Fatal accidents in the Irish construction industry 1991-2001: A survey of contributory factors.

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EXECUTIVE SUMMARY

The research examines the factors contributing to fatalities in the Irish construction industry for the period 1991-2001. A review of the relevant literature is presented together with a summary of two theoretical models of accident causation.

Investigating inspectors for the Health & Safety Authority completed questionnaires relating to each fatality. Information was obtained in relation to contributory factors at Headquarter (HQ), Site Management (SM) and Injured Party (IP) levels.

- Statistical analyses revealed a ratio of 2:1:1 for SM, HQ and IP factors respectively, replicating the results of previous research by the HSA and the HSE. That is, inspectors identified site level factors twice as often as either HQ or IP factors when assessing the causes of a fatality *(see p.39)*.

- The 2:1:1 ratio is maintained across individual years, across employment status and incident type *(see pp.41-43)*.

- The data was examined for the impact of the Safety, Health and Welfare at Work Regulations (1995). No significant alteration in contributory factors arose from the introduction of the Regulations. However, this result is compromised by the scarcity of data for the years 1991-1994.

- The SM items that cited most often are: *(see p.49)*
  - Failure to implement a Safe System of Work
  - Failure to identify hazards on site

- The HQ items most often cited are: *(see p.50)*
  - Failure to carry out adequate hazard identification and risk assessment
  - Failure to take adequate consideration of design factors or features
  - Competence of dutyholders (Project Supervisor for the Design Stage, Project Supervisor for the Construction Stage, designer, contractor)

- At IP level the following items featured: *(see p.51)*
    - Unsafe act / risk-taking behaviour because of inadequate Safe System of Work
    - Using initiative to solve problem (not trained / experienced for task)

- A factor analysis extracted underlying themes in the dataset. The strongest factor comprised a majority of HQ items, identifying failures that occur at the inception of a project *(see p.44)*.

- Summary analyses revealed the following: *(see p.38)*
    - falls from height accounted for 44% of fatalities over the 11 years
    - data for the period 1998-2001 revealed that 45% of sites where a fatality occurred did not have an appointed PSDS /PSCS

In line with modern theories of accident causation, which emphasise the importance of factors upstream of the accident event, it is proposed that future legislation and campaigns should focus on events and actors at the HQ level. The knock-on effects of failures suggests that remedial action at HQ level could pre-empt errors further along the project chain.

Recommendations are made in relation to data collection and future research.

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INTRODUCTION

It is important to recognise the significance of construction to Irish industry. The construction sector represents 19% of total economic activity in Ireland, employing 185,000 personnel, and a further 75,000 employed in construction-related industries (CIF, 2002).

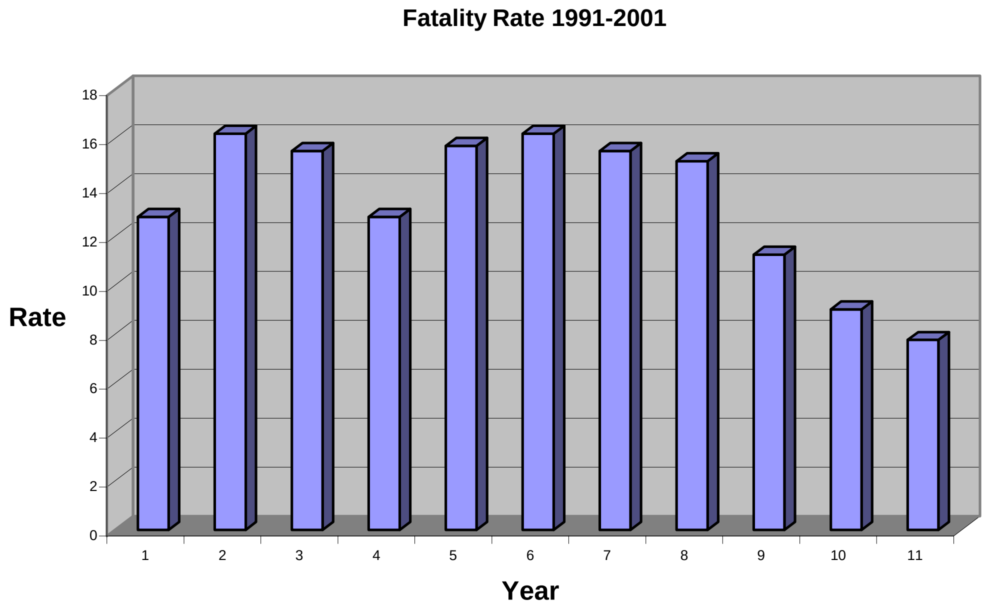
There is widespread concern at the disproportionate number of workplace fatalities and serious accidents in the industry. For example, in 2001, 28% of all fatalities occurred in the construction sector. The figures consistently indicate that Construction is second only to Agriculture and Forestry in terms of fatalities.

Table 1. Total fatalities and construction fatalities 1991-2001

Year	91	92	93	94	95	96	97	98	99	00	01
Total Fatalities	57	46	64	50	78	59	48	70	69	70	64
Construction Fatalities	10	12	11	10	13	14	15	22	18	18	18

There is some cause for optimism - the rate (per 100,000) of construction fatalities is decreasing since 1996 (see Figure 1). However, the unadjusted number of fatalities is unacceptable, remaining at 18 for the last three years.

Figure 1. Fatality Rate 1991-2001



The decrease in the fatality rate is mirrored in levels of safety activity over recent years. There has been a steady increase in the number of inspections carried out by HSA inspectors, with a corresponding increase in the percentage of construction sites that have safety consultations and safety representatives. The number of recorded safety statements has also increased. However, this figure represents safety statements available for each employer rather than the safety and health plan for an entire site. The safety and health plan is the responsibility of the Project Supervisor Construction Stage and incorporates the safety statements of all the contractors on-site. The percentage of sites with a full safety and health plan would be more indicative of the levels of safety activity.

Table 2. Safety Activity 1998-2001

Year	1998	1999	2000	2001
Inspections	4707	4052	5066	6508
Safety Statement %	49.9	51.7	57.2	71.4
Safety Consultation %	35.6	32.1	37.3	44.3
Safety Representative %	6.2	7.1	9.3	12.4

The breadth of the industry presents a unique challenge for the application and integration of health and safety regulations. According to the HSE, the construction sector represents 'a challenging regime in which to manage health and safety' (HSE, 2001, p.5). The sector includes enormous diversity in terms of the size and range of its activities. It is also an 'inherently hazardous environment with direct exposure to height, forces, power etc.' (HSE, 2001, p.5).

Construction activity necessarily involves change. Compared to relatively stable manufacturing or retail environments, construction involves constant change, to the extent that each development on a building project alters the working environment. Thus, the preparation of a safety and health plan that encompasses the duration and scope of a construction project is problematic. 'Change is known to be one of the prime conditions which induces unsafe behaviour, either when a system is in a state of transition or after the introduction of new items of equipment, operating personnel or revised procedures' (HSE, 1992, p.29). The degree of change inherent in construction projects may induce unsafe behaviour, while at the same time precluding straightforward defensive measures.

It is difficult to legislate for the enormous variation in the size of construction projects. Safety regulations are required to apply generically across the spectrum, from domestic extensions to major infrastructure projects.

