practice areas that are highly process dependent (such as scaffolding) and reliant on numerous individuals and organisations. As such this increased the propensity for error at various points in the process. Conversely, some practice areas are less process driven and reliant on the expertise of one group of specialist contractors. Although these activities may be inherently hazardous there are often fewer interactions between organisations and fewer opportunities for multiple causes.

## 10.2 REDUCING MAJOR HAZARD RISKS MUST BE ADDRESSED AT SOCIETY, INDUSTRY, PROJECT AND SITE LEVELS

Reducing major hazard risks must be addressed at the industry and society in general as well as at project and site levels. This can be illustrated by adapting the James Reason 'plates' model, shown here representing the actions of industry and society; project team; and site team to try to prevent adverse events – in this case catastrophes. The holes in the plates are errors, omissions or defects. Where the holes line up, an accident can occur.



Legislation, including CDM (2007) lays all the necessary foundations for the control of catastrophic events but industry's understanding and implementation is lacking. Failings in education, training and the industry's lack of a safety culture typified by a superficial appreciation of safety considerations from designers, managers and workers both on and off sites.

Industry and society must address the legislative, educational, training and cultural issues; project teams must address procurement, design, resources and organisational challenges; and the site team must ensure good quality, competent people and processes along with effective supervision.

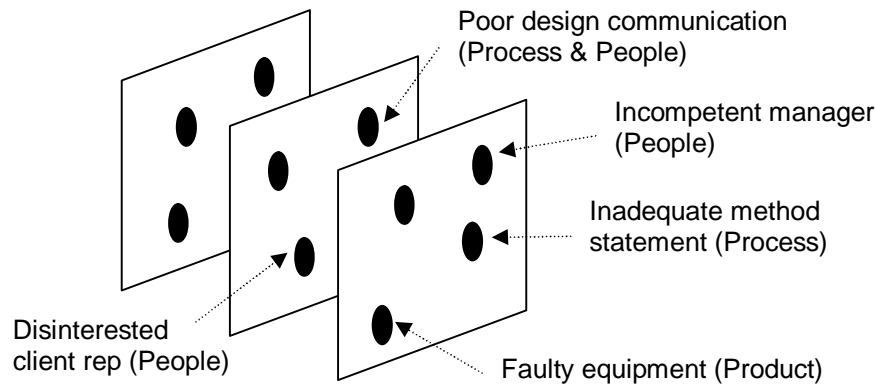
In reality the simple model above can be represented with considerably more plates with action by the client, the designers, the checker-reviewers, the construction planners and managers and the supervisors and workers. Whatever the number or description of the plates, the key concept is that they can never be completely without holes, although the owner of each plate can make a difference and reduce the chance of an adverse event by working to close the holes in their own plate.

## 10.3 PEOPLE, PROCESS AND PRODUCT ALL PLAY THEIR PART, BOTH IN CAUSING AND PREVENTING CATASTROPHIC EVENTS

The case studies indicate that no single focus on people, product or process will guarantee the prevention of major hazards. However, lessons gleaned from other hazardous industries suggest that catastrophic events were primarily due to failures within systems of organisation. Products seemed to have a smaller influence than people or processes. In most cases, where events were seen as attributable to defective products, an underlying link was found in the management or processing of checking procedures and the action of people associated with various tasks.

Causal factors from the case studies and on-line survey include site management and worker issues, lack of site control and failure to recognise hazardous scenarios. Having good people involved and available, having good processes for checking detail on site and checking the quality and use of products has the potential to eliminate major hazard risks.

This can be mapped onto Reason's plates by considering the holes in the plates, which have the potential to allow accidents to occur, to be defects or deficiencies in people or process or products.



#### **10.4 COMPETENT PEOPLE ARE THE KEY TO SUCCESS**

Notwithstanding the people, process, product interaction, the on-line survey showed that having good people involved and available was the most effective control for prevent catastrophic events. The survey also stressed the need for competence for all stakeholders – the right people in the right place with the right time and resources to do the job that is required.

The need for particular designated persons was emphasised, particularly in the area of temporary works. According to the HSE, the causes of many past failures of temporary works were foreseeable and could have been prevented by proper consideration when planning

#### **10.5 RISK IDENTIFICATION, ASSESSMENT AND MANAGEMENT IS ESSENTIAL**

Many cases demonstrated a fundamental failure to recognise hazardous scenarios. Failure to recognise hazardous scenarios was often attributed to the lack of competence of personnel (education, training and experience). Hazard and risk management was seen as a necessary core competency. This may be due to the lack of perception that conjoined events (fairly minor triggers) may well lead to major hazardous events (multiple causality) coupled with the low probabilities associated with construction major hazards.

There are implications at all levels of the industry from client, designers, principal contractors, subcontractors and site personnel. Where there is ignorance about risk this is often shared throughout projects (shared ignorance). Thinking deeply, individually and as a team, was a highly ranked control factor in the on-line survey. Contemporary direction has arguably become focused on the packaging and presentation of construction site health and safety management, rather than the fundamental methods and processes of risk management.

#### **10.6 PROJECTS ARE COMPLEX WITH MANY INTERFACES THAT MUST BE MANAGED EFFECTIVELY**

Construction projects cannot be considered as simple sequential processes and the case study projects featured complex processes operating in highly parallel systems. There are multiple interfaces, physical, organisational and interpersonal. In recognising complexity, it is vital that effective communication and interfaces between disciplines are managed well. Client and procurement issues need to be addressed.

The interfaces between permanent and temporary works and between temporary works and plant or equipment were considered to be particularly problematic.

## **10.7 GAINING AND COMMUNICATING KNOWLEDGE THROUGHOUT THE TEAM AND ACROSS INDUSTRY IS CRUCIAL**

Many project teams failed to recognise major hazards. However, even when they were identified, they were often not communicated to other disciplines or organisations within the projects.

The benefit of learning from past failures or ‘near misses’<sup>1</sup> was raised by many respondents – some guidance exists but it is not well used. Lessons learned should be widely disseminated throughout the industry to enhance shared understanding on risk and hazards (e.g. by organisations such as CROSS and SCOSS) – these could bypass confidentiality constraints and concerns over litigation.

## **10.8 ELIMINATE HAZARD WHEREVER POSSIBLE AND AS EARLY AS POSSIBLE**

As well as becoming better at recognising the hazards in the first place teams need to be able to deal with unusual hazards. Whenever possible, hazards should be eliminated, especially during the design (both permanent and temporary works) and pre-construction phases. It was acknowledged that, at times this was difficult but that this must still be the primary aim – there was considerable feeling that this was not being done well at the moment. Several on-line respondents argued that using engineering judgement and compliance with existing codes and advice is important, but it was noted that more advice is needed and consequently some subjective decisions may still be necessary. In any case, this is in line with the SFARP<sup>2</sup> approach in the UK.

In assessing and managing the risk care must be taken not to just ‘tick the boxes’ whilst missing the ‘big picture’ by concentrating only on ‘everyday’ risk management. Care has to be taken to avoid complacency and not to say that an approach can be taken just because it is ‘the way we have always done it’.

## **10.9 DON’T LET TIME AND COST PRESSURES DEFLECT EFFORT**

The mitigation of risk must often consider complex and competing operational, legal, political and economic demands impacting on decision makers. Teams need to face the challenges from project priorities such as time, cost, quality and aesthetics as well as the risks from major hazards.

Small projects and small organisations appear to have some special challenges. Project teams need to address complications with the supply chain and procurement methods, particularly dealing with sub and sub-subcontracting and interfaces.

## **10.10 EXPECT CHANGE AND DEAL WITH IT**

Part of the complexity of construction projects is because things are often changing, sometimes due to circumstances beyond the control of all the project stakeholders and sometimes caused by brief changes, design adjustments or incorrect work done on site. Effective management of change was seen as essential, because, as details and methods change, so do the hazards and new

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<sup>1</sup> ‘Near miss’ should in the context of this report perhaps be ‘near hit’ or ‘near accident’.

<sup>2</sup> SFARP – So Far As is Reasonably Practicable – see Glossary

hazards can arise from the solutions to the old hazards. Given the speed at which the industry is subject to change (technology, process and procedure), stakeholders must review practice in the context of future safety challenges.

### **10.11 “CHECK, CHECK AND CHECK AGAIN”**

Full *reviews* as well as more limited *checks* were deemed essential, both those by in-house teams as well as those by independent inspectors. The reviews and checks were seen as essential throughout the project process – in design as well as construction. The lack of independent reviewing was a particular point of concern for many respondents.

The absence of specific regulations to address the threat of catastrophic events influences a culture where there is a fundamental lack of checking and review procedures that could encourage the recognition of hazardous scenarios.



## **APPENDICES:**

### **A Glossary**

#### **A.1 ALARP (As low as reasonably practicable)**

The HSE guidance [<http://www.hse.gov.uk/risk/theory/alarplance.htm>] explains that “ALARP” is short for “as low as reasonably practicable”. Also “SFAIRP” [or SFARP] is short for “so far as is reasonably practicable”. The two terms mean essentially the same thing and at their core is the concept of “reasonably practicable”; this involves weighing a risk against the trouble, time and money needed to control it. Thus, ALARP describes the level to which we expect to see workplace risks controlled. With major hazards and catastrophic events in is to be expected that reasonable practical would be very considerable to reduce the risk to a very low level.

See also ‘R2P2’ (Reducing risks, protecting people) which discusses levels of risk.

#### **A.2 Catastrophic event**

Catastrophic events are events that are beyond the ordinary or routine and are (in the UK) characterised by being of *low probability but high consequence*. In this report the phrase ‘Major Hazard’ is also used to categorise such events.

Examples of catastrophic events would be:

- § Structural collapse of permanent structure
- § Collapse of temporary works
- § Collapse of plant such as cranes
- § Major Fire
- § Tunnel collapse
- § Disruption of underground services.

Catastrophic events would be those having the following potential consequences:

- § Potential for multiple deaths and serious injuries in a single incident and/or
- § Serious disruption of infrastructure (eg road, rail ) and/or services (eg power, telecoms)

In addition, such events may well have the following features:

- § Ability to damage or even destroy organisations commercially, either directly or through loss of reputation
- § Creation of public demand for action, possibly leading to demand for a public enquiry and/or changes to relevant legislation.

#### **A.3 CDM 2007**

CDM 2007 is shorthand for the Construction (Design and Management) Regulations 2007. These regulations apply to all construction work (as defined in the Regulation) in Great Britain.

#### **A.4 Check, audit and review**

There are many types and combinations of checking, auditing and reviewing. Depending on the situation, they may be in-house, in-house but involving a separate team, by others appointed by the team or by others independently appointed by an outside body such as the client or a

statutory body. The prefix ‘independent’ is used when there is a strong element of independence from the core team.

Checking of safety critical calculations or processes should always be carried out in conjunction with an element of review by a suitably experienced independent person because either (a) the checking has not included review of what is being done or (b) it is often what has *not* been calculated or the manner of making the calculation which matters, not the mathematics per se.

The terms ‘audit’ and ‘review’ have similar meanings but with a more ‘aggressive’ implication when an ‘audit’ is carried out.

Reviewing is the preferred term for an informed examination of concept as well as detail. It will normally include the provision of helpful comments and may be part of a continuous process to give added confidence in a progressive, timely manner which avoids disrupting the project and ultimately improves the chance of delivery in a reliable, predictable manner.

The term ‘peer review’ has been used for the type of review where concepts are examined and challenged at an early stage by mature, experienced people, looking at the big picture and avoiding assumptions or the following of published advice or codes without a clear understanding of the engineering principles involved.

For more on this issue please refer to the SCOSS Topic paper (REF: SC/09/035) about ‘Independent reviewing through peer assist’

(<http://www.scoss.org.uk/publications/rtf/SC09.035%20-%20WEB%20IR%20Draft%20form%20of%20Agreement%20Jan%202009.pdf>)

## **A.5 COMAH**

COMAH is shorthand for ‘The Control of Major Accident Hazards Regulations 1999’ which aim to ensure that businesses (a) take all necessary measures to prevent major accidents involving dangerous substances and (b) limit the consequences to people and the environment of any major accidents which do occur.

The COMAH Regulations apply mainly to the chemical and petrochemical industries, fuel storage and distribution. They may also affect businesses that store fuels (including gas), have large warehouses or distribution facilities (or) manufacture and store explosives.

## **A.6 Complexity**

Construction work is usually complex in *organisation, technology and methodology*.

*Organisational complexity* is evidenced by the number of interfaces which exist on most projects and the fact that almost invariably (a) each project is different and (b) the companies and people involved are different and there is considerable complexity in any construction project.

*Technical complexity* is evidenced by the number of different materials and elements assembled, some made off-site but many made (or completed) on-site, then assembled into a whole.

*Methodological complexity* is evidenced by the complex work methods employed, using a range of on-site plant and equipment and involving the delivery, storage, transport and lifting required for the assembly of the many separate parts.

## A.7 CROSS (Confidential Reporting On Structural Safety)

CROSS was established by SCOSS in 2005 to improve structural safety and reduce failures by using confidential reports to highlight lessons that have been learnt, to generate feedback and to influence change. CROSS uses reports on the concerns of engineers and others for the benefit of the public and practitioners in the construction industry. No concern is too small to be reported and nothing is too large. Key features of the scheme are to:

- be non-judgmental
- promote a positive attitude to learning from experience
- be seen by all sides of industry as impartial
- analyse and evaluate reports
- provide advice and guidance in Newsletters
- give feedback to industry and regulators
- provide complete confidentiality for reporters

The website ([www.cross-structural-safety.org](http://www.cross-structural-safety.org)) contains many useful features and is designed to simplify registration and reporting as well as having a database of reports. This contains all the CROSS reports that have been published together with extracts from SCOSS publications.

## A.8 Dynamic risk assessment

Dynamic risk assessment is “the continuous assessment of risk in the rapidly changing circumstances of an operational incident, in order to implement the control measures necessary to ensure an acceptable level of safety” (HM Fire Service Inspectorate, 1998).

The term is also used in construction to describe the practice of making ad-hoc adjustment of the method statement as required on site, in response to changing circumstances.

## A.9 ‘ERIC’ methodology

ERIC is a simple method of explaining the risk hierarchy:

- § Elimination of hazards
- § Reduction of levels of risk
- § Information is provided to those who need it
- § Control of residual risk

In reality, often it is only those involved prior to construction (eg designers and preconstruction planners) that can eliminate hazards and it is usually the contractors that control the residual risk.

### Consideration of potential catastrophic events in ERIC

For catastrophic events, the process of hazard identification and subsequent safety risk management is identical but when high severity potentially catastrophic risks are noted further *thinking* needs to be done (often in a workshop of stakeholders, ensuring that people with expert knowledge of the work involved and its risks) to deal with the identification of potential hazardous events, the hazards involved and the options for hazard elimination and risk reduction. This will involve thinking through the logic of how events might unfold (e.g. by Fault Tree Analysis) and what can reasonably and proportionately be done.

The risks must be reduced ‘as low as reasonably practicable (ALARP or SFARP). All decisions are liable to include commercial issues of time and money, but these must be balanced against the potential impacts of a catastrophic event.

## A.10 Innovation

The word ‘innovation’ means different things to different people. In safety risk management the primary concern is to identify and manage risk – so any innovation which increases risk is of concern.

Most construction is to some degree ‘innovative’ because teams/roles/relationships are always different and have to cope with varied projects/designs as well. No two projects are identical (see also ‘*complexity*’). ‘Blue skies’ innovation in which something is being done for the first time is extremely unusual in construction; it will merit a high level of management of risk throughout, as new hazards and/or risks may become evident as the work proceeds.

Doing things ‘in an innovative way’ is more common. Quite often the novelty will be more in the experience of those involved (others having done the same thing elsewhere) but the risks are similar to ‘blue skies’ innovation unless someone who has had prior experience is involved as an advisor or independent reviewer.

‘Safety-driven innovation’ is an emerging concept of innovation which may drive safety due to the added level of thinking and attention which accompanies the innovative work. See further mention in 4.4 of this report. Innovation was identified as playing a role in only 4 of the 62 case study events – but two of these were large catastrophic events involving major loss of life in one case and infrastructure in the other case. This demonstrates that new and novel techniques, of whatever nature, should be handled very carefully using competent, properly resourced safety risk management processes.

## A.11 Interfaces

The construction industry operates with a myriad of physical, organisational and interpersonal interfaces, each of which presents opportunities for mis-communication and mis-understanding which may affect safety risk management. Types of interface can be ‘hard’ or ‘soft’ and typically include:

### ***Organisational & interpersonal*** (‘soft’ interfaces)

- § Client/contractor
- § Contractor/supply-chain
- § Designer/constructor
- § Project phases, sites and disciplines
- § Manager/team

### ***Physical*** (‘hard’ interfaces)

- § Tower crane/base structure
- § Piling rig/piling platform
- § Cladding panel/support structure

## A.12 Latent defects

Latent defects are defects in a design or in construction which do not manifest themselves during the construction phase (or in the post-construction defects-rectification period). A structure may be fatally flawed and collapse in-service due to a latent defect. A structure may contain a latent defect which only becomes apparent during later construction work such as a modification or during demolition.