The diversity of employment arrangements in the sector also prohibits any overarching safety policy. The widespread use of sub-contractors and self-employed workers creates a situation where multiple approaches to safety exist on one site, resulting in a 'complex communication chain' (HSE, 2001, p.24). The 1992 HSE research notes that 'one of the greatest problems faced by those responsible for the overall management of a project is the need to integrate a wide variety of subcontractor 'styles' within the overall project. The complex chain of command may lead to the diffusion of responsibility and accountability for safety performance. The development of the role of Project Supervisor for the Construction Stage (PSCS) in the Safety, Health and Welfare at Work (Construction) Regulations 1995 aimed to improve co-ordination of the various groups on-site to ensure minimum standards of safety performance.

LITERATURE REVIEW

2.1 Research into management, organisational and human factors in the construction industry (HSE, 1992)

The structure of the current study is adopted from a multi-level analysis commissioned by the HSE (1992). The research examined factors contributing to serious accidents in the construction industry at management, organisational and human level. The stated objective of the research was to examine 'the extent to which safety performance in the industry may be undermined by factors beyond the control of the individual worker' (p.2). Thus, in line with modern accident theory (see section 4), the aim is to shift the emphasis from errors on the part of the individual to the management and organisational errors that cause poor safety performance.

Interviews and postal surveys were used to gather information across the construction industry, representing civil engineering, house building, management contracting, main contractors and sub-contractors. Safety managers, project managers and site managers were among those interviewed. Reports of 30 fatal and serious accidents were examined in detail.

The three groups of contributing factors are of relevance to the current study. Headquarter (HQ) issues represent 'problems at a general safety policy level or related to factors at a project management rather than a site management level' (p.19). Site Management (SM) issues represent 'problems in immediate or on-going site management'. Injured Party (IP) factors relate to the individual worker and his immediate colleagues.

The analysis revealed a ratio of 2:1:1, with the SM category featuring twice as often as the other categories. The pattern of linkages between the groups was found to be sequential: headquarter factors influence site factors which influence other site factors, site management factors influence individual factors. In terms of linkages the most influential items were evident at HQ level:

- Inadequate safety training of management (15 links across the 30 studies)
- Poor system for controlling plant maintenance (10 links)
- Other HQ factor (17 links)

And at SM level:

- Failure to communicate SSW to operators (15 links)
- Failure to set up SSW for permanent task (13 links)
- Failure to identify hazards on site (12)
- Provision of wrong equipment for task (10)

A further exercise gauged project managers', site managers' and sub-contractor managers' own perceptions of the factors that most undermine safety performance on-site. Respondents were presented with nineteen factors arising from the first stage of the research. There was consensus across the groups regarding the most important factors:

- Lack of time
- Lack of skilled supervisors
- Inadequate safety training for workforce
- Lack of skilled workers
- Over-reliance on sub-contractors

The authors conclude that accidents do occur 'because of factors which essentially lie outside the individual's control, such as overt time pressures, lack of appropriate equipment, or inadequate training' (p.27). They propose an alternative approach to accident investigation, a version of Reason's (1990) model of accident causation that identifies the underlying causes of unsafe behaviour at SM and HQ levels. The theory is described in detail in Section 4.

2.2 Summary of information from survey into fatal accidents 1995-1997: Construction Industry (HSA, 1998)

In 1998, the HSA conducted an internal review of Irish construction fatalities for the period 1995-1997, using the questionnaire from the HSE (1992) study (above). The project differed from the HSE study in several respects. The HSA limited the sample to fatal incidents. Rather than obtaining information from on-site personnel, questionnaires were completed by the Authority's investigating inspector for each incident. Data was gathered for 39 out of 42 fatalities.

Survey information revealed that 63% of fatal incidents happened to employees (employed by either the main contractor or a sub-contractor). 21% of victims had been self-employed. The 'Housing and Apartments' sector of the construction industry had the highest percentage

(31%) of fatalities, followed by ‘Civil Engineering’ (21%). Other categories with 15% and less were ‘Industrial’, ‘Commercial’, ‘Farm Buildings’, ‘Maintenance’ and ‘Other’. In terms of specific trades, ‘General Labourers’ constituted 27% of all fatalities, while ‘Block layers’ and ‘Roofers’ represented 10% each.

Similar to the HSE findings, almost half of fatalities (49%) were as a result of ‘falls from heights’. Falls from heights were particularly prevalent among roofers, block layers and steel erectors.

Summary statistics revealed that Irish data replicated the ratios of the HSE study. Headquarter responsibilities represented 26%, site management contributed 56%, and Injured Party factors accounted for the remaining 21%. Information is provided about which items are the primary contributors in each section. ‘Failure to consider the implications of building design’ was the most important factor (75% - definite and possible contribution) in the HQ section. At SM level the ‘failure to supervise employees and subcontractors’ was the largest contributor (53% - definite and possible contribution). In the IP section, ‘unsafe act/risk-taking behaviour due to an inadequate SSW’ was most often cited.

2.3 Construction health and safety for the new millennium (HSE, 2000)

A report commissioned by the HSE on ‘Construction health and safety in the new millennium’ (Brabazon et al., 2000) reviewed approaches to the management of health and safety and suggested opportunities for improvement in the UK. The study utilised several methodologies:

- A statistical analysis of HSE injury data
- Consultation with representative groups from the construction sector (n = 89)
- Evaluation of interventions implemented in France, Sweden and USA

Analysis of the injury data showed that the overall rate of fatalities had decreased slightly (10%) since the introduction of the Construction (Design and Management) Regulations (CDM) 1994. An evaluation of the CDM regulations (HSE, 1997) could not identify any ‘substantive evidence of improved health and safety arising from the introduction of the CDM Regulations. The overwhelming comment was that “it was too early to tell”’ (p.163). The

2000 study suggests that the effects of the regulations had begun to filter through, although the evaluation document notes that ‘the plethora of health and safety legislation since 1990 has made it impossible to attribute any of the increase in awareness and behavioural changes to a specific set of regulations’ (p.163).

Several of the conclusions from the consultation phase are relevant to the current research. Respondents expressed the opinion that the CDM regulations had helped to clarify the responsibilities of the various roles. Secondly, it was concluded that certain groups did not have sufficient knowledge and expertise, specifically the client, designer and worker while supervisors and site managers ‘are perceived to have an increased level of understanding of health and safety’ (p.*v*). Translating this to the current research structure, it suggests that deficiencies exist at HQ (designer and client) and IP (worker) levels.

The international survey failed to uncover any major issues or solutions that were not already being considered in the UK.

Recommendations for improving construction health and safety included the following:

- Client influence
- Management ownership and commitment
- Safety by design

Client influence over the construction project is significant. The authors suggest that clients be obliged to use this influence to promote health and safety e.g. a requirement to take an active part in the selection and approval of subcontractors. Or, ‘as an alternative strategy, reduce the sensitivity of construction health and safety to client influence’ (p. *vi*). The latter implies a ‘degree of independence in the health and safety function’ (p. *vi*) such that it proceeds as part of the construction project regardless of client input. However, this would require fundamental legislative changes and is unlikely to be acceptable to the proportion of clients (often larger clients) who wish to take an active role.

Management ownership and commitment is a factor that regularly features as a pre-cursor of good safety performance. The authors suggest that an awareness of the commercial disadvantages and reputational hazards of poor safety performance may motivate improvements in management commitment.

Safety by design advocates thorough risk analysis of the design. This entails either training designers in health and safety issues or recruiting health and safety experts to work with the designer at the design stage.

Fitting Brabazon et al.'s conclusions into the current paradigm, one recommendation relates to increasing 'safety skills' among operatives especially in relation to safety-critical construction work, but the other six recommendations (including the three outlined above) concern actors and events at HQ level.

2.4 Improving health and safety in construction. Phase 1: Data collection, review and structuring (HSE, 2001)

In 2001 the HSE commissioned a project to collate available accident data for the construction sector for the period 1996-2001. The aim was to examine the data for the underlying causes of accidents. The principal data source was the RIDDOR system, a database of reported accidents across all UK industries.

Sample results from the statistical analysis of the data include the following:

- It was established that roofers and scaffolders were the trades with the highest rates of fatalities (p. 4.11)
- Falls from height are the most significant direct cause of fatalities and major injuries (p. 4.18)

Data relating to 'underlying causes' was available for HSE investigated fatalities. The underlying causes most often related to falls from height were 'unsafe transient work' and 'failure to control risk'. The same factors dominated the causal analysis of fatalities in the category 'struck by something collapsing / overturning.'

The second phase of the study utilised an Influence Network technique to organise and structure the data, to identify the major influences on health and safety performance in construction. For example, 'falls from height' was analysed for influences at four levels –

direct, organisational, policy and environmental. Influences were rated by a group of experts; with rating ‘1’ indicated the ‘worst aspects with considerable scope for improvement’ (p. 0.9). Influences rated ‘1’ in relation to falls from heights included:

- Workforce recognition of risk (direct level influence)
- Compliance (direct level influence)
- Design for safe construction (organisational level influence)

Recommendations for the prevention of construction accidents were also given a multi-level structure. Areas with potential for intervention include safety management by the principal contractor and client contracting strategy (similar to concerns at HQ level in the current framework); training, supervision, information feedback and design for safe construction in the way work is organised (an amalgam of HQ and SM factors); and competence, communications, situational awareness and compliance at the direct level (similar to the IP issues on the current questionnaire).

2.5 Safety behaviour in the construction sector (HSA & HSE-NI, 2002)

Research on safety behaviour in the construction sector was commissioned by the HSA and the HSE-NI (2002). This study spanned 18 sites that varied in size, were urban and regional, and were located across Southern and Northern Ireland. The methods used to obtain data included systematic site observations, a safety survey completed by 244 operatives, interviews with 59 site managers and 10 HSA and HSE-NI inspectors, together with an examination of safety documentation at 10 sites.

The data is restricted to site and individual levels; although the management interviews and analysis of safety documentation offer some insight into headquarter actions and priorities.

A factor analysis of the management survey extracted two factors:

- General safety management factor (communication, training, planning etc.)
- Effectiveness of the safety system (impact of audits and hazard reports on organisational action)

The two factors are not significantly correlated 'indicating that commitment to a range of safety management activities does not necessarily imply an effective response to audits and hazard reports' (p.68). Policy alone is not sufficient to bring about safety improvements – policy must be updated and activated in response to incoming safety information.

The results indicate that levels of compliance with safety requirements were variable across sites. Only two factors correlated with safety compliance:

- the presence of a safety representative
- effectiveness of response to audits and hazard reports

However, the results do not allow any causal conclusions – for example, it is impossible to state whether sites with safety representatives are more likely to have high compliance, or if compliant sites are more likely to have safety representatives.

Unusually, the general safety management factor did not relate to compliance, prompting the authors to question why so many of the activities 'undertaken in the name of safety apparently have so little influence on safety compliance and safety behaviours' (p.3).

3. CONSTRUCTION LEGISLATION

The data will be examined within the relevant legislative framework. A brief overview of the legislation at a European level is followed by more specific accounts of the Irish and UK transpositions of the European Directive.

3.1 European Legislation

The Construction Sites Directive (92/57/EEC) was published by the European Union in 1992. Since then, member states have introduced legislation to improve safety and health standards at temporary or mobile construction sites. Dias (2002) summarises the directive as initiating 'a new concept of safety and health based on a new chain of responsibilities (including the owner), new safety and health documents (the prior notice, the safety and health plan and the safety and health file) and new safety and health stakeholders (the safety and health coordinators for the design phase and the construction phase' (p.1).

Ten years on, attempts are being made to assess the impact of the directive across Europe. Contributors to the discussion offer different perspectives. The European Federation of Building and Woodworkers (EFBWW) reports that there has been no systematic reduction and elimination of a wide range of hazards following the adoption of the directive – 'Accident levels on construction sites have remained extremely high' (p.1). They cite research from Austria and the UK illustrating that the disproportionately high accident rates have continued. Dias (2002), however, notes the positive impact on safety and health awareness. 'Safety and health in construction is now an issue that most stakeholders are aware of and take care of' (p.1).

The failure of the directive to reduce accident rates may be due to several factors.

It is important to note that although the Directive was published in 1992, most member states did not implement legislation until much later. Carruthers (2002) observes that the bulk of legislation was in place before the due date of 31 December 1993 but that some countries did not complete the transposition until 2001 (p.4). Consequently, the effects of the new legislation may not yet have filtered through the system.

The Directive imposes the minimum standards for health and safety on member States. Many countries have transposed stricter rules, so that legislation is not consistent across the Union. Dias distinguishes between countries that have 'worked' the directive, creating policy that marries the central directive with the unique aspects of the national construction industry, and countries that merely transpose the directive without any adaptation or amendments (e.g. Luxemburg and Portugal). Ireland is in a third category - countries that have continued to revise and clarify their initial legislation. For example, Ireland has extended the duties of the coordinator for the construction phase to include tasks such as developing the safety and health plan and the safety and health file, and coordinating measures to ensure that only authorised staff are permitted on-site. Belgium, France, Portugal and the UK have also added duties, but the remaining states limit the duties to those outlined in the Directive. It is to be expected that legislation will have differential effects according to the level of detail with which it has been transposed. The European Federation of Building and Woodworkers (2000) anticipate a problem in the future when services are offered on a Europe-wide basis –'Where coordinators' services are provided throughout Europe this could undermine the higher standards of qualifications required in some countries' (p.9).

The role of coordinator provides an example of how the legislation may vary across Member States. There are differences in relation to the qualifications and further training required of the coordinators. Dias ((2002) outlines how some countries have included requirements in the legislation (e.g. France, Italy, Belgium), others offer training but have not made it a requirement in the legislation (Spain, Portugal). Some countries' legislation states that the coordinator must be 'competent' (e.g. Ireland), while others have decided that no new training is necessary for coordinators.

With regard to the overall effectiveness of the Directive and the consequent legislation, it seems that there is not sufficient data available to make any assessment at a European level. Improved safety performance in individual countries may be attributable to the specific transposition of the Directive or to the piecemeal introduction of legislation. It may be some time before the benefits or otherwise of the Directive are manifest in European accident figures.

3.2 Irish Legislation

The Safety, Health and Welfare at Work (Construction) Regulations 1995 represent the first phase in Irelands' transposition of the Construction Sites Directive. These have since been superseded by the Safety, Health and Welfare at Work (Construction) Regulations 2001.

The 1995 regulations 'aimed at improving the management and co-ordination of health and safety on construction sites' (HSA, 2000). The Regulations increased the obligation on those who are involved in the planning stages of a construction project e.g. clients, designers, project supervisors. These are the actors who can ensure that 'account is taken of health and safety at every stage of the project, from initial concept through to design, construction and eventual maintenance' (HSA, 2000).

Given the fragmented nature of the industry, it is often problematic to assign responsibility for errors. For example, a failure on the part of a designer may not manifest itself until years later during building maintenance. The Regulations bring into focus the roles and responsibilities of all actors involved in a project. This serves to clarify accountability and subsequent liability.

Of particular relevance to the current research are the extended duties of the client and designer. The HSE report (1992) notes that clients can vary ' in the level of expertise they bring to bear in specifying their requirements, selecting advisors and managing the construction process. Some clients have a continuous building programme; others build only once in a lifetime' (p.36). Client influence can significantly affect 'the priority given to safety over the whole project life-cycle, from tendering and resourcing through to site management and incident investigation' (p.36). Legislation aims to standardise client input so that safety concerns are considered from the inception of the project.