## A.13 Major hazard

A major hazard is one which, either alone or in conjunction with other hazards, could give rise to a catastrophic event (or a 'top event' – see Glossary). When hazards are being identified at the start of the safety risk management process, potential 'catastrophic events' need to be identified specifically (see 'Consideration of potential catastrophic events in ERIC above) and analysed to gain a full understanding of the contribution which particular hazards play.

## A.14 Peer review

Peer review is a generic term that is used to describe a process of self-regulation by a profession or a process of evaluation involving qualified individuals with the related field. Peer review methods are employed to maintain standards, improve performance, and provide credibility. See also *check audit and review* above.

## A.15 R2P2 - 'Reducing Risk, Protecting People'

The HSE report 'Reducing Risk, Protecting People' ([www.hse.gov.uk/risk/theory/r2p2.pdf](http://www.hse.gov.uk/risk/theory/r2p2.pdf)) examines how decisions might reasonably be made about high risk scenarios, based on statistical assessment of outcomes and the acceptability of certain levels of risk. The concept of *tolerability and tolerability limits* lies at the centre of R2P2, being applied to particular 'risks'. The scenarios which occur on construction are however so many and varied that the underpinning statistical data for each individual 'risk' is unlikely to be available.

## A.16 Risk Management

Risk management encompasses all the activities directed towards the management of risk, in whatever context it is being considered, so as to achieve a safe system of work. Management of safety risks (see '*Safety risk management*' will **always** need to be considered.

## A.17 Robustness

Robustness in construction is the quality of being able to withstand in a proportionate manner the forces and environment which are experienced. There is also a definition in BS EN 1991-1-7 as "the ability of a structure to withstand events like fire, explosions, impact or the consequences of human error without being damaged to an extent disproportionate to the original cause".

Note: robustness can also refer to (for example) robust processes and the definition given above does not preclude the importance of other such aspects of robustness.

## A.18 Safety Risk Management

Safety risk management is the management activity and process whereby:

- § hazards are identified
- § hazards are eliminated if reasonably practicable, taking all relevant factors into account
- § the level of risk due to remaining hazards is reduced as far as is reasonably practicable
- § information is provided to those who need it
- § residual risk is controlled

This can be summarised by the ERIC approach. Designers and constructors should communicate as much as possible and ideally work as an integrated team. All interfaces should

receive special attention, involving (for design activity, including *temporary works* - see below) designers and the CDM Co-ordinator and (for site activity) the Principal Contractor or, for smaller projects, the main contractor.

### **A.19 SCOSS (Standing Committee on Structural Safety)**

SCOSS has been in existence for some 34 years. Its remit is to identify trends or practices which might lead to a concern in respect of structural safety. It is supported by the Institution of Civil Engineers, the Institution of Structural Engineers and the Health and Safety Executive.

The SCOSS Committee is a group of experienced construction industry people who keep an eye on contemporary practice and identify issues that should be of concern. Information is published on these topics and every two years a full report is published which is widely circulated and provides authoritative guidance to the industry and to government. These reports and details of the topics considered may be seen on its website at [www.scoss.org.uk](http://www.scoss.org.uk)

### **A.20 SFARP or SFAiRP (So Far As is Reasonably Practical)**

This term is applied in CDM 2007 when discussing management of risk. There is continuing debate about what SFARP means. If a potential catastrophic event (hazard) is identified which cannot reasonably be eliminated, its level of risk should be reduced by design as low as is reasonably practicable, in a proportionate manner. (See *ALARP* in Glossary). This is a sensible SFARP response to the identification of a potential catastrophic event, where the proportionate response is to reduce risk *ALARP*.

For catastrophic events, the level of risk should be reduced to a very low level indeed. The construction industry has insufficient data or experience to make numerical assessments and each project and site in any event presents a unique series of challenges. Therefore, assessment of levels of risk for potentially catastrophic events in construction needs to be carried out with an appreciation that risk levels for such events must be very low; and this may well lead to *additional precautions being taken* beyond those commonly thought to be adequate in the industry.

### **A.21 ‘SME’ (Small and medium enterprise)**

There are many formal definitions of an SME, varying across a wide spectrum of ‘size’. Much construction work is carried out by small, informal groups of individuals, families and friends who hire themselves out wherever there is work to be had. There are also many small operations taking on only small contracts such as house extensions.

### **A.22 Systemic failure**

A failure may be described as ‘systemic’ if it is not related specifically to an event, but is instead related to the manner in which an organisation, or project, is managed and organised. If a systemic failure is experienced but is not identified and acted upon there is a chance of the same or similar failure, occurring again even if the people and circumstances associated with the original fault are not the same.

## **A.23 Temporary Works**

Anything required during construction to achieve the final structure. This includes:

- § Items such as formwork and falsework needed to form and support the building or structure
- § Consideration of the permanent structure in its intermediate (temporary) states and its modification as necessary
- § Additional works to achieve the final building or structure, which may be removed or left in place
- § Work at interfaces with construction plant and equipment.

## **A.24 Top Event**

Top Event is a term used largely within nuclear and petro-chemical industries and is a component part of a Fault Tree Analysis (FTA) process. It refers to events which are of major impact, catastrophic to the business or organization and needing special attention. However, because of the low level of recognition in the built environment sector and the possible connotation that ‘top’ means ‘all OK, best in class!’ i.e. positive rather than negative, the term has not been adopted for this report.

Nevertheless, the term may gain credence in the construction industry, in particular because the types of risk involved require consideration ‘at the top’ i.e. board level and should be ‘top of the agenda’ for directors and senior managers.

The term ‘Top Event’ is also explored in the literature review (Section 6.2.2 of this report).

## **A.25 Triangulation**

The use of triangulation was characterised by Burgess (1984) as a way of implanting methodological rigour to research through the use of cross checking and cross referencing utilising multiple methods, data sources, theories and investigators. The four types of triangulation that Burgess (1984:145) identifies are;

- § Data triangulation includes data collected over time, space and by different people or organisations.
- § Investigator triangulation involves the use of more than one researcher.
- § Theory triangulation requires the use of competing theories; and
- § Methodological triangulation incorporating the combination of different but appropriate research methods.

*Reference: Burgess R.G., (1984), In the Field: An Introduction to Field Research, London, Routledge*

## **B Proposals for further work**

### **B1 Industry engagement**

The research involved a considerable amount of contact with various industry stakeholders, but further investigation of particular issues may be beneficial. Ideas for further engagement are as follows:

- § Exploring some of the issues which have arisen at industry events, using the voting button facility
- § Seeking further engagement with clients, insurers and operatives
- § Examining the processes used within a range of companies to control the risk of catastrophic events occurring (NB it is understood that SCOSS are working on this already)
- § Exploring what might be appropriate leading performance indicators for use within companies
- § Map the special interest groups which operate within the industries and consider how their effectiveness of their activities might be enhanced.

### **B2 Safety risk assessment**

A range of activities may contribute to a long-term improvement in competence, including:

- § Knowledge mapping and learning planning
- § Preparation of industry guidance on the identification of major hazards and the management of residual risks
- § Promotion of the potential benefits of independent review
- § Study of the risk profile in the tunnelling industry, with particular respect to the NATM method.

### **B3 Contractual models and their impact**

The research did not seek to investigate the relative impacts of different contractual models on the frequency of catastrophic events. It would be informative for industry stakeholders to work together to understand the pros and cons of the various types of contract in this respect, and the measures which might be put in place to reduce the levels of risk.

It was suggested that the degree of independent review of work on site has reduced (see 4.8) and this particular concern could be researched.



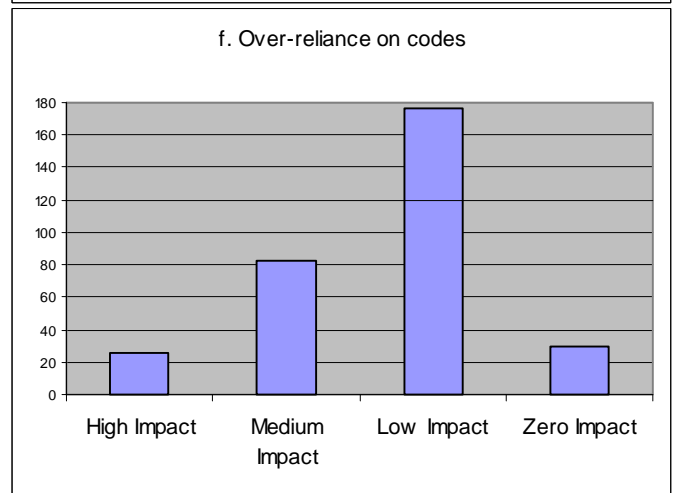
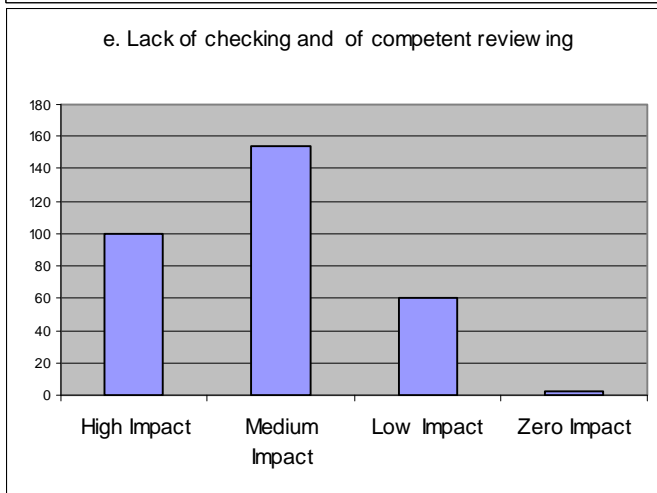
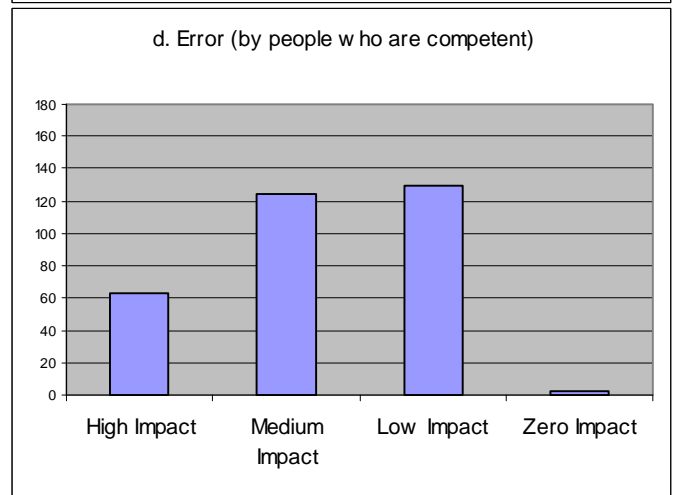
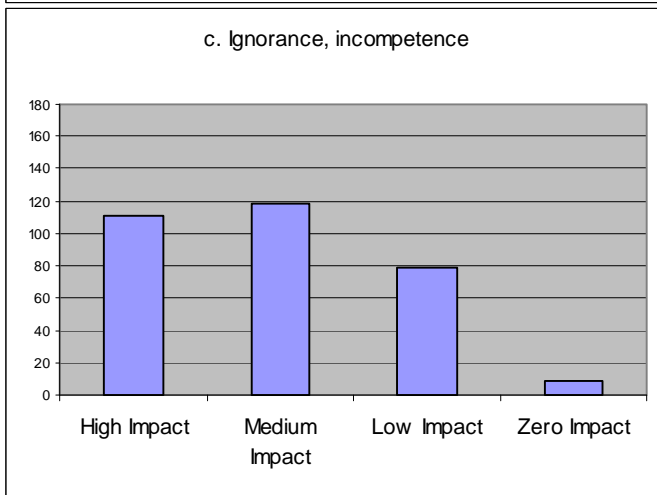
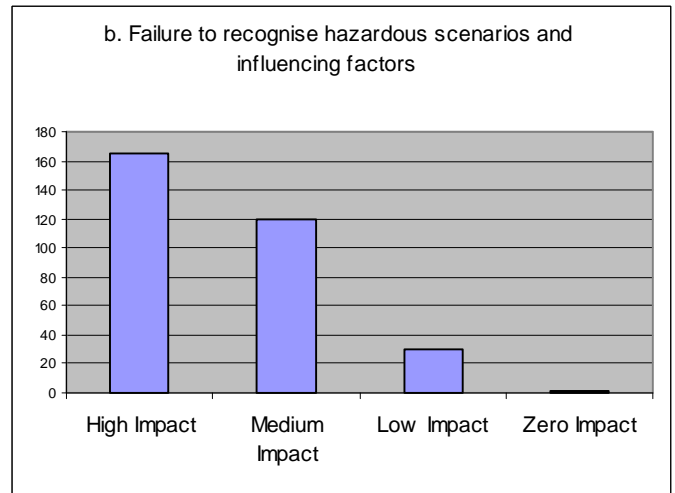
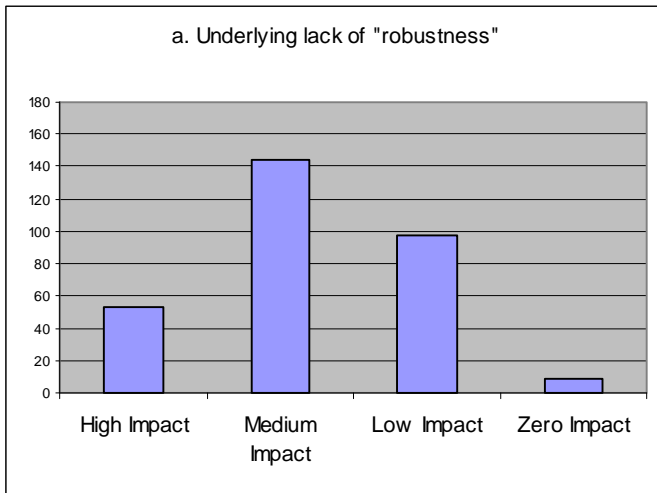
## C On-line survey questions

Questions	No of responses
<b>Experience</b>	
1. What is your main source of experience?	397
2. How many years experience do you have in the construction industry?	396
<b>Factors</b>	
3. How much do you think the following factors affect Catastrophic Events?	
a. Underlying lack of "robustness"	306
b. Failure to recognise hazardous scenarios and influencing factors	320
c. Ignorance, incompetence	319
d. Error (by people who are competent)	322
e. Lack of checking and of competent reviewing	318
f. Over-reliance on codes	316
g. Interface problems between the various parties	322
h. Lack of experience	319
i. Poor team-working	324
j. Lack of site control	320
k. Conscious risk-taking	319
l. Underfunding	315
m. Inappropriate maintenance and/or modification of a structure	317
n. Lack of proper change control	318
o. Vandalism or malicious act	315
p. Unreasonable time pressures	320
q. Design process not effective, not coordinated	320
r. Designers working in boxes; no-one responsible for providing overview	318
s. Drawings not clear, significant risks not apparent or highlighted	318
t. Over-complex procurement with unclear responsibilities	318
u. Over-reliance on software analysis which cannot be easily verified	319
v. Design which didn't consider/explain how construction could be done	320
w. Lack of involvement on site by designers	319
4. Which of the above factors do you personally think are the most important? Please name the 3 most important (eg a, j, v)	307
<b>Controls</b>	
5. How effective do you think the following things are in controlling Catastrophic Events?	
a. Our legislative framework	296
b. Independent review and checking of design within the team	299
c. Independent certification	294
d. Following good practice for normal situations	300
e. Thinking deeply individually and as a team about hazards	299
f. Considering risks <i>consciously</i>	301
g. Applying CDM 2007 principles for risk management	298
h. Having good people involved and available	301
i. Managed interfaces, communication and cooperation	301
j. Adequate resource	302
k. Adequate access to knowledge (especially records)	300
l. Sensible programmes, well-managed	301
m. Good management of information	301
n. Checking of concepts	297
o. Checking of calculation	299
p. Checking of detail on site	301
q. Good change management	300