As of the 6 June 1995 **clients** were obliged to:

- Appoint a competent Project Supervisor for the Design Stage (PSDS)
- Appoint a competent Project Supervisor for the Construction Stage (PSCS)
- Terminate or renew these appointments as necessary
- Keep available the Safety File for inspection
- Allow a sufficient timeframe for the safe completion of the work.

The current study measures the impact of these new responsibilities with the following questionnaire items:

- B Competence of dutyholders (PSCS, PSDS, client, designer)

- C3 Failure to take adequate consideration of project timescale
- D Poor system for controlling maintenance of plant
- G Failure to develop adequate Safety and Health plans

The 1995 regulations required **designers** to:

- Take account of 'General Principles of Prevention'
- Take account of any Safety and Health Plan or Safety File
- Co-operate with the PSDS / PSCS as appropriate
- Provide PSDS and PSCS with information on Particular Risks
- Take into account any direction from the PSDS or PSCS

Items on the questionnaire that are relevant to these responsibilities include:

- C1 Failure to take adequate consideration of design factors or features
- C2 Failure to take adequate consideration of PPE
- E Failure to learn lessons / be aware of similar accidents
- F Failure to carry out adequate hazard identification and risk assessment
- G Failure to develop adequate Safety and Health plans

The updated Safety, Health and Welfare at Work (Construction) Regulations 2001 allocate further responsibilities for Project Supervisors. The PSDS is required to prepare elements of the preliminary safety and health plan in writing. The PSCS is required to facilitate the appointment of a site safety representative on any site with more than 20 workers. Changes at site level include the introduction of the Safe Pass system for all construction workers and mandatory certification for activities such as 'mobile crane operation' and 'site dumper operation'. The PSCS is responsible for keeping records relating to Safe Pass and certification. The duties of the client and designer remain unchanged.

The new requirements are being phased in during 2002/2003, and represent the first phase in proposed amendments to the Regulations. Although these changes are outside the timeframe of the current study, they are relevant to the extent that this research is commissioned in anticipation of further amendments.

The existing and proposed regulations represent a shift in emphasis such that the onus for co-ordination and planning moves off-site. Through increased responsibilities for clients and designers and the appointment of dedicated supervisors, the bulk of safety-related issues are considered before construction begins. The regulations also extend the lifespan of construction projects in relation to safety issues, acknowledging the activity and decisions that take place both before and after the construction phase.

In terms of the current dataset, it is hypothesised that the implementation of the 1995 regulations should have reduced the contribution of HQ factors to subsequent fatalities.

3.3 UK Legislation

It is useful to make comparisons with similar legislation in the UK. The Construction (Design and Management) Regulations 1994 were introduced on 31 March 1995. Similar to the proposed Irish legislation, the regulations extended the responsibility of the designer across the lifespan of the construction project - 'All designers contributing to a project have a duty to avoid foreseeable hazards associated with the construction work and subsequent maintenance and cleaning work, as far as is reasonably practicable' (HSE, 1995, p.2).

The designer is required to consider the long-term health and safety implications of the design so that full advantage may be taken of opportunities to eliminate or reduce risks at an early stage. Where risks are inevitable the designer has a 'duty to combat those remaining risks with measures that will protect workers and people affected by the works' (HSE, 1995, p.2). Other duties require the designer to provide relevant health and safety information for the pre-tender health and safety plan and the safety file, to inform the client of their duties in respect of the project and to co-operate with others involved at the design stage.

The Regulations make provision for the appointment of a 'Planning Supervisor' (similar to the PSDS in Ireland), who co-ordinates the health and safety aspects of the design phase. Similar to the Irish situation, it is acceptable for the designer to assume the extra duties of the Planning Supervisor if competent to do so.

The HSE commissioned an evaluation of the CDM Regulations in 1997, less than 2 years after their implementation. The reason for this 'accelerated evaluation' (p.9) was to specifically analyse the costs and benefits of the implementation phase of the Regulations. It is acknowledged in the report that this exercise could not capture long-term effects 'since the initial investment costs such as those associated with identifying and developing the necessary competencies and systems to implement the Regulations were likely to dominate' (p.9).

234 interviews were conducted using a semi-structured questionnaire. Respondents included clients, designers, planning supervisors and contractors from both the public and private sectors. A small sample was also drawn from the supporting professions e.g. insurance, legal professions, trade associations. Responses were consolidated using a multi-relational database.

Areas of concern arising out of the Regulations included the following:

- ***The role of the Planning Supervisor.*** Responses revealed that in practice the Planning Supervisor performed many duties beyond those required by the CDM Regulations, with their role being dictated by the client in some cases. Others were concerned that the Planning Supervisor "is too much a generalist". Dutyholders claimed that 'Planning Supervisors without any practical professional construction qualification have a poor understanding of the issues' (p.161). The authors note that 'the lack of professional background could create unproductive tensions with the other dutyholders' (p.161).

- ***Competence Assessment.*** The requirement to assess the competence of appointees has created cost and a volume of paperwork for clients and contractors. Smaller clients often assume the competency of appointees. The lack of any standardised practice for assessing competence may also undermine the process.

- ***Expenditure.*** The majority of interviewees reported 'little benefit to date by way of reduced expenditure' (p.162) ensuing from the implementation of the Regulations.

Respondents outlined the following benefits:

- ***Focus on project onset.*** Contractors in particular were supportive of the emphasis on design and management in the Regulations. Safety is considered from the onset of the project rather than being factored in at the construction stage.

- ***Co-ordination.*** The increased co-operation and co-ordination among dutyholders is cited as a positive business effect by many interviewees. They describe how teams have been created where none previously existed, and 'enhanced team working where previously difficulties existed' (p.165).

- ***Health and Safety Files.*** Contractors noted the benefits arising from the client making available all safety information in the form of the Health and Safety file. This is relevant for projects involving the adaptation, refurbishment and demolition of existing buildings. Further benefits are anticipated as more and more properly maintained health and safety files enter the system.

Despite the generally positive reaction to the Regulations, real improvements in the form of on-site or financial benefits had still to filter through – 'there is no perceivable improvement in accident rates on construction sites or during maintenance activities which any of the survey sample were prepared to specifically attribute to the introduction of the Regulations' (p.169). The report concluded that while specific issues e.g. the role of the Planning Supervisor, needed clarification through an action programme, substantive changes to the Regulations were not necessary at that juncture.

4. THEORETICAL MODELS OF ACCIDENT CAUSATION

A theoretical perspective allows the categorisation of errors and also highlights areas where remedial measures may be applied. Compared to the complex nuclear and chemical industries, tracing the causes of accidents in the construction industry is relatively straightforward. Consequently, the elimination of contributory factors should not be a complex process.

4.1 Reason's Framework for Accident Causation (1990)

Professor James Reason at the University of Manchester has devised a widely accepted theory of accident causation. The model has been utilised by the HSE in their attempts to understand various disasters and has been adapted by Shell to shape their health and safety policy. Reason's theory is appropriate for the current study because it spans the entire accident sequence from organisational to individual levels. The theory follows modern trends in seeking causal factors that are removed in both time and space from the onset of the incident. Previously, accident investigations tended to highlight the role of the frontline operator as the most obvious and immediate instigator of the accident. Accidents in the construction industry are particularly prone to such interpretations – incidents regularly occur to individuals acting alone. Reason's theory incorporates an organisational level analysis that takes account of the input of management and decision-makers.

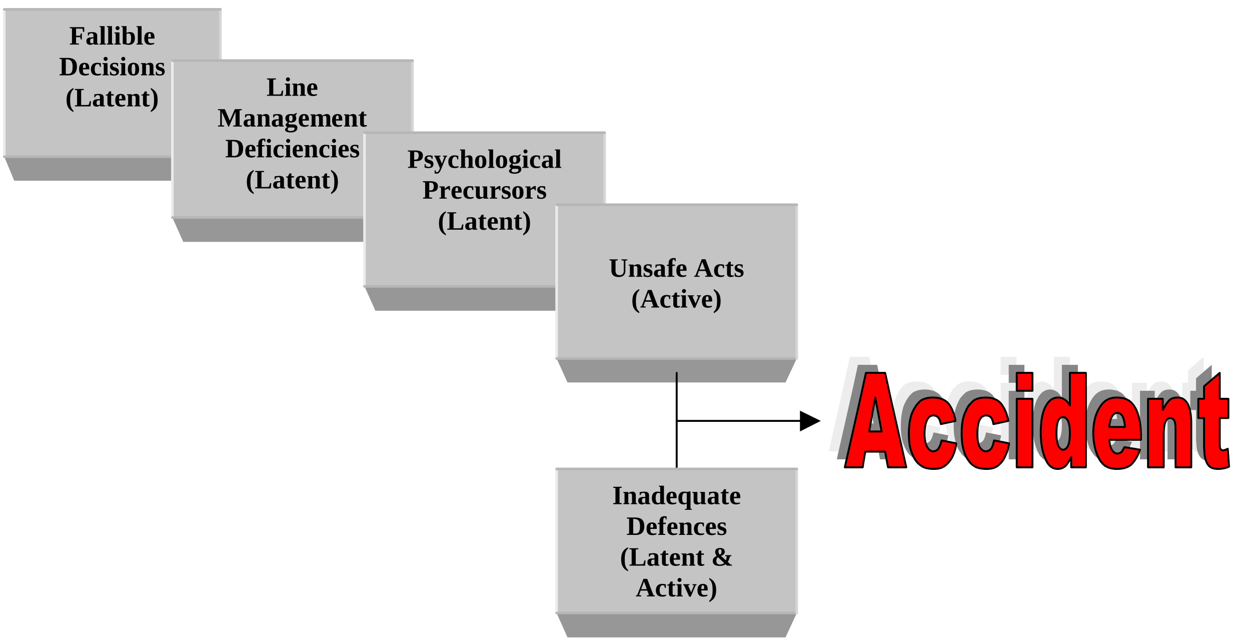


Figure 2. James Reason (1990) – Accident Causation Model

The model divides active and latent failures. Active failures are 'those errors and violations that have an immediate adverse effect. These are generally associated with the activities of 'front-line' operators' (p.476). These correspond to the activities of construction personnel on-site e.g. driving into contact with overhead power lines, failure to wear PPE. Many safety interventions aim at the level of the general operative e.g. programmes to encourage the wearing of hard hats, health check campaigns. However, there are an infinite number of unsafe acts that can precipitate accidents on a construction site – 'the vast majority of them are unforeseeable and occasionally quite bizarre' (Reason, p.481). Thus, attempts to reduce the number of unsafe acts can only have limited value – it may be more useful to aim at the level of latent failures.

Latent failures correspond to errors at HQ and Site Management levels in the current study. They are 'decisions or actions, the damaging consequences of which may lie dormant for a long time, only becoming evident when they combine with local triggering factors…Their defining feature is that they were present in the system well before the onset of a recognisable accident sequence' (p.476). Research by the HSE (1992) states that many of the preconditions of unsafe behaviour originate in poor management decisions or an organisational culture in which safety goals may be considered subordinate to production goals' (p.6). The authors note that 'violations are known to occur more frequently in situations where responsibilities are ambiguous or ill-defined, training poor and time pressures high – not atypical conditions for the construction industry'.

4.2 Constraint-Response Theory (2001)

Suraji, Duff and Peckitt (2001) of University of Manchester Institute of Science and Technology (UMIST) and HSE, have developed a causal model specific to construction accidents. They cite Reason's model as a theoretical description but note the lack of specific detail necessary to guide practical investigation and intervention – 'the effective mitigation of causal factors requires better knowledge of which factors are most influential, who may reasonably be expected to control those factors and how such control may most effectively be achieved' (p.338).

Similar to Reason's model, the Constraint-Response Model extends the scope of the accident causation process to include management and organisational aspects. The model classifies two types of factors – distal and proximal, equivalent to latent and active failures in Reason's configuration.

Distal factors are similar to the factors that are identified at HQ level in the current study:

- Project conception restraints
- Project design constraints
- Project management constraints

Proximal factors operate at the same level as SM and IP factors:

- Inappropriate construction planning
- Inappropriate construction control
- Inappropriate site condition
- Inappropriate construction operation
- Inappropriate operative action

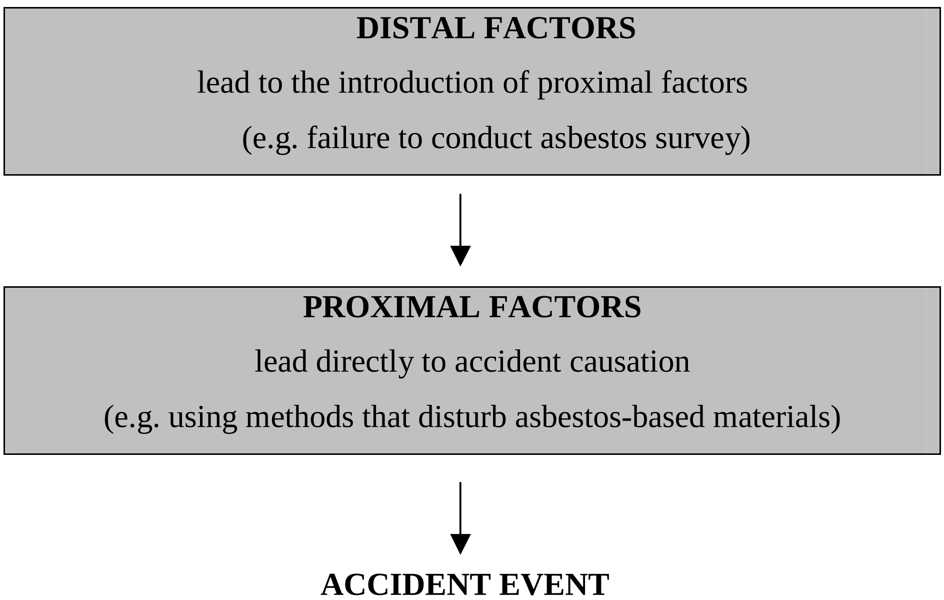


Figure 3. Suraji et al. (2001) – Accident Causation Model

The premise of the theory is that each participant experiences **constraints** on their activity e.g. a client may face difficulties in obtaining funding. The **responses** to these constraints in turn create a set of constraints for subsequent participants. Thus, a client may reduce the project budget such that the designer is constrained by inadequate design budget. The designer may respond by reducing the design resources for the contract. The project management team may in turn be constrained by the late delivery of the design detail, and so on throughout the project chain. The sequence of constraints and responses ultimately create situations where the proximal factors are manifest e.g. 'unsuitable existing topography' (inappropriate site conditions) or inadequate supervision of operative work (inappropriate construction control).