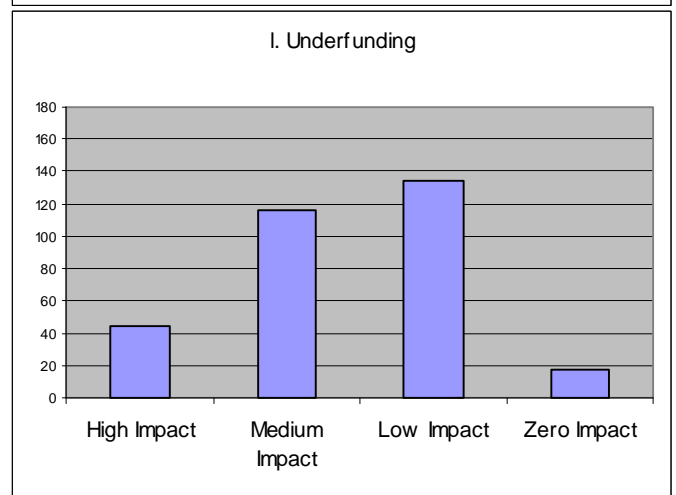
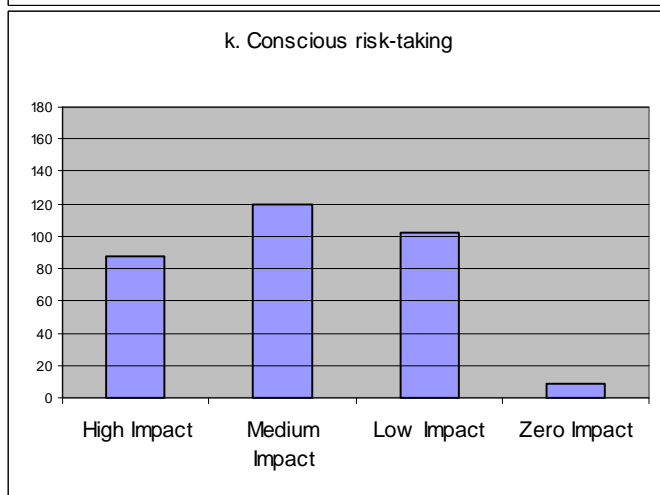
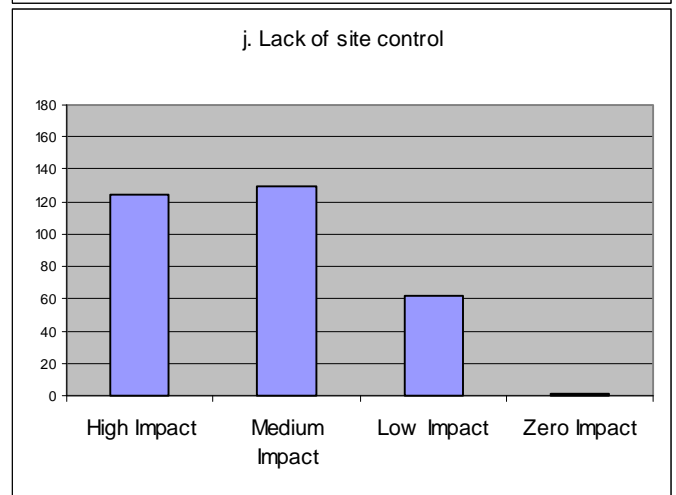
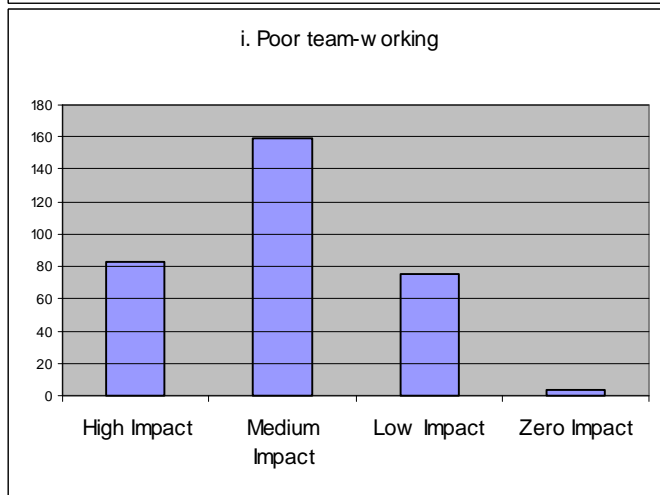
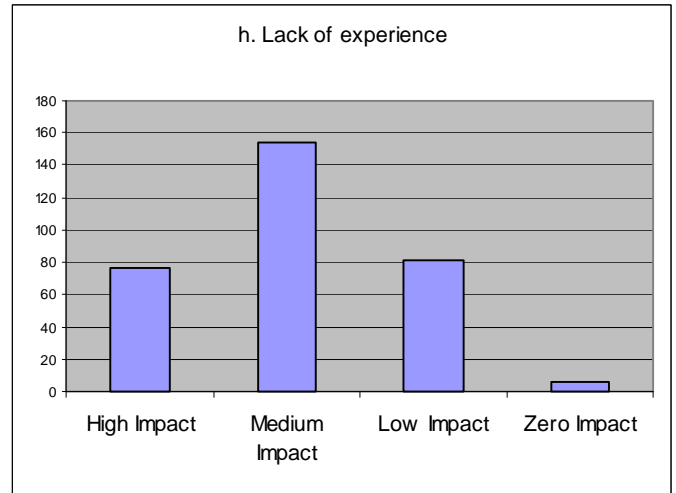
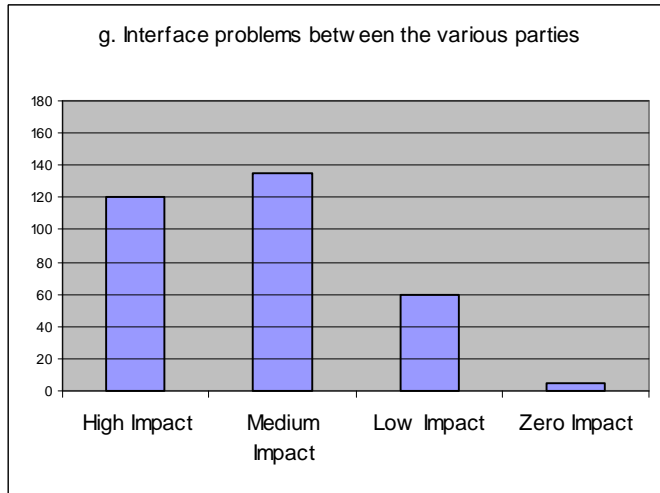
"	290
<b>Risks</b>	
7. Do the risks of major accidents get considered by a formal hazard elimination and risk reduction process?	299
8. In your experience, do people actually try to <i>eliminate</i> hazards?	300
Please add any comments you may have	137
9. When construction involves a major risk such as a risk to lots of people, should extra precautions be taken?	299
Please add any comments you may have	106
10. Are you aware of the work of SCOSS (Standing Committee on Structural Safety)?	291
11. Are you aware of the work of CROSS (Confidential Reporting on Structural Safety)?	300
12. Have you any experience of working on a project where things have gone (or have threatened to go) seriously wrong, harming a lot of people?	298
13. If so, please give brief details, in confidence and/or anonymised	100
14. Would you be prepared to discuss this (in strict confidence)?	231
15. What do you think that (above all else) should be done to prevent catastrophes in construction?	233
<b>Contact details</b>	
16. Would you like to be contacted to contribute further to our research?	293
17. Would you like to be informed about the results of our research?	296
: Name	211
: Organisation	195
: E-Mail address	214
: Telephone number	176

## D. On-line survey responses in graphical form

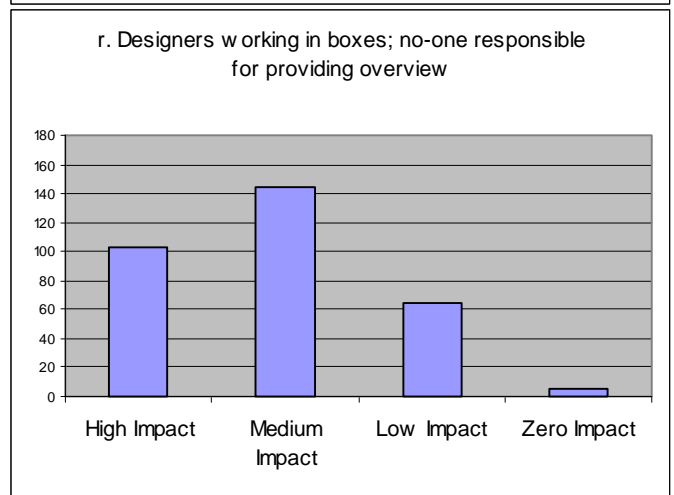
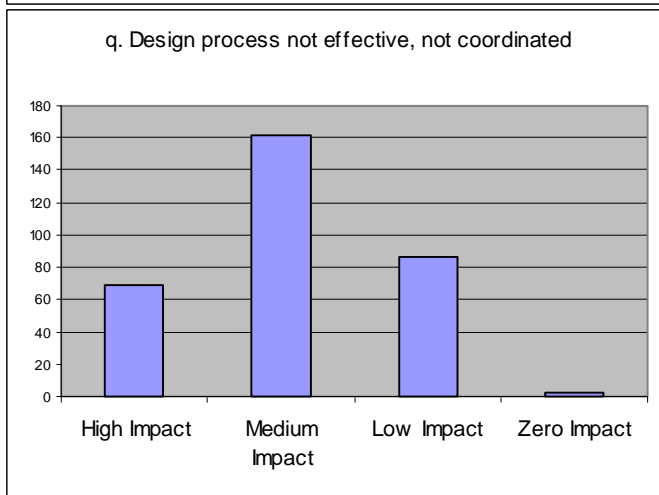
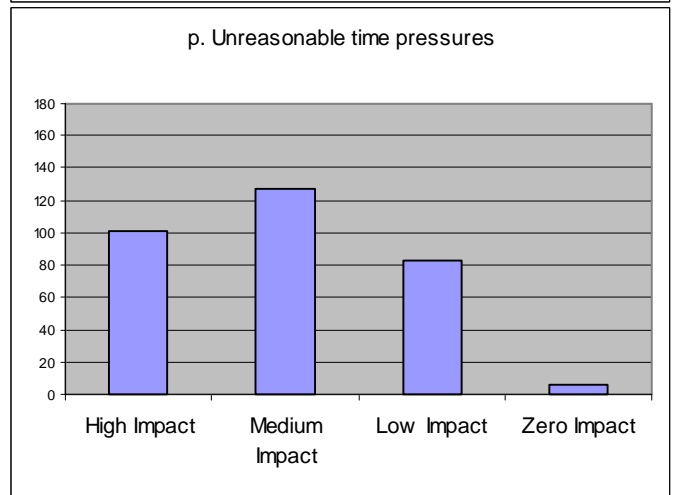
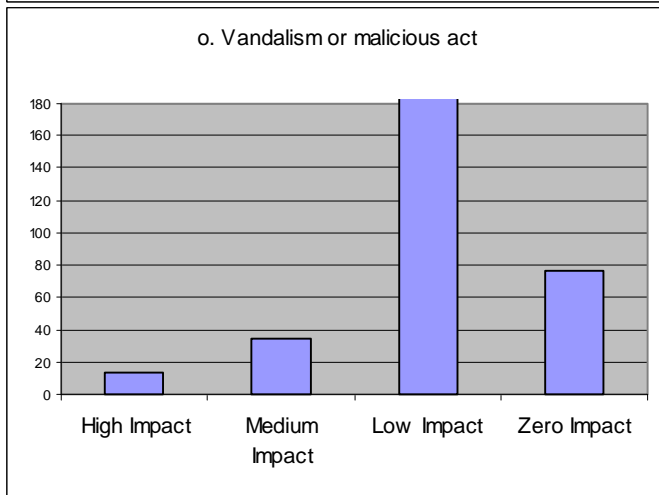
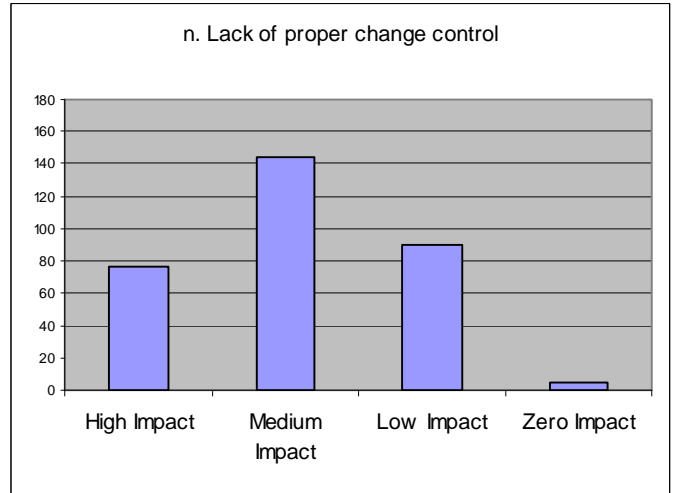
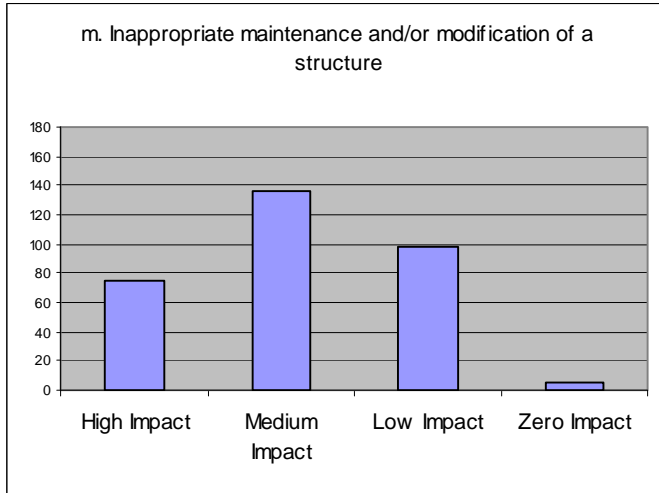
QUESTION 3. How much do you think the following things affect Major Hazards?



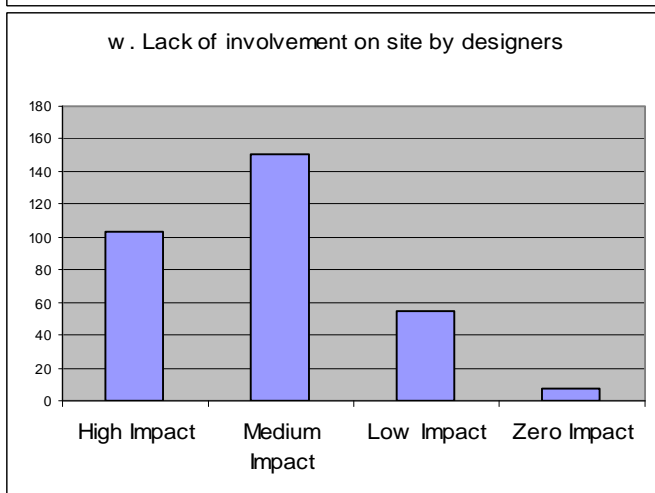
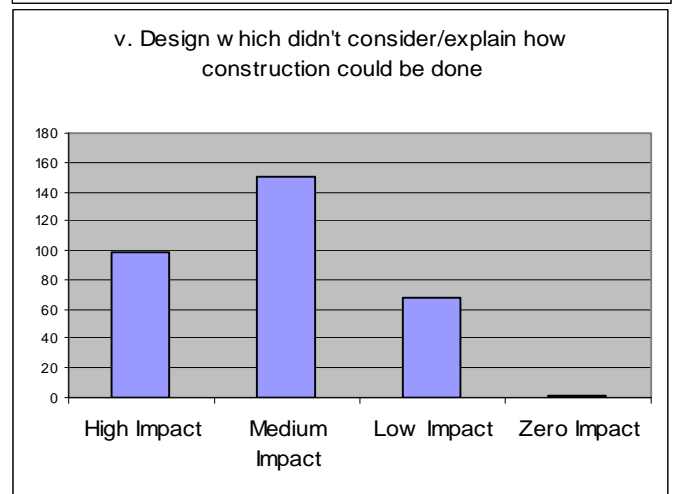
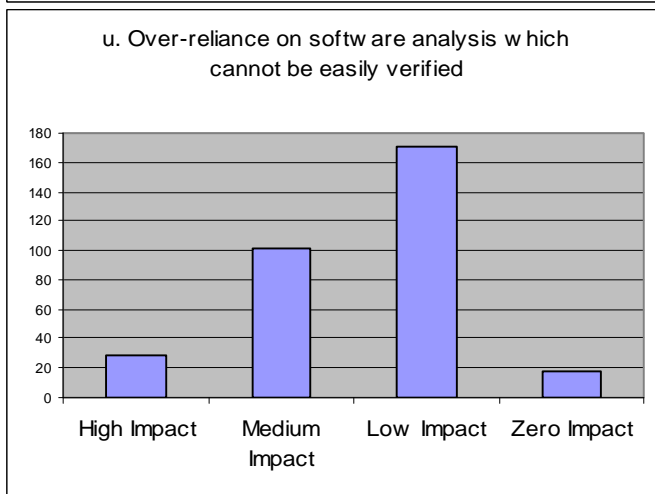
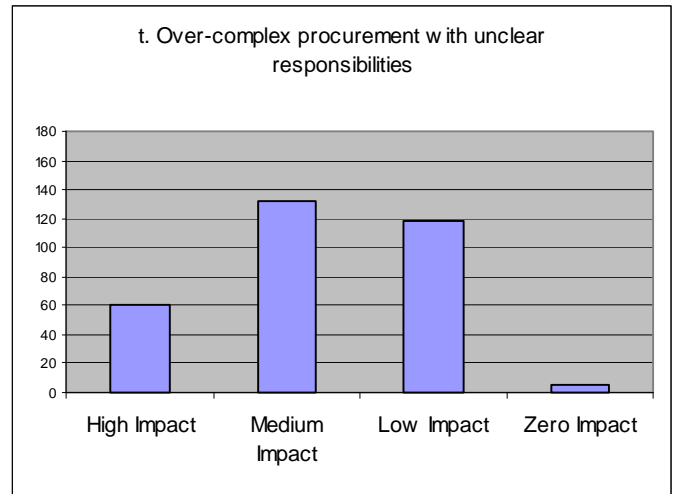
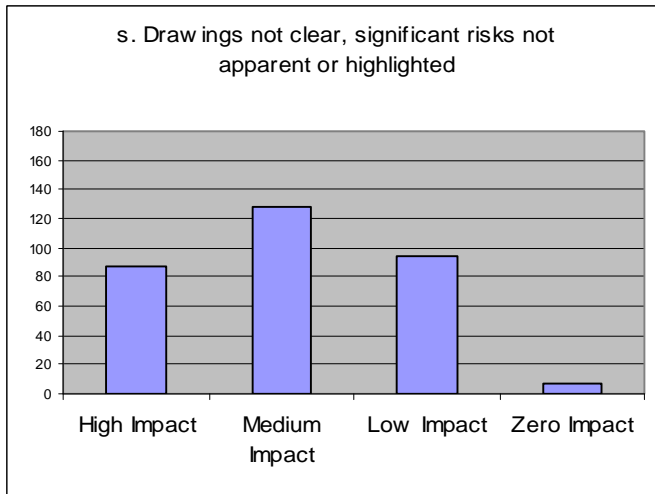
QUESTION 3 *continued...* How much do you think the following things affect Catastrophic Events?