Both theories offer a framework in which to locate the contributory factors identified in the current study. They represent a systemic approach to identifying the underlying causes of accidents, taking account of decisions and actions upstream of the accident event. The models also facilitate the description of accidents with multiple causes at various levels. While Reason (1990) presents a generic model, Suraji et al (2001) have tailored the model to include actors and conditions relevant to the construction sector.

5. METHODOLOGY

5.1 Data Sources

The construction fatalities in this study are those that have been investigated by the Health and Safety Authority of Ireland during the period 1991-2001. Fatality files for the period 1991 – 1994 are stored in hard copy. More recent incidents are stored electronically.

An Inspector for the Health and Safety Authority attends the scene of each fatality. They prepare an investigation report and log the incident on the Authority's SAFE system. Along with demographic information, the fatality is categorised under the relevant NACE code for economic sector e.g. F = construction sector. The accident type is recorded (e.g. fall from height, drowning or asphyxiation) according to a typology devised by the HSE in Britain.

The HSA system does not categorise information relating to the causes of fatalities. Since the aim of this research is to do a causal analysis to identify contributory factors, it was necessary to identify a source for causal information. Previous studies have sampled representatives of project and site management (HSE, 1992). The authors of the HSE research state that 'feedback at this level was essential to obtain a realistic picture of the major influences affecting decision-making during the project life-cycle' (p.7). However, they acknowledge that this confines the scope of their study to the construction phase – 'the issues taken up in this report therefore focus primarily, but not exclusively, on those stages of the project life-cycle which follow the award of a contract to a main works or management contractor' (p.6).

For the current study, health and safety inspectors performed the causal analysis. This source has several advantages. Firstly, inspectors can provide a relatively neutral account of accident causation. Construction personnel may experience pressure to report the incident in such a way as to absolve themselves or their firm from blame. Dejoy (1985) found that supervisors prefer to explain accidents in terms of individual error, rather than attributing the fatality to deficiencies at an organisational level. Inspectors can provide an overview of the incident, detecting contributory events at every level. Secondly, inspectors are trained and qualified in accident investigation. Their expertise may facilitate an accurate assessment of the incident. Finally, inspectors adhere to various procedures for the collection of information on fatalities. Therefore, they have accumulated a bank of reliable data for every fatality file.

Data for the years 1995-1997 was available from a previous research project (HSA, 1998).

5.2 Method

The questionnaire is adapted from an instrument that has previously been used by the HSE (HSE, 1992) and the HSA (HSA, 1998). The questionnaire is modified for the construction industry context and several items have been added to extend sections that are of particular relevance to the current research (Appendix 2). Using the same questionnaire facilitates comparisons with previous studies.

The structure of the questionnaire reflects current configurations of accident causation, as outlined in the literature review. A range of factors are examined at three different levels – Headquarter, Site and Individual. The framework allows problems to be located at particular levels, and also for possible cross-level relationships to be identified. Respondents are requested to mark items that made a Possible Contribution (P) and / or a Definite Contribution (D) to the fatality. Other items are non-applicable (N/A).

A file comprising the survey questionnaire and incident details (incl. accident report, photographs, correspondence, where available) was prepared for each fatality and sent to the investigating inspector. The accompanying letter is Appendix 1.

6. RESULTS

6.1 DESCRIPTIVE SUMMARIES

6.1.1 Study Response Rates

Table 3. Study response rates

Year	Number fatalities	Number responses	% responses
1991	10	5	50
1992	12	6	50
1993	11	5	46
1994	9	5	56
1995	12	12	100
1996	13	12	92
1997	15	15	100
1998	22	15	68
1999	18	13	72
2000	25	22	88
2001	22	22	100
Total	169	132	78

A total of 169 construction and construction-related fatalities occurred during the 10-year period. Data was obtained on 132 of these fatalities, representing a response rate of 78%. The frequency of responses increases after 1994, due to the availability of the investigating inspectors. Only tentative conclusions may be drawn for data prior to 1995, due to the scarcity of data.

6.1.2 Number of fatalities 1991-2001

Figure 4. Fatalities 1991-2001

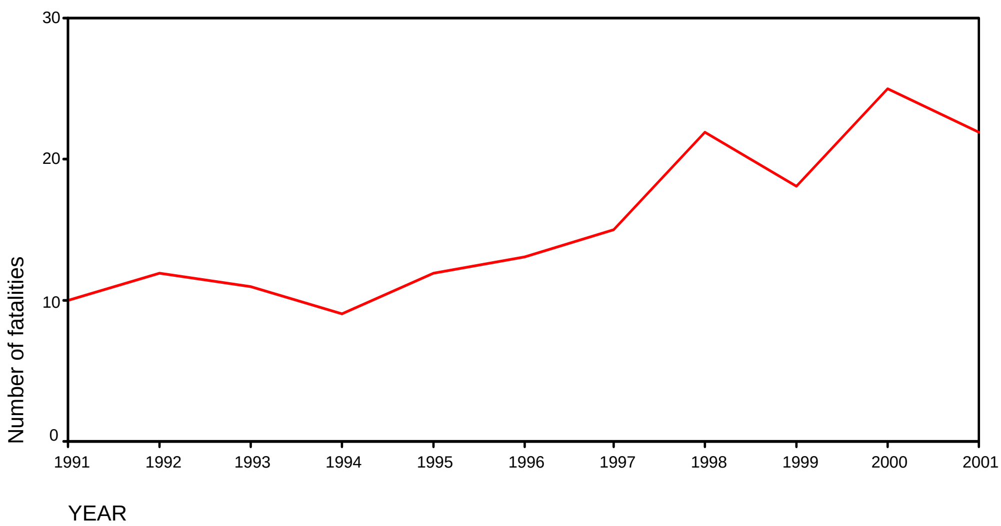
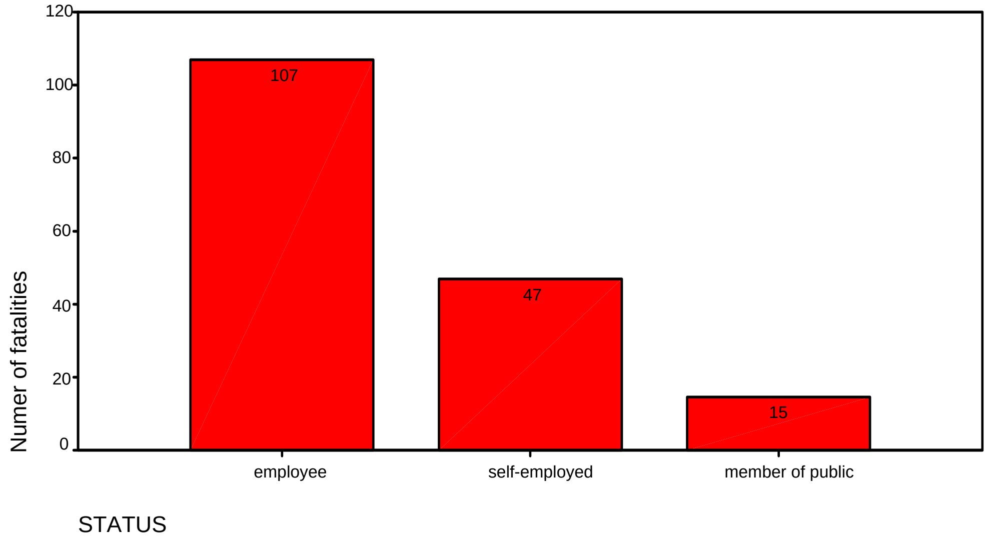


Figure 4 indicates a steady increase in the number of fatalities over the 10 years. Factors underlying the increase are examined in detail in the discussion chapter.