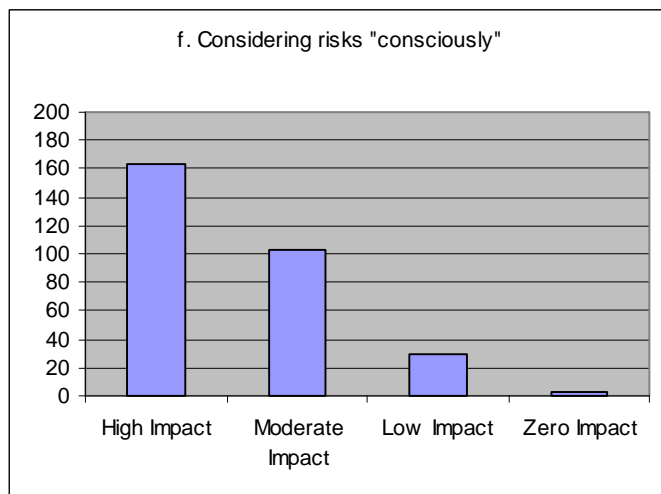
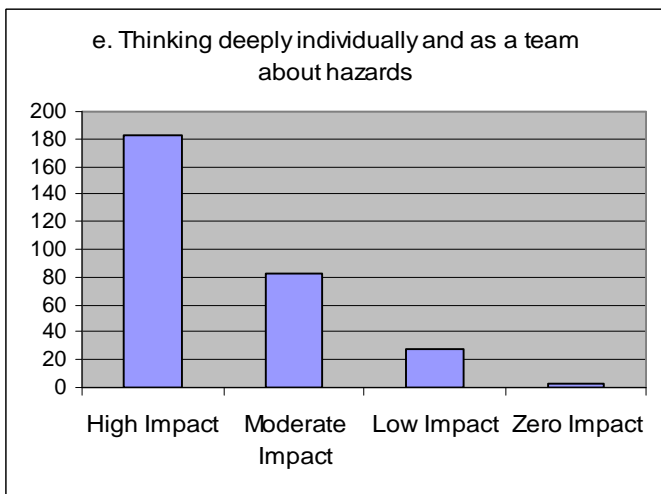
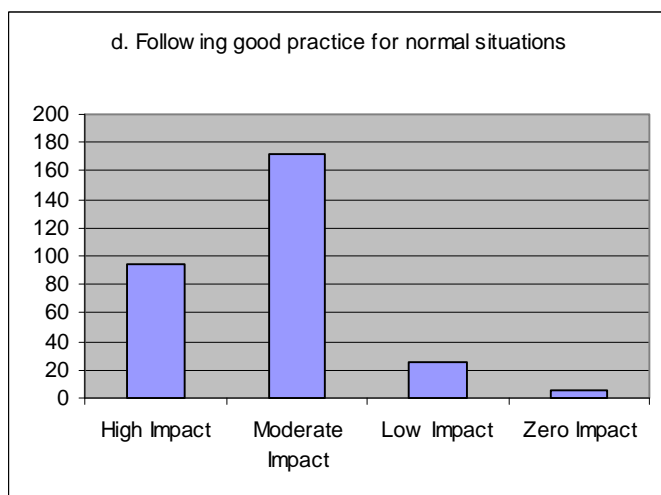
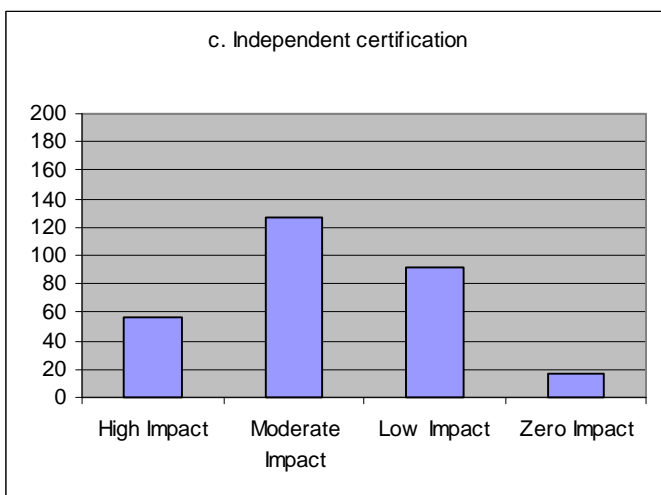
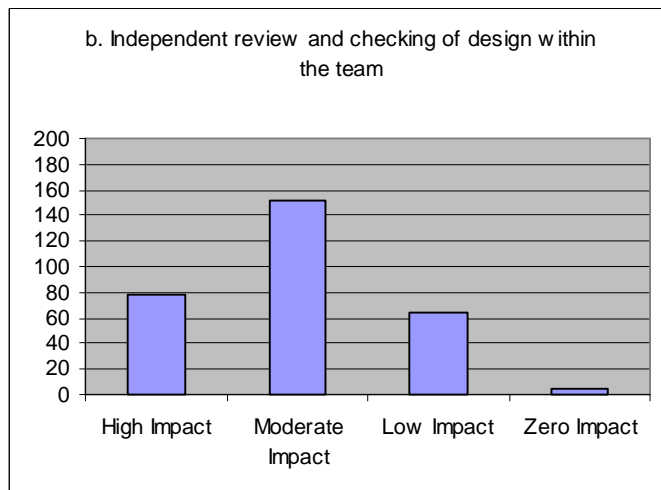
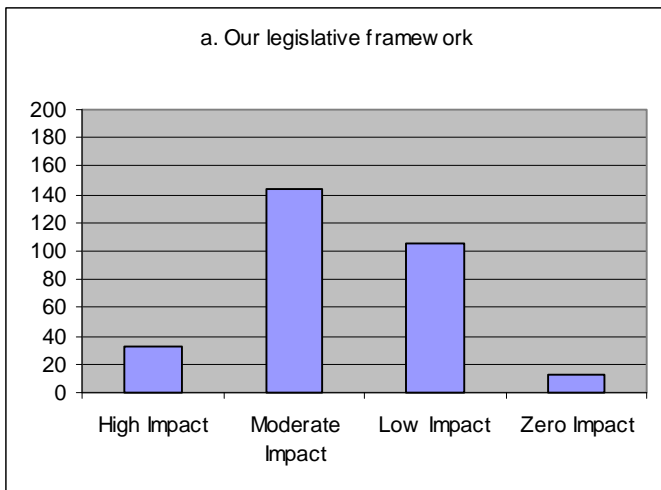
QUESTION 3 *continued*... How much do you think the following things affect Catastrophic Events?



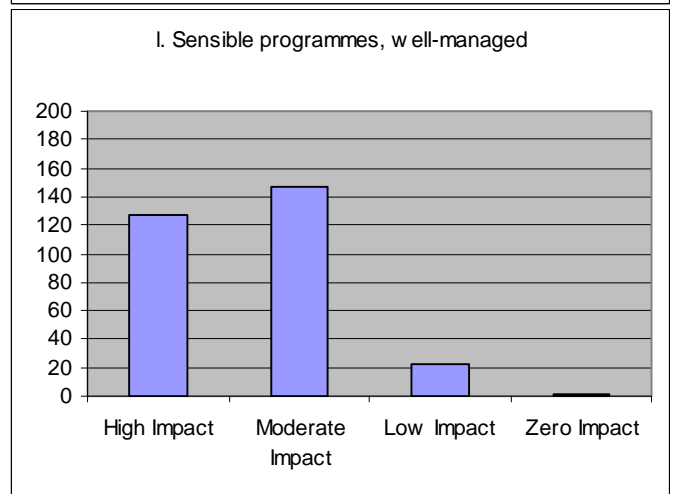
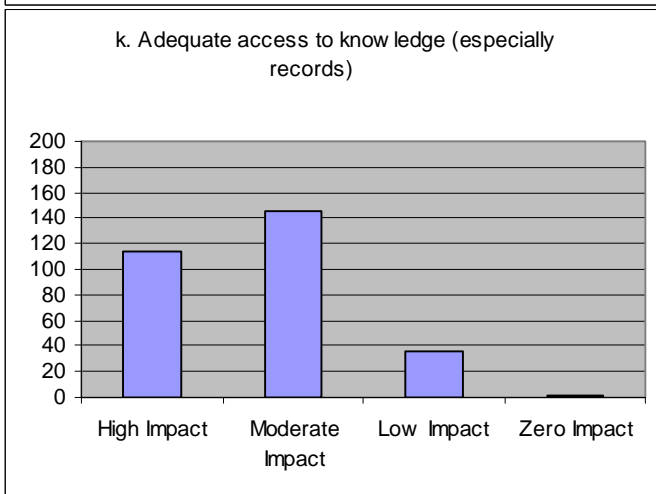
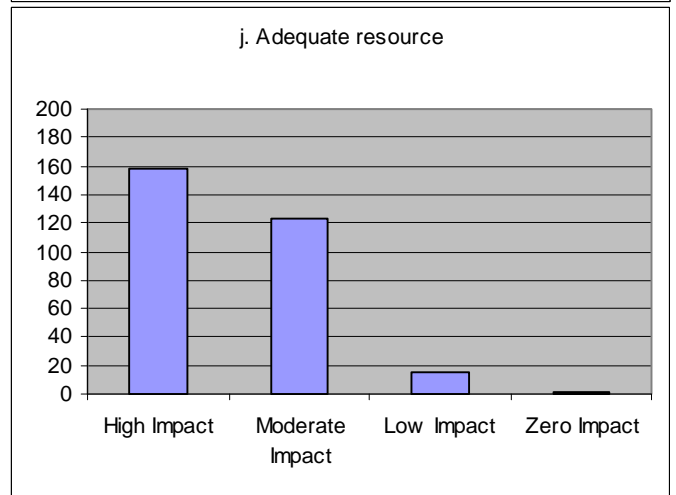
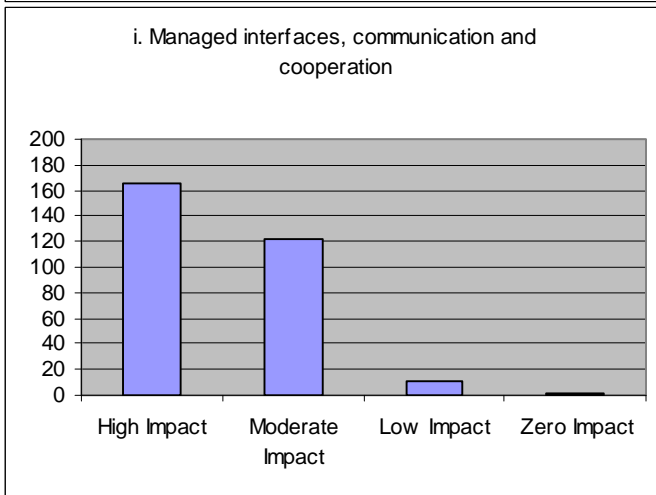
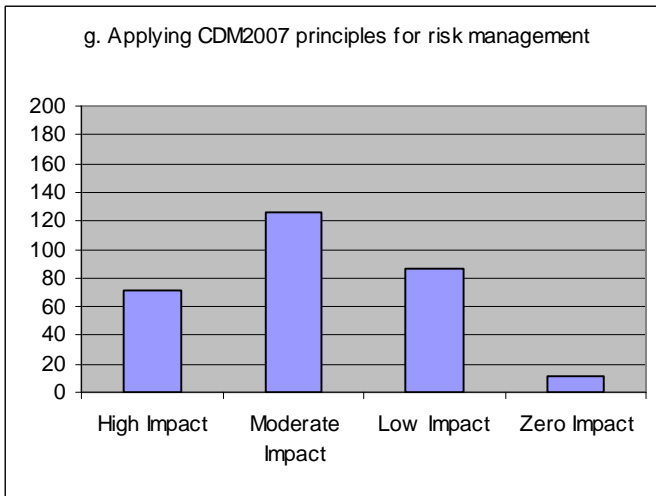
QUESTION 3 *continued...* How much do you think the following things affect Catastrophic Events?



QUESTION 5. How effective do you think the following things are in controlling Catastrophic Events?

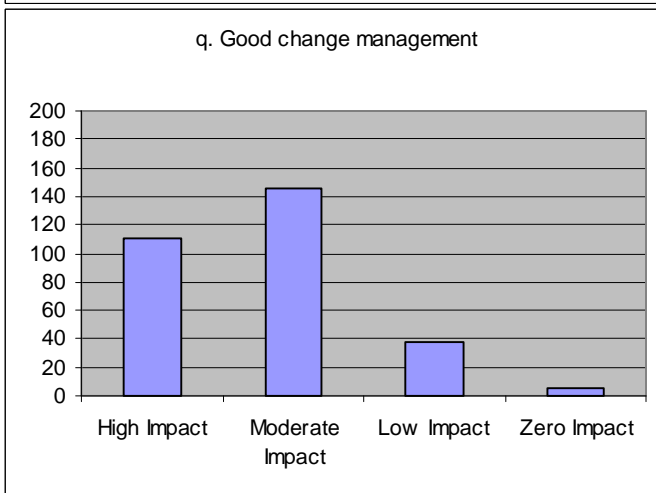
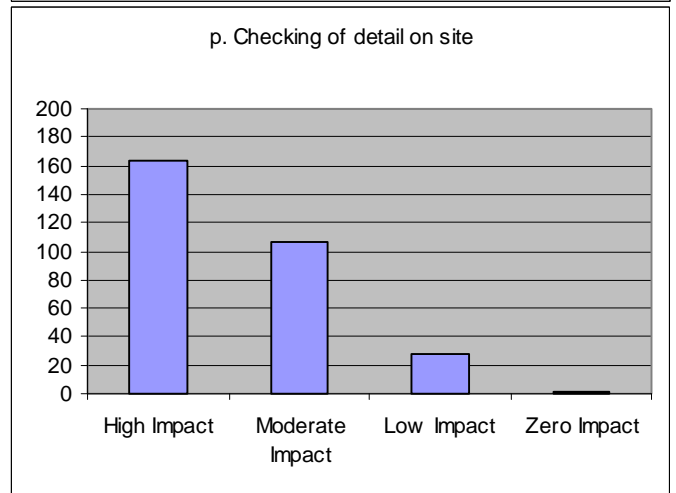
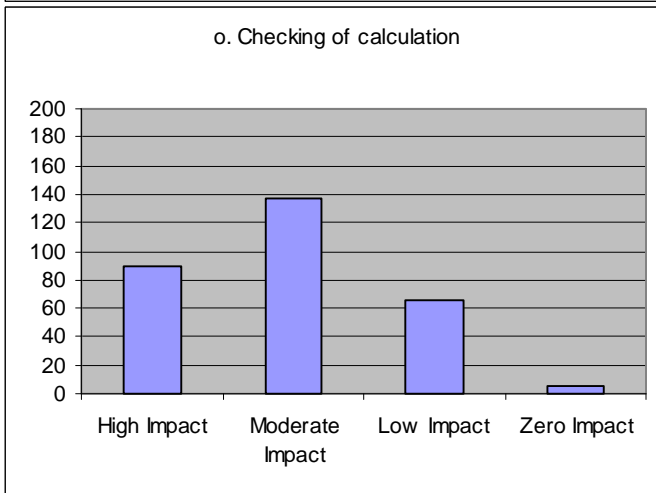
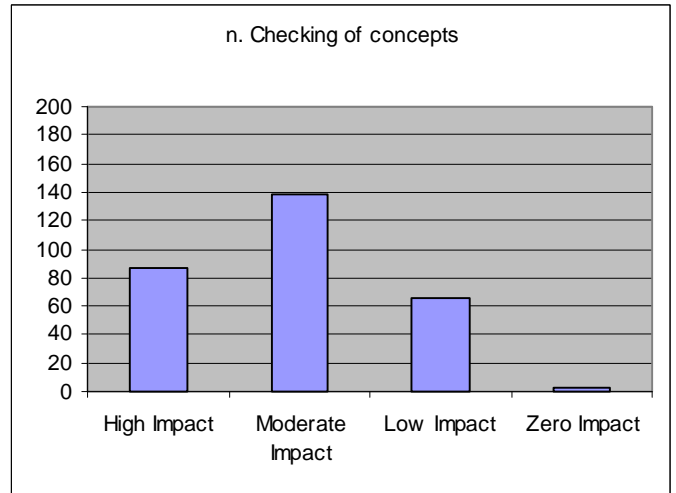
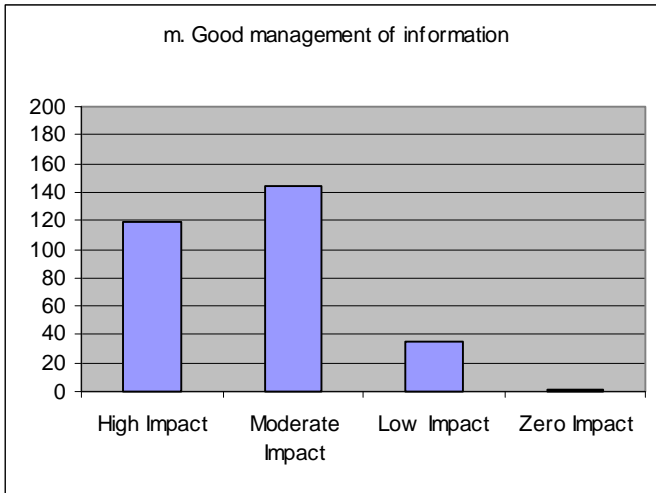


QUESTION 5 *continued...* How effective do you think the following things are in controlling Catastrophic Events?

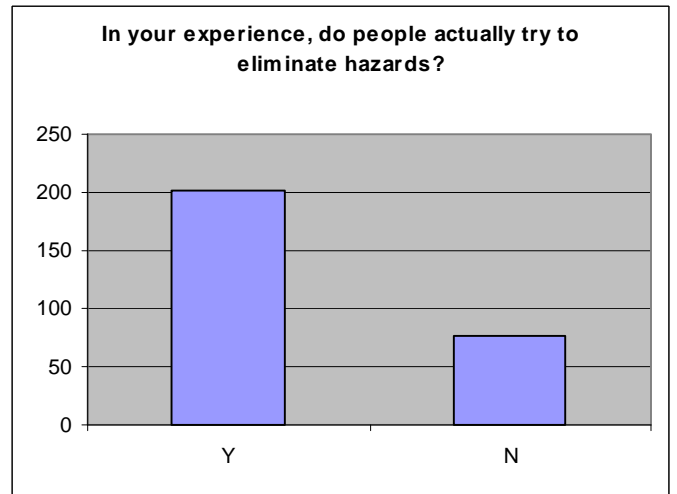




QUESTION 5 *continued...* How effective do you think the following things are in controlling Catastrophic Events?



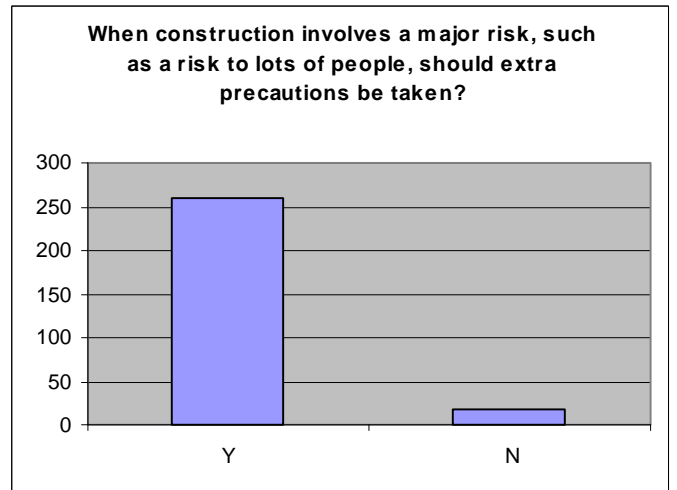
**Question 7:**



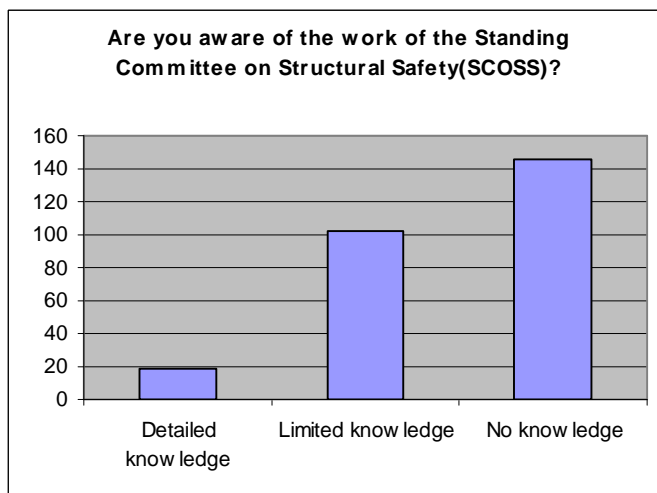
**Question 8:**



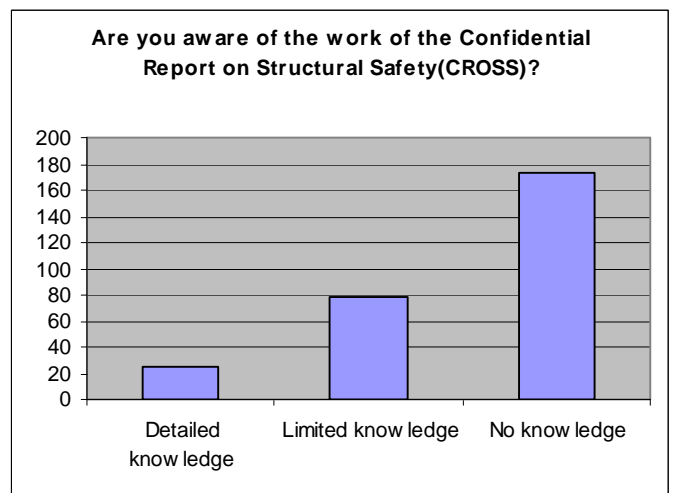
**Question 9:**



**Question 10:**



**Question 11:**



## **E. Case study questions**

### **Case Study – Project Reference**

**Project details:** *Brief* description

**What happened?** *Brief* description

**Is the actual technical reason for the problem known?** *Brief* description

**Are key underlying reasons known?** *Brief* description

**Sources of information (documents, people spoken to):**

### **Impact**

**What impact did the triggers have to make this a potential or actual ‘major hazard’ scenario?**

### **Questions**

1. Clearly might affect a public road, railway, crowds of people etc
2. Put at risk important infrastructure or working facilities
3. Involved activities which are recognised as particularly hazardous (such as demolition)
4. Clearly required higher levels of skill than normal
5. Faced particular challenges such as difficult access/soils/water/weather

### **Causative Factor**

**What were the key causative factors?**

### **Questions**

6. Underlying lack of robustness
7. Failure to recognise hazardous scenarios and influencing factors
8. Ignorance, incompetence
9. Error (by people who are competent)
10. Lack of checking and of competent reviewing
11. Criminality
12. Over-reliance on codes
13. Interface problems
14. Lack of experience
15. Poor team-working
16. Lack of site control
17. Conscious risk-taking
18. Underfunding
19. Inappropriate maintenance and/or modification of a structure
20. Poor management of late design changes
21. Poor management of late changes in build procedures
22. Ad hoc on-site changes to planned build procedures
23. Vandalism or malicious act
24. Unreasonable time pressures
25. Design process not effective, not coordinated
26. People working in boxes, no-one clearly responsible for providing design overview

- 27. Drawings not clear, hazards not apparent or highlighted
- 28. Over-complex procurement with unclear responsibilities
- 29. Over-reliance on software analysis which cannot be easily verified
- 30. Design which didn't consider/explain how construction could be done
- 31. Other factors (please specify): **Open Ended Question**

### Controls

What controls *should* have operated but *didn't*?

### Questions

- 32. Our legislative framework (if so, why?)
- 33. Independent review and checking of design within the team
- 34. Independent certification of design and construction by an official body
- 35. Following good practice for normal situations
- 36. Thinking deeply individually and as a team about hazards
- 37. Considering risks *consciously*
- 38. Applying CDM 2007 principles for risk management
- 39. Having good people involved and available (knowledgeable, trained, experienced, motivated, caring, assiduous)
- 40. Managed interfaces, communication and cooperation
- 41. Adequate resource
- 42. Adequate access to knowledge (ESP. records)
- 43. Sensible programmes, well-managed
- 44. Good management of information
- 45. Checking of concepts
- 46. Checking of calculation
- 47. Checking of detail on site
- 48. Management of late design changes
- 49. Management of late changes in build procedures
- 50. Prevention of ad hoc on-site changes to planned build procedures
- 51. Other factors (please specify) : **Open Ended Question**

### Open Ended Question:

- 52. What additional controls would have made *a real difference*?

### Additional Features – (Yes/No Response)

### Questions

- 53. Was there an *SME* issue here?
- 54. Does the event involve a *chain of small things* happening?
- 55. Does the event involve an *innovative* design or activity?
- 56. Does the event involve *complexity*?
- 57. Does the event involve something *unusual*?

**Conceptual Analysis** - Column of Risk<sup>1</sup>: How much did any of the following failures influence the event?

**Questions\***

- 58. Foundation:** Client failing to appoint a competent team and use procurement process that facilitated communication and cooperation?
- 59. Block 1:** Lack of an integrated design process (including temporary works) with appropriate reviewing and checking throughout?
- 60. Block 2:** Failure of the team (designers and contractors) to assess Risks and spot the potential Hazard (eliminating, reducing, informing and planning)?
- 61. Block 3:** Failure to put in place Controls and the site team not provided with information and training
- 62. Block 4:** Failure to have Experienced personnel on site at all times with appropriate cover when needed
- 63. Block 5:** Failure of the Site Team to be well organised and briefed; and the Operatives are not well supervised
- 64. Block 6:** Failures in the Late Design Change process (or no special measures applied)

**What impact did the following have on the event?**

**Questions**

- 65. People:** All individuals involved in safety critical implications of the work.
- 66. Process:** All support systems including procurement, design, management, supervision, checking and reviewing.
- 67. Products:** All tools, material, plant as generally deemed fit for purpose. Does not include specification (or choice) by people of the products used.

---

<sup>1</sup> 'Column of risk' is a concept (which was not subsequently pursued) in which the key elements affecting construction risk are identified and examined.

## APPENDIX F – CASE STUDY PEN PORTRAITS

The case studies have been anonymised and are presented to illustrate the complex issues associated with major construction hazards that lead to catastrophic events. Care has been taken to ensure that the case studies are presented without reference to any individuals or private organisations (with the exception of reference to any generic statutory bodies such as fire or police services). This is to protect the identity of all contributors and organisations in line with the confidentiality policy adopted throughout the duration of the research.

The information below and in Table 10.1 is provided to assist the reader in examining the case study summaries provided in this section of the report:

**Project Detail:** Outline of the particular construction work/project that was being carried out

**Major Hazard Event:** Overview of what actually happened

**Consequence:** Summary of what happened to make this a major hazard event (for instance):

- Low probability: high consequence
- Potential for multiple deaths and serious injuries affecting workers and members of the public (MOPs) on and/or offsite in a single incident
- Serious disruption of infrastructure and services
- Potential to damage or even destroy organisations commercially; and
- Political implications – public enquiries, demands for new legislation

**Potential Causative Factors:** List of potential (and actual) causative/contributing factors.

**Case No:** Individual case study number

**The Project reference:** Internal categorisation code used to identify case study (by case study group and practice area as given in Table10.1)

**Table 30.1: Index of Categorisation Codes**

<b>Case Study Groups by Practice Area</b>	<b>Code</b>
<b>Structural collapse of permanent structures</b>	<b>SC</b>
Bridges	<b>SC1</b>
Buildings	<b>SC2</b>
Structural collapse during demolition (including refurbishment)	<b>SC3</b>
<b>Collapse of temporary works</b>	<b>CTW</b>
Formwork, falsework, launch gantries, shoring, propping	<b>CTW1</b>
Scaffolding etc	<b>CTW2</b>
<b>Cranes, mobile plant and equipment</b>	<b>C&amp;MPE</b>
Tower cranes	<b>C&amp;MPE1</b>
Free-standing cranes, piling rigs and other plant inc large MEWPs	<b>C&amp;MPE2</b>
<b>Associated sub-terrain activities</b>	<b>AST</b>
Tunnelling and groundworks	<b>AST1</b>
Disruption of underground services	<b>AST2</b>
Excavations and earthworks	<b>AST3</b>
<b>Fire</b>	<b>F</b>

## Case Study Summaries

<b>Project Detail</b>	Demolition of two storey Building	<b>Case No.</b>	01
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	Outer skin of building peeled away and landed on a person. Material spilled onto the road		
<b>Consequence</b>	Demolition work fell on a person causing disability. Material spilled onto the roadway, risking disruption to infrastructure		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Possible weather conditions</li> <li>• No proper demolition plan</li> <li>• Lack of thorough risk assessment</li> <li>• No proper exclusion area</li> <li>• Lack of training, instruction and experience of the workers</li> <li>• Poor and transient supervision</li> </ul>		

<b>Project Detail</b>	Refurbishment and adaptation of an existing building	<b>Case No.</b>	02
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	Major collapse to façade and one third of the building		
<b>Consequence</b>	Disruption to local infrastructure and risk to people located in the building		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Inexperienced contractor appointed by the client and no CDMC</li> <li>• No formal drawing for the works</li> <li>• No competent reviewing</li> <li>• Cost cutting approach by client</li> <li>• Professionals were not informed of changes to the scope of work</li> <li>• Limited number of props were used ie unsafe temporary works</li> </ul>		

<b>Project Detail</b>	Demolition of a car park	<b>Case No.</b>	03
		<b>Categorisation Code</b>	CTW1
<b>Major Hazard Event</b>	Cantilevered section fell off during erection – failure of the temporary props		
<b>Consequence</b>	Failure of props could have caused major fatalities and disruption of project		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Props should not have been in use.</li> <li>• Recall process not followed through.</li> <li>• Defective props had been sprayed red and the props which failed were sprayed but contractor spray their equipment red as standard</li> <li>• Site checks on products insufficient.</li> <li>• Temp works designers didn't tell site about use of 'special' props.</li> </ul>		

<b>Project Detail</b>	Construction of two new large blocks of mixed use in city centre	<b>Case No.</b>	04
		<b>Categorisation Code</b>	C&MPE2
<b>Major Hazard Event</b>	Mobile elevating work platforms (MEWP) was manoeuvred with boom elevated; ran over a cover which was buried by a working platform of crushed stone.		
<b>Consequence</b>	Topped over next to a location where a bus had just departed. Operator survived, badly injured		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Working over unknown hatch covers.</li> <li>• Site surveys before didn't find/mark what was there;</li> <li>• No plan for managing/protecting.</li> <li>• Inadequate information to operatives,</li> <li>• Parked next to services manhole box which was collapsing.</li> <li>• Company procedure didn't deal with vehicle movements.</li> <li>• A persistent failure around the site</li> <li>• Inadequate surveys and lack of provision of information on site</li> </ul>		



<b>Project Detail</b>	Bridge launched over a railway line	<b>Case No.</b>	05
		<b>Categorisation Code</b>	SC1
<b>Major Hazard Event</b>	PTFE-faced packs dislodged and bridge construction dropped		
<b>Consequence</b>	Debris was scattered over outlying areas causing disruption to transport system and presenting a major hazard to public and nearby building infrastructure		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Late changes to work plan without any review by others beyond the site team doing the work</li> <li>Principal Contractor failed to manage this risk</li> </ul>		

<b>Project Detail</b>	Construction of a tunnel under a built-up city area	<b>Case No.</b>	06
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	Large crater opened up adjacent to houses		
<b>Consequence</b>	Risk to the public, transport and local infrastructure		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Inadequate site research</li> <li>Unusual ground conditions</li> <li>Residual risk not considered adequately</li> </ul>		