6.1.3 Employment Status

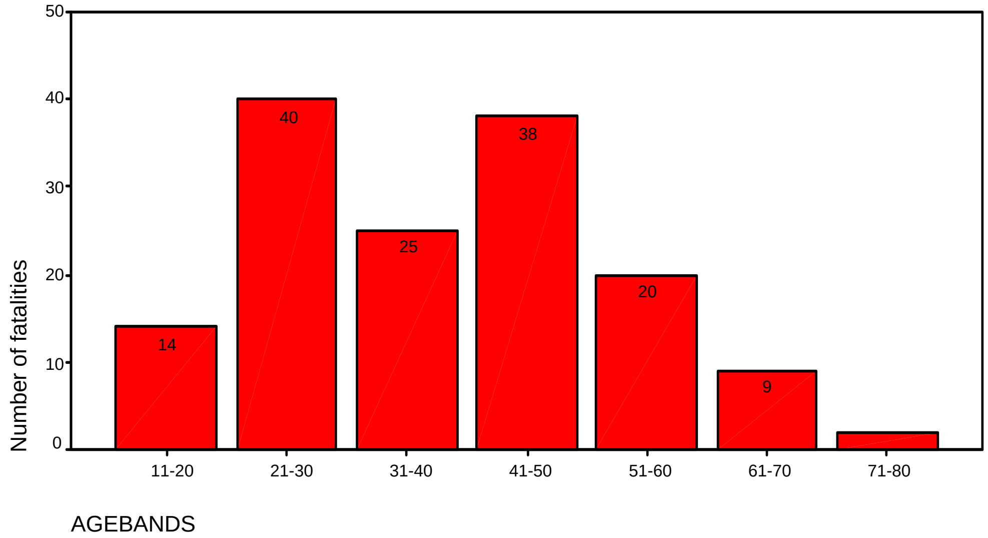
Figure 5. Employment status: fatalities 1991-2001



63% of all victims were employees, 28% were self-employed and 9% were members of the public. Excluding members of the public, 69% of all workers who were fatally injured were employees, and 30% were self-employed workers.

6.1.4 Age Profile

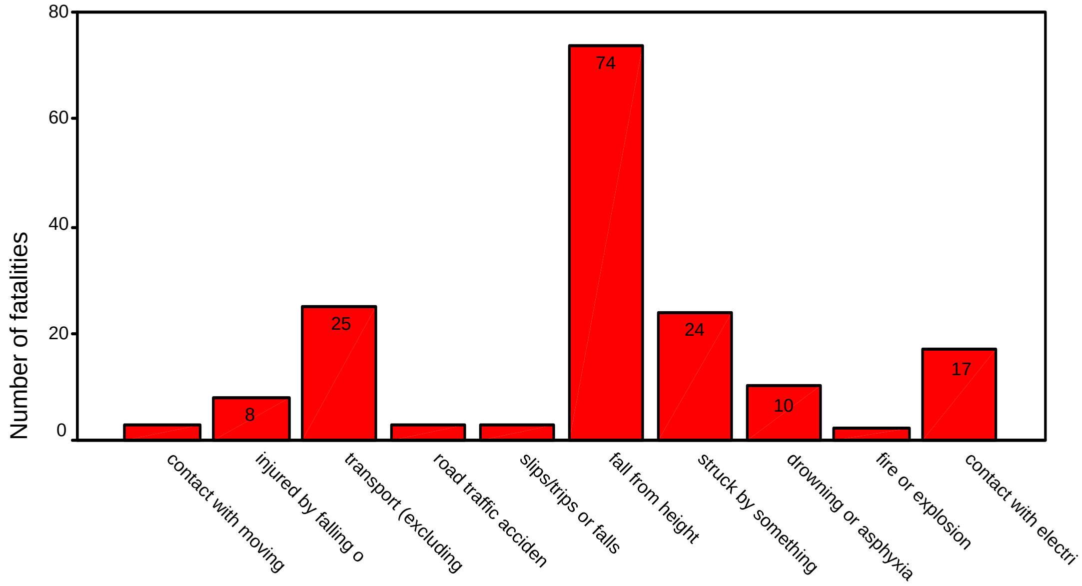
Figure 6. Age profile: fatalities 1991-2001



Members of the public have been excluded from this description (n = 15). 6 missing values have also been omitted. The remaining sample (n = 148) ranges from age 16 to age 77, with a mean age of 39 (*sd* = 14). Most incidents occurred to individuals in the 21-30 age band (24%) and the 41-50 age band (23%).

6.1.5 Incident type

Figure 7. Incident type: fatalties 1991-2001



Consistent with other studies, almost half of the fatalities in the construction sector (44%) are attributable to 'falls from heights'. Other incident types that accounted for over 10% each are 'transport (excluding RTA)', 'struck by something collapsing / overturning' and 'contact with electricity'.

6.1.6 Appointment of PSDS / PSCS

Since the Safety, Health and Welfare at Work (Construction) Regulations 1995, it has been the responsibility of the client to appoint the PSDS and the PSCS. The data in Table 2 specifies that these appointments were made at 55% of the sites where fatalities occurred. The 'Not Applicable' category applies to accidents occurring on farms or private dwellings.

Table 4. Summary of PSDS / PSCS appointments

Was PSDS/PSCS appointed?	Fatalities 1998 -2001
Not Applicable	6 (not construction site)
No	30 (45%)
Yes	36 (55%)
Total	72

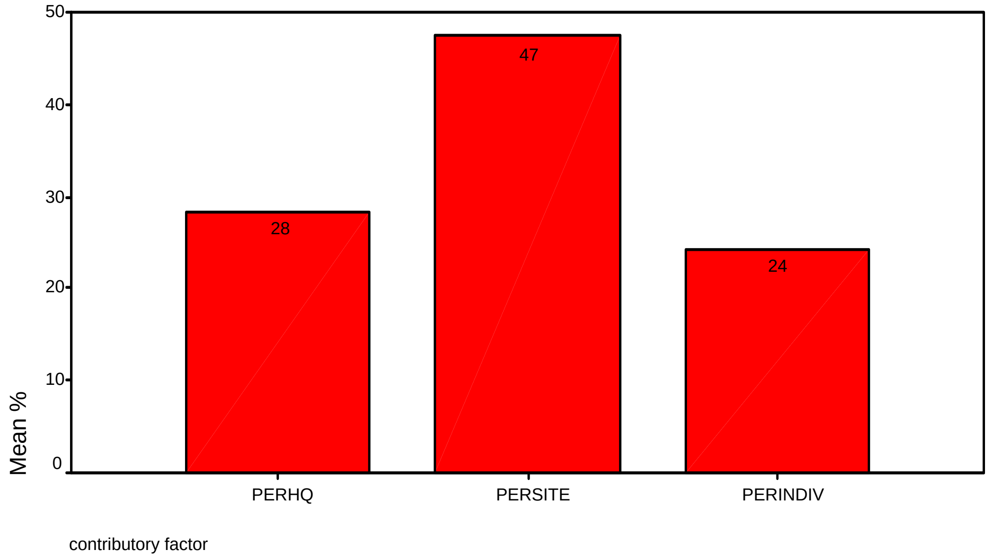
6.2 STATISTICAL ANALYSES

The following sections outline the relative importance attributed to HQ, SM and IP factors in construction fatalities. Analyses establish whether the factor ratios vary over the decade, or with age, employment status or incident type. Finally, an exploratory factor analysis is performed to identify underlying themes in the dataset.

6.2.1 Contributory Factor Ratios

The proportionate contribution for each factor is given in Table 5. The results replicate the 2:1:1 ratio established in the HSE (1992) study and the HSA (1998) study. Site Management deficiencies constitute 47% of causal attributions. Headquarter and Injured Party issues represent 28% and 24% respectively.