<b>Project Detail</b>	Erection of steel roof over sports stadium	<b>Case No.</b>	07
		<b>Categorisation Code</b>	SC2
<b>Major Hazard Event</b>	Partial collapse of a rafter occurred during the welding work to join the rafter to its end supporting member		
<b>Consequence</b>	Possibility of fatalities and injury to site personnel (many hundreds on site) Major project disruption and added cost as workforce walked off the site.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Human error</li> <li>Operative cut out a temporary stiffener supporting a major member</li> </ul>		

<b>Project Detail</b>	Construction of steel box-girder bridge	<b>Case No.</b>	08
		<b>Categorisation Code</b>	SC1
<b>Major Hazard Event</b>	Collapse of major sections of the bridge during erection		
<b>Consequence</b>	Major fatalities and worker injury, disruption to project		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Major on-site problems</li> <li>Lack of professionalism</li> <li>Failure to assess risk</li> <li>Fundamental project and engineering errors</li> <li>Poor communication</li> <li>Poor management of late changes</li> <li>Poor communication between professions</li> </ul>		

<b>Project Detail</b>	Construction for a new major highway involving deep excavation (next to an existing highway)	<b>Case No.</b>	09
		<b>Categorisation Code</b>	AST3
<b>Major Hazard Event</b>	The excavation collapsed due to failure of the earth pressure propping		
<b>Consequence</b>	Major fatalities and worker injury, disruption to project, disruption to major highway		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Failure of the propping system due to under-estimation of loads</li> <li>poor detailing of connections</li> <li>Poor risk management throughout the design process and site execution,</li> <li>Poor monitoring and failure to notice/act upon warning signs</li> <li>No effective independent review and checking by experienced people</li> </ul>		

<b>Project Detail</b>	Construction of cantilever-launched concrete box-girder bridge	<b>Case No.</b>	10
		<b>Categorisation Code</b>	SC1
<b>Major Hazard Event</b>	Bridge construction collapsed during launch		
<b>Consequence</b>	Collapse of bridge, multiple deaths		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Failure of box during launch due to inability to support the bearing loads at the slide bearings</li> <li>• Failure to ensure robust details and accuracy of positioning of slide pads.</li> <li>• Lack of competent review</li> <li>• Poor team working</li> <li>• Lack of site control</li> <li>• Poor management of late design changes</li> </ul>		

<b>Project Detail</b>	Major building demolition	<b>Case No.</b>	11
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	Removal of props from a projecting piece of slab caused the slab to fall		
<b>Consequence</b>	Risk of injury and fatalities to workers		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Manner in which structure worked wasn't understood;</li> <li>• There was a change of procedure, a piece which was part of a suspended slab was left and later it was assumed it would cantilever. It should have been seen that it wasn't a cantilever by the adjacent soffit (beam and pot flooring span at 90 degrees)</li> <li>• Engineer didn't communicate with site (but plan was changed and he didn't know)</li> <li>• Risk should have been investigated</li> <li>• Variations to planned procedures</li> </ul>		

<b>Project Detail</b>	Bridge construction	<b>Case No.</b>	12
		<b>Categorisation Code</b>	C&MPE2
<b>Major Hazard Event</b>	Inadequate bearing provided by the piling pad caused the piling rig to overturn		
<b>Consequence</b>	Disruptions to a public road, railway, risk of injury to general public		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Inadequate bearing provided by the piling pad</li> <li>• An obstruction had been found, which was removed by excavator and the hole backfilled, probably in an uncontrolled manner, before the piling mat was restored.</li> <li>• Lack of site management</li> <li>• Variations to planned procedures</li> </ul>		

<b>Project Detail</b>	Erection of telecommunications mast	<b>Case No.</b>	13
		<b>Categorisation Code</b>	SC1
<b>Major Hazard Event</b>	Mast collapsed		
<b>Consequence</b>	Possibility of worker injury or fatalities		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Defective design</li> <li>• Lack of experience and incompetence of designers</li> <li>• Client lack of knowledge lead to the appointment of inexperienced designers</li> </ul>		

<b>Project Detail</b>	Refurbishment of a large office block for open-plan space	<b>Case No.</b>	14
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	Structural collapse of top floor		
<b>Consequence</b>	<ul style="list-style-type: none"> <li>• Operative seriously injured and passers-by nearly killed/injured</li> </ul>		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Inadequate propping and loss of lateral stability as walls were removed</li> <li>• Developer didn't plan properly</li> <li>• No temporary works or structural engineer for this part of the works; architect involved but didn't ensure structural engineer was involved</li> <li>• Inadequate propping</li> <li>• No CDM activity for this part of the works</li> </ul>		

<b>Project Detail</b>	Construction of a new sewer	<b>Case No.</b>	15
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	Void opened up in the road over the line of tunnelling		
<b>Consequence</b>			
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Unusual ground conditions, probably loss of fines during unexpected water ingress</li> <li>• Very difficult ground conditions.</li> <li>• Inadequate response to water ingress</li> </ul>		

<b>Project Detail</b>	Hotel construction	<b>Case No.</b>	16
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	Scaffold used for façade construction collapsed		
<b>Consequence</b>	One scaffolder died, two were injured. Prosecution of companies involved (PC and façade subcontractor). Scaffold subcontractor subsequently went out of business.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Scaffold members failed, almost certainly by buckling of posts</li> <li>• Scaffold was not designed properly and also was overloaded.</li> <li>• Missing bracing.</li> <li>• Inspections were not regularly undertaken</li> <li>• Low amount of tying, increased slenderness.</li> <li>• Loading tower was to be removed, so extra pallets of tiles were taken up;</li> <li>• Tower parts were also taken onto the scaffold; corner fell</li> </ul>		

<b>Project Detail</b>	Sewer construction project	<b>Case No.</b>	17
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	A length of tunnel collapsed, created significant surface depression.		
<b>Consequence</b>	Potential for injuries and fatalities. Disruption to project lead to economic loss by contractors and project sponsors		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Minor leak led to water leakage and ground disruption.</li> <li>• This effected the strength of the tunnel structure.</li> <li>• Geological data did not give clear and full information about sand characteristics or the thickness of the peat.</li> <li>• Contractors did not have a procedure for addressing complex ground conditions</li> <li>• Inadequacy in investigation and hence planning and preparation for potential events</li> </ul>		

<b>Project Detail</b>	Refurbishment of a city centre building façade	<b>Case No.</b>	18
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	During high winds a suspended platform came loose and smashed into the building causing building materials to disintegrate and fall onto street below		
<b>Consequence</b>	Hazard of injury and fatalities to workers and the general public. Transport disruption		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The platform had not been tied at roof or ground level in the windy weather, as specified by the manufacturer.</li> <li>• Contractor did not carry out adequate safety checks</li> <li>• Failure to recognise the implications of the hazard</li> <li>• The system had been incorrectly operated,</li> <li>• The platform system had been modified and hence made less safe</li> </ul>		

<b>Project Detail</b>	Construction of a new car park	<b>Case No.</b>	19
		<b>Categorisation Code</b>	AST2
<b>Major Hazard Event</b>	A nearby high-pressure gas main was almost penetrated during some excavation work		
<b>Consequence</b>	There was major risk of damage to local infrastructure as well as the potential for major injuries and fatalities		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The car park construction was in the vicinity of a gas pipeline</li> <li>• Final stages of the project were unduly rushed and driven by the client</li> <li>• The risks were not adequately identified</li> <li>• Clients ignored initial warnings</li> <li>• Various parties did not interact adequately</li> <li>• Inherent dangers were not appreciated</li> <li>• Pressures to ignore warnings were increased by late design changes and their subsequent requirements</li> <li>• Hazards were known but were not adequately considered on the design drawings</li> <li>• Contractors lacked experience</li> <li>• Contractor was not familiar with the hazards</li> </ul>		

<b>Project Detail</b>	Relatively small development for owner involving a new-build shop with flats over	<b>Case No.</b>	20
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	Building and adjacent scaffold were undermined by subsequent excavation work leading to the possibility of building collapse		
<b>Consequence</b>	Potential for major disruption to local infrastructure, injuries and fatalities. There were prosecutions and fines as a consequence of this event		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Inexperienced contractor was employed on the project</li> <li>• Contractor also provided drawings (beyond scope of experience)</li> <li>• Constructor commissioned a safety consultant who prepared an Health and Safety plan, which identified danger of undermining the ex. footings – but contractor didn't read them.</li> <li>• Building control inspector didn't have much impact – although he did draw PC's attention to the potential problem</li> <li>• Excavation started for the footings – undermined adjacent footings by 1.5m along 2/3 of the wall</li> <li>• Footings were excavated too deep and trial holes not completed as specified.</li> <li>• No-one formally engaged as temporary works designer</li> <li>• Lack of sub-contractor supervision</li> </ul>		

<b>Project Detail</b>	Construction of a metro tunnel through variable ground	<b>Case No.</b>	21
		<b>Categorisation</b>	AST1
<b>Major Hazard Event</b>	Collapse while constructing switch tunnel, inrush of soft materials and water. Hole was under a building, which was badly damaged.		
<b>Consequence</b>	Major damage to building and implications on local infrastructure.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• An old well under the building</li> <li>• Risk of tunnels not adequately addressed; wide tunnel could not support conditions at the foot of a tunnel</li> <li>• Risks from tunnels not taken seriously enough</li> <li>• Lack of knowledge and experience of this type of project by all parties involved</li> <li>• Failure to consider above ground infrastructure</li> <li>• Failure to consult building owner</li> <li>• Lack of investigation of potential hazards</li> </ul>		

<b>Project Detail</b>	Construction of a 12-storey office building in a major city centre	<b>Case No.</b>	22
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	During stormy weather, scaffold partially collapsed leaving substantial sections of the scaffold left hanging precariously over the adjacent roads and railway line.		
<b>Consequence</b>	Potential damage/disruption to local building and transport infrastructure		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Unusual weather conditions</li> <li>• Insufficient drawings were made. Numerous under calculations led to a very poorly specified and erected scaffold system</li> <li>• Scaffold system was not tied adequately to the adjacent building given the height (12 storey) of the scaffold and subsequent high winds.</li> <li>• A large number of unbalanced ties were observed.</li> <li>• Overloading of the anchors causing the scaffold system to fail followed by the failure of the tie as a whole.</li> <li>• Expansion plugs had not been fully driven home by installers.</li> <li>• There were three lifts of sheeted scaffold (6 metres height) above the highest level of scaffold ties which were not attached to the building in any way.</li> </ul>		

<b>Project Detail</b>	Strengthening work to a bridge that included the installation of new gantry runway beams and the removal of one of the original runway beams.	<b>Case No.</b>	23
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	A gust of wind moved the gantry along the runway beams, against the slope, and the trolleys at one end came off the beams causing the gantry platform to swing violently to a vertical position throwing the workmen to their deaths.		
<b>Consequence</b>	Four workers died		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• High gust of wind</li> <li>• Risks were not adequately considered</li> <li>• The climatic limitations on the use of the gantries under high wind speeds and directions (and their limitations) were not properly understood and adequately monitored</li> <li>• Lack of suitable equipment; lack of safety and risk assessment procedure; lack of competent personnel</li> <li>• Adequate end stops should have been provided at all open end of runway beams that were capable of safely stopping the gantry in all foreseeable circumstances</li> <li>• Inadequate system was used to prevent uncontrolled movement</li> <li>• All safety critical features of the gantry had not been designed to fail to safety where possible</li> <li>• Preference was not given to secondary or back-up safety systems to provide a suitable degree of redundancy rather than relying solely on the over-engineering of components</li> </ul>		

<b>Project Detail</b>	A two-storey workshop building was being erected between, and adjacent to, the railway line, railway station and a supermarket car park	<b>Case No.</b>	24
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	52 metre length of the scaffold toppled over across the adjacent railway line		
<b>Consequence</b>	Damage to railway infrastructure and disruption of transport services		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• High winds and vibration from oncoming trains caused the scaffold to collapse</li> <li>• The choice of a freestanding scaffold system was inadequate</li> <li>• No adequate safety calculations were made to ensure the safety of working personnel</li> <li>• The addition of debris netting to a height of 9 metres made it almost inevitable that the scaffold would topple over at some stage under unremarkable wind conditions.</li> <li>• There was no complete and specific calculation for the non-standard configuration to justify the tie arrangements and scaffold layout given.</li> <li>• Specific calculations had not been carried out to ascertain the measures required to ensure adequate strength and stability of the freestanding scaffold</li> <li>• The scaffold system with ledger bracing did not comply with the standard set of system configurations given in BS EN 12810: 2003</li> <li>• The scaffold system lacked strength and stability</li> </ul>		

<b>Project Detail</b>	Work in the excavation close to the lower borough rubble retaining wall	<b>Case No.</b>	25
		<b>Categorisation Code</b>	SC2
<b>Major Hazard Event</b>	Partial collapse of the rubble wall led to cracking at the road side		
<b>Consequence</b>	The incident involved situations where people might be working in an excavation where they were liable to be buried by a collapse, and people may fall into the excavation		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Lack of adequate calculations</li> <li>• Structural engineers decided the wall was being undermined in places because the foundations were not as good as they first thought.</li> <li>• Cracking on the road side which was of concern to the client and engineer although the Information was not properly communicated to the relevant parties (site manager and contract manager).</li> <li>• Work should have been undertaken under the direction of a suitably qualified structural engineer.</li> <li>• Sufficient steps were not undertaken to prevent persons or vehicles falling into the excavation.</li> <li>• No sufficient risk assessment or method statement had been formulated. All practicable steps had not been taken to prevent danger of collapse of the excavation and the excavation was not sufficiently supported to prevent danger</li> </ul>		

<b>Project Detail</b>	Preparatory works for redevelopment of an underground station	<b>Case No.</b>	26
		<b>Categorisation Code</b>	AST2
<b>Major Hazard Event</b>	There was an explosion when the mains electricity cables were stretched to breaking point		
<b>Consequence</b>	One of the workforce in the excavation was killed		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Incorrect setting out for initial cable diversion.</li> <li>• Poor site controls and contractor self certification.</li> <li>• No safety barrier between the operative and the electricity cable</li> <li>• Position of diverted cable not questioned or challenged – contractor self assurance</li> <li>• Moving services, particularly electricity cables, is common practice. Cable was already stretched to near breaking point</li> <li>• No safe system of work in place</li> <li>• No independent checking of setting out or work practice</li> <li>• Site staff either incorrectly instructed on cable diversion or the diversion was never checked</li> </ul>		

<b>Project Detail</b>	During motor way work the incident involved a site investigation that meant drilling over an underground tunnel.	<b>Case No.</b>	27
		<b>Categorisation Code</b>	AST2
<b>Major Hazard Event</b>	The casing or the shell from the borehole rig protruded into the underground tunnel, ripping through the offside of a moving underground train.		
<b>Consequence</b>	Could have derailed train and caused significant injuries to driver and passengers. Nobody was injured although the incident caused major disruption to the transport services		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Critically important information about the works was not passed on to appropriate parties</li> <li>• No one questioned the basis for the borehole grid coordinates even though some would have been aware of the potential for an incorrect grid coordinate system being used in error</li> <li>• On site checking of the borehole location only confirmed the initial setting out.</li> <li>• Appropriate personnel were not in attendance during important discussions</li> <li>• Risks should have been identified in the contract specification or at least the design consultants or site investigation contractor should have been alerted to the possibilities</li> <li>• Drilling onto cast iron and /or into a void at depth should have resulted in the work being stopped</li> <li>• Drawings may not have shown borehole positions relative to underground tunnel</li> <li>• Design for the site investigation process was not effective and not coordinated</li> <li>• Lack of communication between two different transport agencies</li> <li>• Errors by all members and all levels of the drilling crew team</li> </ul>		

<b>Project Detail</b>	A metro station construction between piled walls some 15m deep on a new metro line under a main highway	<b>Case No.</b>	28
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	It was an explosion due to a fractured gas main which took place under a temporary road deck beneath which was the construction of a station on a metro line		
<b>Consequence</b>	This one incident caused the deaths of more than 100 persons including 50 children		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• There was a lack of gas detection equipment</li> <li>• There was a failure to consider this type of risk</li> <li>• The source of the gas was in an adjacent construction area next to the covered over station construction</li> <li>• A fracture caused a “80mm” hole in the gas main and the local people had smelled the gas and had called out the local gas company</li> <li>• A blast seared through the 340m length of the underground station construction</li> <li>• A drain 1.4m away from the broken gas main provided a conduit for the gas between the open site and the covered-over metro construction</li> <li>• There were various sources of ignition particularly any hot work being done under the deck</li> </ul>		

<b>Project Detail</b>	Construction of a NATM tunnel under a major international airport	<b>Case No.</b>	29
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	3 tunnels collapsed		
<b>Consequence</b>	Massive project disruption, delay and cost		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Poor standards of construction</li> <li>• Poor monitoring of the work by the designer</li> <li>• Extremely poor management/engineering by design and construction parties on site and poor communication between them</li> <li>• Different management cultures between interfacing organisations</li> <li>• Poor monitoring of the movements not being interpreted properly.</li> <li>• No proper system for emergency repairs.</li> <li>• Hazards were not appreciated</li> <li>• Contractor had a lack of direct and relevant experience</li> <li>• Ad-hoc site repairs were carried out without proper planning and without any independent review</li> </ul>		

<b>Project Detail</b>	Extension was being made to a metro system using an NATM system	<b>Case No.</b>	30
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	Major collapse at the ground level occurred		
<b>Consequence</b>	Workers and members of the public were killed as a result of tunnel construction work		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The primary cause of the face instability (and this the whole collapse) was the transfer of water above the construction works into the face of the tunnel construction.</li> <li>• Failure to recognise ground compositions effectively</li> <li>• Above this level to the road was waterlogged gravel with a high level water-table</li> <li>• The face being excavated became increasingly unstable</li> <li>• Questionable risk control methods</li> <li>• Lack of risk management – no response when sand/water rushed in</li> <li>• Inadequate clay cover, no assessment of reduced cover and ignoring of risk of hydraulic connection</li> <li>• Designed with low cover; contractor possibly took on the risk without talking about it</li> <li>• Lack of good risk assessment by both designer and contractor</li> <li>• Lack of experienced and competent people involved</li> <li>• Risk taking practices</li> </ul>		

<b>Project Detail</b>	Modification of an existing double-track rail tunnel in which the invert was being lowered to permit bigger freight wagons to pass.	<b>Case No.</b>	31
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	Tunnel collapsed		
<b>Consequence</b>	Workers killed		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Effect of modification on tunnel not properly evaluated</li> <li>• A complete failure by client group to assess structural risk</li> <li>• Failure to consider a warning from experienced persons involved</li> <li>• Failure of contractor to assess the risks</li> <li>• Clear thinking about structural behaviour</li> <li>• Making assumptions</li> <li>• Failure to act on concerns</li> </ul>		

<b>Project Detail</b>	Construction of an undersea rail tunnel, twin-bore with cross passages, using TBMs.	<b>Case No.</b>	32
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	Modification was undertaken with the anti-flooding door open, water rushed in and flooded both tunnels		
<b>Consequence</b>	Massive project delay and extra costs		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Failure to maintain watertight security in TBM</li> <li>• Lack of knowledge and control at the workplace</li> <li>• Lack of competent supervision by management</li> <li>• Lack of proper work procedure with risk assessment</li> <li>• Ignorance and incompetence at management level</li> <li>• Work process not considered thoroughly</li> <li>• Interface problems between designers and contractors</li> <li>• Lack of an overall and careful consideration of risks for that work process and a more careful consideration of that work before starting.</li> </ul>		

<b>Project Detail</b>	Demolition work to tower block flats adjacent to retail park development	<b>Case No.</b>	33
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	An exclusion zone had to be put in place for the safety of town centre users as the demolition work was considered unsafe by the HSE. The contractor had not closed off the area and residents and public were set to continue using the area. However there was a major risk of collapse of the former tower block onto a shopping centre precinct. The HSE showed particular concern about the stability of the structure which was supported on six columns and a slender wall spanning from the ground floor to the underside of the second floor.		
<b>Consequence</b>	The area had a high volume of retailers and the general public. Risk to workers and to the public with possible catastrophic consequences		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The potential hazard arose some years ago with the removal of a stairwell pre-dating 1965/66</li> <li>• Underlying hazard only recognised through HSE intervention.</li> <li>• There was a certain degree of pressure for the contractor to complete the work discretely and not to restrict access to the area</li> <li>• The structure was considered to be particularly weak in the North and South direction.</li> <li>• Inadequate planning of 1960's hybrid / system of built flats with the all important stair and lift core demolished in advance of the accommodation 'wings'</li> <li>• The stair core and lift shafts had been removed</li> <li>• The prop and tie of the 1<sup>st</sup> floor had been removed leaving the wall spanning in excess of 16'0"</li> <li>• Demolition work hadn't taken into account the danger to the public</li> <li>• Historical drawings had not been checked adequately</li> </ul>		



<b>Project Detail</b>	Refurbishment of city centre building,	<b>Case No.</b>	34
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	There was an intervention by an HSE civil engineer following sight of a 30m high tube and fitting scaffold. The extension was later found to be un-braced. Further un-braced and inadequately restrained scaffold standards. were also found		
<b>Consequence</b>	The temporary works required urgent modification to ensure its structural safety and to remove serious risk of structural collapse. Located in a busy city centre street with direct impacts upon worker safety and the general public. Direct potential for temporary work collapse and possible effects on the permanent structure.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• There was a miscalculation in the design of the temporary works leading to a short supply of scaffold materials</li> <li>• The main contractor did not check and adequately question the plans of the sub-contractor</li> <li>• Inappropriate supply of scaffold fixings and parts</li> <li>• Once it was recognised that fixings were not fit for purpose, adequate time was not allowed for the appropriate fixings to be supplied</li> <li>• The design process for temporary works was not effective and not coordinated properly</li> <li>• Competent engineers did not react to the situation once faults were identified</li> <li>• Some suggestion of collusion between contractors due to the obvious nature of the hazard</li> </ul>		

<b>Project Detail</b>	Refurbishment and expansion of a city centre building	<b>Case No.</b>	35
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	The collapse was due to overloading with scaffold components and defective construction of the system		
<b>Consequence</b>	Major city centre route with potential for mass casualties and/or fatalities. Major disruption to the city centre area (business and transport activities)		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>§ Defective construction of the scaffold systems</li> <li>§ Lack of relevant checking of the system and failure to follow supply specifications</li> <li>§ The scaffold was overloaded</li> <li>§ Failure to recognise hazardous scenarios and influencing factors</li> <li>§ Major errors at all levels of the project development</li> <li>§ Poor team working</li> <li>§ Failure to consider residual risks</li> <li>§ Managed interfaces, communication and cooperation between contracting parties</li> </ul>		

<b>Project Detail</b>	Major redevelopment of a city centre building	<b>Case No.</b>	36
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	Collapse of 30 metre scaffold system. The access scaffolding collapsed perpendicular to the building construction		
<b>Consequence</b>	One fatality and several major injuries. Major disruption to city centre area		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Use of non-standard equipment</li> <li>• Lack of training of site personnel to the new scaffold system</li> <li>• Poor design of temporary structure</li> <li>• Failure to follow supply contractors specifications</li> <li>• Inappropriate use of software to facilitate the design process</li> <li>• Lack of appropriate temp works design; hoist supplier; and main contractor</li> <li>• Overloading had rendered the structure unstable.</li> <li>• The scaffold had not been adequately tied to the building structure</li> <li>• Lack of proper footing which subsequently compromised strength and stability</li> <li>• Temporary removal of adjustment ties and deflection of the scaffold columns from the main structure by a “jacking out” procedure</li> <li>• Overloading of building blocks onto 3 separate lifts</li> <li>• A graduate design engineer was left to bear responsibility for much of the work</li> <li>• The specialist scaffolding sub-contractor had not ensured that the design of the access scaffold (tie, height and pattern) had adhered to the recommended calculations (Completion or Handover certificate). Under strict compliance, overloading would not have occurred if the main contractor had ensured that only two scaffold lifts were operating at any one time</li> </ul>		

<b>Project Detail</b>	City centre building development	<b>Case No.</b>	37
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	Partial collapse of scaffold system		
<b>Consequence</b>	Risk to residents of the tower block, workers and the public in the possible event of a scaffold system collapse		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>The scaffold supplier had recently been changed. The contractors failed to use a familiar system</li> <li>Sub-contractor should have trained individuals to be competent with the system. Failure to provide adequate training on the new scaffold system</li> <li>Inadequate design of scaffold system resulted in movement of the scaffold away from the building development</li> <li>There was excessive distance between ring bolt and transom.</li> <li>The scaffold was not tied to the building in accordance with drawings.</li> <li>Failure to check information provided by suppliers - Ties were not staggered in accordance with technical information provided by the supply contractor</li> <li>The stability of the scaffold was significantly compromised.</li> <li>At roof level the scaffold had deflected away from the building which risked significant falls from height between the inside edge of the scaffold and the face of the building</li> </ul>		

<b>Project Detail</b>	Building development	<b>Case No.</b>	38
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	The scaffold was a three bay 20metre high loading tower. Two sections of a scaffold loading bay tower approximately 20 meters in height collapsed.		
<b>Consequence</b>	A subcontractor, who was working on the scaffold 12 meters from the ground, fell roughly 5 meters into the components of the collapsing tower and was struck by a board and other components, suffering severe head lacerations, a broken wrist and a broken rib. The incident happened at 10am at a relatively dormant period of activity. There was potential for further multiple injuries and fatalities had the incident occurred at a more active period		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>The primary factors were failure to appreciate that such a structure would require significant temporary work design</li> <li>Failure to provide information on the safe loading for this structure</li> <li>Failure to control the loading of material onto the structure</li> <li>The loading bay tower collapsed as a pallet of building blocks weighing one ton was loaded onto it</li> <li>The scaffold system was not fit for purpose. The scaffolding tower was not designed and then overloaded</li> <li>There was insufficient plan bracing and the outer bay was carrying approximately 10 ton of concrete block immediately prior to the collapse. The structure had been severely overloaded although a number of factors contributed to the final collapse</li> </ul>		

<b>Project Detail</b>	Major redevelopment of a city centre building	<b>Case No.</b>	39
		<b>Categorisation Code</b>	CTW2
<b>Major Hazard Event</b>	During an inspection of a refurbishment project to a city centre building, the HSE noticed that the scaffolding banner was not properly tied to the scaffold and the building.		
<b>Consequence</b>	Due to this being a main shopping area and main traffic route there was potential for public fatalities.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>There was no design drawings for the banner or for the scaffold and ties required to support it. There was no design for the banner and likewise for the scaffold and ties to support the banner.</li> <li>The use of proprietary hand railing components for the banner frame was considered to be unsafe and inappropriate for such an application.</li> <li>The worker/s assigned to the specific task should have been conscious of risk</li> <li>The obvious dangers to the public were overlooked</li> <li>Engineers were not meticulous about all aspects of the temporary works</li> </ul>		

<b>Project Detail</b>	Gas mains renewal works in a major city centre	<b>Case No.</b>	40
		<b>Categorisation Code</b>	AST3
<b>Major Hazard Event</b>	A prohibition notice was served		
<b>Consequence</b>	Potential risks to road users of such poorly shored/supported excavations in the event of a collapse of the sides endangering roadway (e.g. a large vehicle entering an excavation). Multi injury potential.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• No clear design process in place by the contractors</li> <li>• Lack of adequate support during excavation works</li> <li>• Plastic trench sheets were used with only 2 adjustable props with bolts mid span</li> <li>• Supervisors failed to provide suitable guidance to operators</li> <li>• Supervisors and site engineers failed to monitor and control the works</li> <li>• Lack of experienced engineers</li> <li>• No client or design level checks</li> </ul>		

<b>Project Detail</b>	Cofferdam method used for the construction of a 665-metre culvert during a city centre excavation	<b>Case No.</b>	41
		<b>Categorisation Code</b>	AST3
<b>Major Hazard Event</b>	The sand bag bund used to secure the culvert area from flooding collapsed		
<b>Consequence</b>	Two workers almost drowned during the incident		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The contractor consciously made the decision to secure one end of the cofferdam with sandbag bunds, or barriers, to prevent flooding when the tide came in, which effectively rendered this a confined space.</li> <li>• Contractor admitted that they had failed to ensure the health and safety of employees who were constructing the culvert</li> <li>• There was insufficient management of hazards</li> <li>• Workers were not briefed and did not work to method statements (e.g. Emergency Procedures, Access/Egress requirements). Operations were inadequately managed and they failed to construct a sandbag barrier in accordance with the design set out in the company's method statement</li> <li>• There were management staffing issues, through holidays, sickness and change in staff</li> <li>• There was a failure to communicate sufficient method statement and emergency procedures</li> </ul>		

<b>Project Detail</b>	Design and build contract to construct two tunnels as an extension to a transportation system	<b>Case No.</b>	42
		<b>Categorisation Code</b>	AST1
<b>Major Hazard Event</b>	A breach occurred in the lining of the tunnel wall due to excess compressed air pressure causing water leaking into the tunnel during construction of a cross passage.		
<b>Consequence</b>	The blowout which occurred created a large crater in the grounds of a local school and showered nearby buildings with debris. Incident occurred at night. Had the blow-out occurred just a few hours later, then a public disaster may have resulted. Almost undoubtedly there would have been significant numbers of seriously injured schoolchildren, with possible loss of life among those closest to the location of the blow-out.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Calculations carried out for the contractor were inadequate.</li> <li>• There was not enough overburden to resist internal forces exerted by the compressed air and this led to a rapid escape of pressure.</li> <li>• The risk of blowout due to internal pressure build-up in the tunnel was overlooked.</li> <li>• Design consultant should have warned the main Contractor about the risk of blow out while compressed air was in use in the tunnel.</li> <li>• Lack of coordination between the design and main contractors.</li> <li>• The consequences and range of alternatives construction methods had not been discussed between contractors (Design and Construct).</li> <li>• Contractors should have checked requirements</li> <li>• There was a failure of the contractor to carry out and supply adequate calculations</li> </ul>		

<b>Project Detail</b>	Refurbishment of church roof	<b>Case No.</b>	43
		<b>Categorisation Code</b>	CTW1
<b>Major Hazard Event</b>	The job was called to a halt as there were several improprieties noticed including inadequate temporary bracing of the new roof trusses to the church building.		
<b>Consequence</b>	Potential collapse risks to workers / public (including children's nursery / playgroup). Major risks to workers and general public. Potential for major disruption and damage to local infrastructure.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Failure to provide temporary bracing to large heavy timber roof trusses to replacement roof to church.</li> <li>• Inexperience and incompetence of Site Works Engineer</li> <li>• Engineer failed to recognise the risk to this particular development</li> <li>• Failure of contractor to recognise limitations of engineers</li> <li>• Clear design instructions should have been passed over to engineer rather than assumptions made about experience</li> <li>• Interface problems between design and construction</li> <li>• Design team could have run on-site checks</li> </ul>		

<b>Project Detail</b>	Construction of additional steel framed floors to a former newspaper press building	<b>Case No.</b>	44
		<b>Categorisation Code</b>	CTW1
<b>Major Hazard Event</b>	A partial collapse occurred during the construction of additional steel framed floors to the former newspaper press building. The building was being converted into multi occupancy accommodation, which included a section of new build steel frame structures and concrete floor slabs from the upper levels of the existing reinforce concrete framed structure.		
<b>Consequence</b>	Near to, although not directly accessed by, a populated area. If further collapse had occurred the problem could have been greater		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• No calculations were prepared by the consulting engineer. Collapse of the two temporary steelwork support structures occurred while the concrete was being placed</li> <li>• The collapse occurred due to overload of the temporary structure and on-site (ad-hoc) support requirement</li> <li>• The principal contractor had no temporary works design ability</li> <li>• Failure of initial design investigations to identify a service void in the location of the footing of the proposed steel frame structure and of temporary works</li> <li>• Failure to question the relevance for mortar "buttering up" given the depth of concrete removed from the wall heads of a service void.</li> <li>• No mortar specifications provided by the site works engineer</li> <li>• Construction of the reinforced concrete floor slabs should not have commenced until the steel angle supports were secure</li> <li>• Principal contractor and site management supervision arrangements were poor</li> </ul>		

<b>Project Detail</b>	Refurbishment of an existing building	<b>Case No.</b>	45
		<b>Categorisation Code</b>	SC3
<b>Major Hazard Event</b>	There was a partial collapse of a stone support pier during the refurbishment. There was potential for further collapse if work had progressed without temporary shoring having been properly designed.		
<b>Consequence</b>	Immediate danger to workers on site although there was the possibility of public injuries and fatalities had the collapse significantly compromised the integrity of the whole building		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The work was being undertaken by a relatively small contractor who had not requested any proper designs for needling support.</li> <li>• Poor initial advice given by the falsework representative</li> <li>• Failure to design appropriate temporary works for forming a new large opening during refurbishment</li> <li>• Initially there was incorrect information used to work out the loading on new beams for opening out on the building</li> <li>• There was a requirement for a greater density of props than originally detailed in initial drawings</li> </ul>		

<b>Project Detail</b>	Construction of a large leisure centre complex	<b>Case No.</b>	46
		<b>Categorisation Code</b>	SC2
<b>Major Hazard Event</b>	Ceiling collapsed		
<b>Consequence</b>	The incident happened only days before the complex were due to open to the public. No one was inside and there were no injuries although the theatre had the capacity to hold 500 people		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The designs were unworkable resulting in unauthorised changes</li> <li>• There was no evidence of inspection or supervision of installation</li> <li>• Lack of communication between principal contractor and client</li> <li>• Supporting beam breaking loose due to the extreme weight pressure</li> <li>• The false ceiling was not adequately secured leading to a supporting beam breaking loose, causing 200m<sup>2</sup> of ceiling which held the lights and the fire preventing sprinkler system to collapse in one of the auditoria (theatre 7)</li> </ul>		

<b>Project Detail</b>	Construction of five blocks of timber framed apartments and retail units	<b>Case No.</b>	47
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Fire occurred completely destroying all new block developments and causing significant damage to surrounding buildings		
<b>Consequence</b>	Caused major gridlock in area, damaged nearby buildings, serious threat to potential residents of completed apartments, construction workers and fire service personnel due to dangerous fire fighting operational conditions - unsecure access/ retreat and unreliable water supplies		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Lack of compartmentation, completed stairwells and flammability of construction materials</li> <li>• The initial work programme changed although there was no additional measures taken in response</li> <li>• The work program ignored the high fire hazard</li> <li>• Lack of appreciation of the vulnerability of the building at that stage of construction and lack of control of ignition sources</li> <li>• Apparent disjoint between those responsible for site safety and those responsible for the construction program</li> <li>• Suspected careless disposal by operatives of smoking materials in area of highly flammable waste materials</li> </ul>		

<b>Project Detail</b>	Refurbishment of an important tourist attraction and potential commercial centre	<b>Case No.</b>	48
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Suspicion of Arson		
<b>Consequence</b>	Due to dangerous fire fighting operational conditions (unsecure access/ retreat from fire and unreliable water supplies) fire fighters were put at risk		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The structure was old and had been abandoned for many years. It was closed to the public and not maintained and was boarded up awaiting refurbishment</li> <li>• Arson was not detected early, relying on members of the public to alert authorities.</li> <li>• Although the site was boarded up, there was no effective access from sea, or land at low tide</li> <li>• The structure was not maintained at all, but security was ineffective</li> <li>• The site was only accessible by sea, which made the job of fire fighting extremely difficult</li> <li>• As a Grade 1 listed building, it is notable that no fire safety or security measures were in place in spite of the known fire risk</li> </ul>		

<b>Project Detail</b>	Major Refurbishment of an ancient 'heritage' timber built vessel	<b>Case No.</b>	49
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Failure of industrial vacuum cleaner led to serious fire damage		
<b>Consequence</b>	Due to dangerous fire fighting operational conditions (unsecure access/ retreat from fire and unreliable water supplies) put fire fighters at risk. Loss of irreplaceable heritage, and damage of reputation to contractors and heritage trustees		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Industrial vacuum cleaner left on over weekend without sufficient checking</li> <li>Failure of industrial vacuum cleaner led to serious fire damage</li> <li>Contractors and conservationists did not review work processes effectively</li> <li>Security team did not understand the significance of their duties, which included constant checks and monitoring - not merely prevention of unauthorised access</li> <li>Poor communication</li> <li>There was no clear information whether or not flammable gas cylinders were on site, hence fire fighters could not enter the structure</li> </ul>		

<b>Project Detail</b>	Development of a 7 storey high hybrid construction development of approx 82 flats: ground floor comprising reinforced concrete transfer slab over basement car park with a 6 storey high timber framed building above.	<b>Case No.</b>	50
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Fire broke out in the timber frame during construction. Suspected arson.		
<b>Consequence</b>	Approx 50 recently completed occupied flats in adjacent properties were evacuated as they were potentially within the collapse zone of the tower crane. Local railway line had to be closed and local connecting roads were closed for several weeks. The construction site had to be closed leading to time scale delays and subsequent economic losses		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>Contractor not experienced in coping with circumstances such as this and hence lacked required skills.</li> <li>Failure to recognise scenarios, there had been previous well documented incidents in timber framed construction sites</li> <li>Commercial considerations were the overriding decision factor which included insufficient site security once construction was suspended</li> <li>Unwillingness of contractors to invest in adequate security and safety precautions</li> </ul>		

<b>Project Detail</b>	Refurbishment of an important commercial development, and an existing tourist attraction	<b>Case No.</b>	51
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Arson was the suspected cause of the fire		
<b>Consequence</b>	Dangerous fire fighting operational conditions (unsecure access/ retreat from fire and unreliable water supplies) put fire fighters at risk		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>The client consortium who did not engage competent persons to advise them, nor communicate sufficiently with the fire service</li> <li>The structure was run-down and ill-maintained, and the majority of it was 100 years old</li> <li>The fire risk had not been adequately assessed</li> <li>No on-site security operating, and it was known that vandalism was occurring on-site, nothing was done</li> <li>Fire brigade access was difficult and water supplies unreliable due to the nature of the structure</li> </ul>		

<b>Project Detail</b>	Construction of an addition of a 2-storey extension to an existing, operational 4-storey hospital building	<b>Case No.</b>	52
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	It is considered that the most likely cause for this fire was hot works on site, which caused a fire which spread through rubber insulation on an external riser into the roof void of the existing building, compromising compartmentation		
<b>Consequence</b>	Loss of 2 floors of operational health units, loss of entire facility for 10 days, need to evacuate 79 patients and 200 staff. Also resulted in the loss of 40 years of oncological research data		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The work necessitated hot welding on site, although this was done by competent contractors under a hot work permit</li> <li>• Flammability of the weatherproofing material was not recognised</li> <li>• Other combustible materials were present within the service tower which added to the fuel load.</li> <li>• Poor choice of weatherproofing in conjunction with programming of welding</li> <li>• Relevant codes and plans for safety were not applied effectively</li> <li>• No 'fire watcher' was appointed, so the fire was not extinguished when it was possible to do so</li> <li>• Lack of site control with limitations in experienced supervision</li> </ul>		

<b>Project Detail</b>	Rail tunnel excavation under a sea channel	<b>Case No.</b>	53
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Uncontrollable fire broke out on Tunnel Boring Machine during construction -		
<b>Consequence</b>	The workers were placed in serious danger. The project was severely delayed and the financial cost was high		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Fire was caused by a pin-hole leak in the pressurised system containing highly flammable liquid.</li> <li>• Fire risk from pressurised oil which was atomised was understood, however failure to recognise importance of maintenance and checking of high pressure delivery pipe work that contained flammable liquid.</li> <li>• The hazard was not foreseen to be as major as it proved to be.</li> </ul>		

<b>Project Detail</b>	Construction of 5-storey block development consisting of 34 flats	<b>Case No.</b>	54
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Large scale fire.		
<b>Consequence</b>	Threat to significant number of nearby residents and also to their properties and fire fighters due to dangerous fire fighting operational conditions - unsecure access/ retreat from fire and unreliable water supplies. Hazard to residents from smoke and hot gases, loss of security and home for vulnerable people. Adjacent properties were damaged and some gutted. Nearly 200 evacuated and many made homeless. Potential for residents to become trapped.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Lack of knowledge as to recognised hazards from small wood sections and particleboard which were easily ignitable</li> <li>• Once ignited, timber frames under construction lacked fire separation and the fire developed extremely quickly</li> <li>• Risk of arson was not addressed properly</li> <li>• Role of fire advising was not totally clear</li> <li>• Lack of appreciation of the vulnerability of the building at that stage of construction and lack of control of ignition sources</li> <li>• Low levels of site control</li> <li>• The upgrading of site security had been considered and dismissed on cost grounds</li> </ul>		

<b>Project Detail</b>	Major refurbishment during occupation of a high rise building	<b>Case No.</b>	55
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Small fire escalated causing the structural collapse of several floors		
<b>Consequence</b>	Major fire at night caused huge numbers of people watching and subsequent traffic congestion resulting in difficult access for fire service. Loss of major building and power.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Developers did not recognise the increased fire risk of refurbishment whilst maintaining occupation</li> <li>• A small fire, extinguishable by first aid fire fighting, escalated to a major fire and spread upwards and downwards</li> <li>• No labels were identified to show which risers supplied the fire floor</li> <li>• No previous survey by the fire service to ensure they had sufficient information to create an effective plan</li> <li>• Fire brigade attempted to fight fire with hose reels but did not secure water supply and retreated</li> <li>• Numerous errors at all levels of construction and service (including Fire Service, Building Managers, Security)</li> </ul>		

<b>Project Detail</b>	Redevelopment of sea front tourist attraction and commercial units	<b>Case No.</b>	56
		<b>Categorisation Code</b>	F
<b>Major Hazard Event</b>	Fire		
<b>Consequence</b>	Due to dangerous fire fighting operational conditions (unsecure access/ retreat from fire and unreliable water supplies) put fire fighters at risk. Loss of significant tourist and commercial facility for several years, in small coastal town		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Loss of effective water supply led to the fire (which at one point appeared under control) breaking out and destroying much of the development</li> <li>• Hazards on-site were increased due to requirement of developers to generate funds by continuing commercial operations whilst refurbishing</li> <li>• Although a Fire Safety Order (FSO) would apply to this site, the property protection aspects were not given sufficient priority</li> <li>• Lack of hazard overview and effective monitoring due to multiple lease-holders operating in close proximity</li> </ul>		

<b>Project Detail</b>	Construction of pre-stressed precast concrete approach viaducts across a river	<b>Case No.</b>	57
		<b>Categorisation Code</b>	CTW1
<b>Major Hazard Event</b>	The girders of a launching gantry collapsed causing a precast segment to fall and penetrate the deck of the completed portion of viaduct		
<b>Consequence</b>	There were a significant number of construction personnel in area of collapse. No one was injured in the collapse but the recovery of the precast unit, repairs to the viaduct and repairs to the launching gantry caused significant cost and delays to the project.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The event involved the operator applying an emergency stop which cut power to the primary braking system and applied a static brake – friction from this brake caused overheating, reducing the effectiveness of the brake. The 40T hoisting crab and the 200T precast segment ran back on the storage section of the gantry that was not designed for this load and thus collapsed.</li> <li>• Designers of the launching kit did not consider the emergency stop load condition where the dynamic brake would not work (because its power was cut) – the static brake was only envisaged to be used once the hoisting crab was stationary.</li> <li>• The storage section of the gantry was not designed to carry the weight of the hoisting crab and the precast unit as this condition was not envisaged.</li> <li>• This was a product failure, but mainly caused by the designers not considering all the potential adverse incidents.</li> <li>• There was also process and people failure in that the operator had not been advised to only use the emergency stop when the crab and its load were stationary.</li> <li>• There was a lack of independent review of launching gantry design</li> </ul>		



<b>Project Detail</b>	Extension and refurbishment to a hotel	<b>Case No.</b>	58
		<b>Categorisation Code</b>	C&MPE1
<b>Major Hazard Event</b>	As the crane top was lifted on the climbing frame, the crane top fell backwards, rotated through 180° and landed on the roof of the occupied hotel		
<b>Consequence</b>	The tower section that had been used as a balance weight was thrown through the roof of the hotel's banqueting suite where a wedding reception has been due to start 30 minutes later. The operator was injured although no injuries were sustained to members of the public using the hotel.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Two tower cranes had been erected on site, one of which was being increased in height by climbing</li> <li>• The erection supervisor was unfamiliar with the climbing frame and had not appreciated the need for the climbing frame to be fastened to the base of the slewing section, despite the requirement being detailed in the Method Statement.</li> <li>• There were time pressures due to unrealistic targets being set for completion of the various tasks</li> <li>• The erection supervisor did not lead the team effectively and did not carry out effective team briefing on tasks that needed to be carried out</li> <li>• The bolts connecting the crane top to the top of the tower were removed</li> <li>• No nuts or washers were used to connect the crane top to the climbing frame</li> <li>• The crane top was not secured to the climbing frame and the crane top was not balanced about the tower. When the climbing frame was raised, the movement was sufficient to cause the crane top to fall backwards.</li> <li>• As the crane top was lifted on the climbing frame, the crane top fell backwards, rotated through 180° and landed on the roof of the occupied hotel</li> </ul>		

<b>Project Detail</b>	Construction of an office block in a major city centre using tower cranes	<b>Case No.</b>	59
		<b>Categorisation Code</b>	C&MPE1
<b>Major Hazard Event</b>	Crane collapsed		
<b>Consequence</b>	The crane landed in a main city centre area		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Subcontractors were hired who did not have appropriate expertise and there was no in-house expertise</li> <li>• Regular site inspections by experts was omitted in an attempt to save money</li> <li>• The bolted joint between the steel members had not been correctly designed to for tension and was not pre-loaded to accommodate fatigue</li> <li>• The bolts were too short</li> <li>• Checks by the contractor were numerical only and there was no review</li> <li>• There was a failure to spot the inadequate and unspecified bolt size and lack of pre-stress to resist fatigue</li> <li>• During operation and cyclical loading and unloading over time the bolts failed due to fatigue and the crane to collapse</li> </ul>		

<b>Project Detail</b>	Major construction development	<b>Case No.</b>	60
		<b>Categorisation Code</b>	C&MPE1
<b>Major Hazard Event</b>	The front offside outrigger of a tower crane punched through the kerb on which it had been placed and a mobile crane used to hoist a tower crane overturned.		
<b>Consequence</b>	The mobile crane was set up in a public road which ran between the main site and a compound containing the site offices and welfare facilities. The road also contained a number of houses, one of which was being used by the resident engineers, whilst the others were occupied by residents. Several houses were damaged.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The jib of one of the tower cranes was being removed, using a mobile crane, during the dismantling of the crane so that the rail bogies on the travelling base could be replaced</li> <li>• The front offside outrigger was set up on ground with inadequate bearing capacity</li> <li>• There was a lack of effective planning by the appointed person</li> <li>• Inadequate planning and inadequate ground assessment</li> <li>• Lack of assessment of ground conditions and lack of understanding of ground bearing capacity of kerbs and pavements</li> </ul>		

<b>Project Detail</b>	Luffing jib tower cranes were being used in the construction of a large building.	<b>Case No.</b>	61
		<b>Categorisation Code</b>	C&MPE1
<b>Major Hazard Event</b>	A tower section was being climbed in to the tower of one of the cranes. As the section was being lowered onto the top of the tower, the climbing frame collapsed with the crane top		
<b>Consequence</b>	Three members of the erection team were killed as a result of the 120m fall. Debris from the crane was spread over a wide area		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• Cranes were tied to the structure and were being extended, by climbing, as the structure increased in height</li> <li>• There was a lack of effective planning, including contingency planning.</li> <li>• There was inadequate training and lack of appropriate personnel on site.</li> <li>• Manufacturer's instructions for balancing the crane and bypassing of slew interlocks were not adequately followed</li> <li>• Lack of anemometer on the crane</li> <li>• Bypassing of interlocks to prevent inadvertent slewing</li> <li>• Incorrect balancing of the crane.</li> </ul>		

<b>Project Detail</b>	A luffing jib tower crane was being erected on site for general lifting duties on a city centre construction project	<b>Case No.</b>	62
		<b>Categorisation Code</b>	C&MPE1
<b>Major Hazard Event</b>	The crane top fell onto the partially completed structure, the counterweights became detached and fell into the building		
<b>Consequence</b>	A joiner working below was killed. The crane operator survived with minor injuries.		
<b>Potential Causative Factors</b>	<ul style="list-style-type: none"> <li>• The forward moment of the jib was not sufficient to overcome the wind force at maximum in-service wind speed, allowing the luffing rope to become slack.</li> <li>• The guarding on the sheave block did not prevent the rope detaching from the sheave</li> <li>• A gust of wind was sufficient to blow the jib back, allowing the luffing rope to go slack and the rope to jam alongside one of the sheaves</li> <li>• The operator, in an attempt to lower the jib, paid out a significant amount of luffing rope from the winch, which looped down behind the crane. The rope then became free from the sheave block and the jib fell, until arrested by the luffing rope</li> <li>• The crane design was later considered defective</li> <li>• There had been a lack of adequate assessment at product design stage</li> <li>• Inadequate margins allowed by the manufacturer for jib stability.</li> <li>• Possible discrepancies with understanding the relevant European Standards</li> </ul>		



# Preventing catastrophic events in construction

The construction industry recognises the hazardous nature of its activities, which can be seen in the high toll of accidents its workers suffer compared with other industries - ranging from lost time injuries to fatalities. There is also a high incidence of ill-health among construction workers, including fatal diseases such as cancer arising from asbestos exposure. However, the industry may not be sufficiently aware of the potential for it to be associated with more major or catastrophic events (those involving multiple deaths and/or significant damage to property and infrastructure).

Larger construction organisations have been applying 'holistic' risk management techniques to manage project risk. Low probability but high-consequence issues have often been included in these considerations. Most issues addressed have had purely commercial consequences eg sudden loss of a major contract or customer. However, some issues do have significant health and safety implications.

This project has examined these 'low probability but high-consequence' safety hazards by looking at:

- the types of catastrophic event which have occurred or which might occur during construction;
- the reasons for occurrence when there have been (or could have been) catastrophic events during construction, including an examination of the underlying factors;
- the controls which should contribute to an avoidance of a catastrophic event; and
- where the UK construction industry could improve.

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