Figure 8. Contributions at HQ, SM and IP levels: fatalities 1991-2001



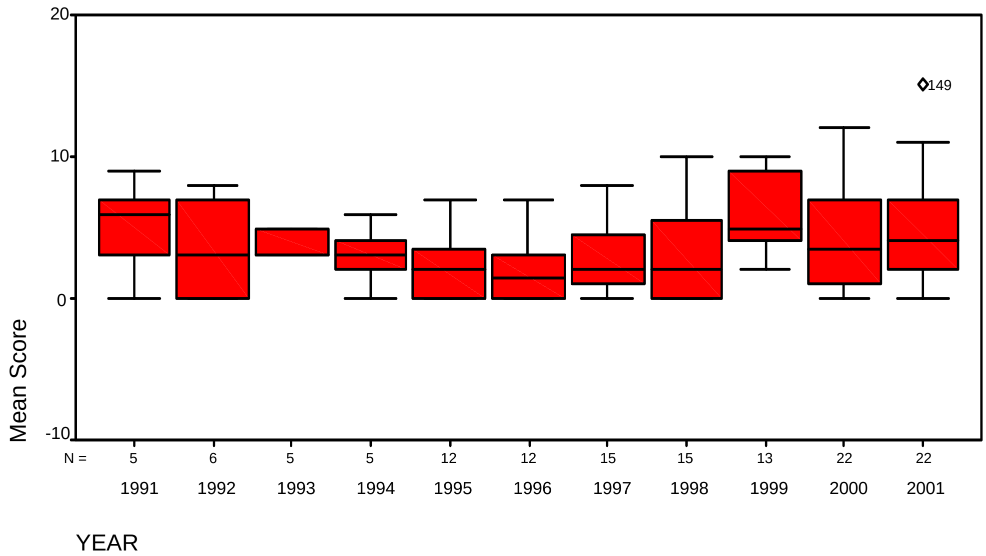
Exploratory analyses revealed no significant change in any of the factors over the ten-year period. The pattern represented in Figure 8 is reflected in the ratios for nine out of the ten years. Calculations for 1991-1994 are based on very few cases, but three of the years maintain the ratio. 1991 is the exception, with individual factors making the largest contribution.

Table 5. Percantage Contribution to fatalities 1991-2001

	N	HQ %	SM %	IP %
1991-2001	**132**	**28.31**	**47.35**	**24.34**
1991	5	32.24	30.23	37.54
1992	6	16.44	57.30	26.26
1993	5	40.14	43.83	16.04
1994	5	29.18	43.86	26.96
1995	12	21.24	50.95	27.81
1996	12	23.42	48.35	28.23
1997	15	25.83	43.90	30.27
1998	15	27.44	41.96	30.59
1999	13	37.02	49.14	13.84
2000	22	33.84	45.92	20.24
2001	22	25.89	54.02	20.10

Increased responsibilities at HQ level since 1995 suggest that the factor structure may have changed over the decade. The box plot[1] in Figure 9 represents the contribution of HQ factors to fatalities. (Box plots for SM and IP are in Appendix 3). An initial examination of the box plots does not reveal a trend for any of the factors.[2]

Figure 9. Headquarter factors 1991-2001



Correlational analyses (Appendix 3) confirm the absence of a significant increase or decrease in any of the three factors over the ten-year period.

[1] The boxplot facilitates a cursory examination for trends. The line in the middle of the box represents the median score for that year. Compare median lines across the graph to discern any trend.
[2] The boxplots expose outlying values (e.g. case 149 in Figure 6 above). These are extreme values that distort the data. Outliers have been omitted from the analyses.

An alternative approach is to compare ratios for all fatalities investigated before and after the 1995 regulations. For the purposes of this statistical test the dataset was split in two – the first group contains all fatalities up until the end of 1995 (the regulations were implemented on 6 June 1995) and the second group contains fatalities from 1 January 1996 onwards. Table 6 provides the mean percentage score for both groups at each contributory level.

Table 6. Mean (%) scores for 1991-1995 compared with 1996-2001

	Year	N	Mean (%)	Standard Deviation	Std. Error Mean
HQ	96-01	92	3.72 (29)	3.30	.34
	91-95	31	3.29 (27)	2.76	.50
SM	96-01	92	5.83 (47)	4.03	.42
	91-95	31	5.97 (47)	3.77	.68
IP	96-01	92	2.09 (23)	1.87	.20
	91-95	31	2.48 (26)	1.63	.29

The mean scores suggest some difference between the two groups but do the differences reach significance level? An independent samples t-test was performed to answer this question. The results are available in Appendix 3.4. They indicate that the ratio of causal factors has not altered since the implementation of the 1995 regulations.

6.2.2 Contributory factors and employment status

The ratio of contributory factors maintains its overall pattern when applied to the employment status categories. Employees and self-employed workers have very similar patterns. There is slight variation for members of the public – HQ and SM factors are most important with IP factors contributing only 18%. Members of the public are not involved in the construction work and, as such, often take no active part in the sequence of events leading to an accident.

Table 7. Ratios x Employment Status

Status	N	HQ (%)	SM (%)	IP (%)
Employee	85	3.85 (29)	6.24 (47)	2.24 (24)
Self-employed	34	2.48 (26)	4.19 (48)	2.06 (26)
Member of Public	13	4.85 (29)	7.54 (47)	2.15 (24)

Of particular interest in this study is to examine what factors *within* the construction industry contribute to accident involvement. To this end, members of the public were deselected from the dataset so that the impact of the factors on construction workers only might be ascertained. The dataset was further divided according to whether the deceased was an employee or self-employed. An independent samples t-test was conducted to investigate the significance of the variation between the two groups. Significant relationships were obtained for HQ factors ($t = 2.103$, $p < 0.05$) and SM factors ($t = 2.577$, $p < 0.05$). Employed and self-employed workers vary significantly in the extent that Headquarter and Site Management factors influence fatalities. Specifically, HQ and SM factors have more impact on fatalities among employees.

This result makes intuitive sense. Employees have a direct and dependent relationship with the employer. They are part of a larger system, and their attitudes and subsequent behaviours are controlled to some extent by the employing organisation. Thus, any deficiencies in planning and management are passed along the organisational chain and suffered by employees. Self-employed workers are less affected by policy and management deficiencies on a construction project. Their status allows some autonomy from the larger organisation. The self-employed worker may already have developed safe methods of working, and hence be less susceptible to poor safety systems on-site.

6.2.3 Contributory factors and age

A correlational analysis reveals that age is related to the influence of HQ and SM factors. The results in Table 8 indicate relationships in a negative direction, such that as age increases, the impact of HQ and SM factors decreases. Deficiencies at HQ and management levels pertain less to fatal accidents for older workers than for younger workers. There is no significant positive relationship with individual factors so it does not follow that fatalities among older workers are due to an increase in unsafe behaviour by the individual.

Table 8. Bivariate correlation: contributory factors x age

		Age	HQ	SM	IP
Age	Pearson Correlation	1	-.263**	-.214*	-.011
	Significance (2-tailed)	.	.003	.015	.906
	N	163	128	128	128

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

There are several possible explanations for this outcome. Firstly, it may be the case that the older workers in the sample were doing construction or construction-related work, but not on a construction site e.g. farm construction or maintenance work. Therefore, headquarter and site issues are not applicable and will have no bearing on such fatalities. Alternatively, older workers may have the necessary experience and expertise to avoid, or be unaffected, by deficiencies at policy and management levels.

6.2.4 Contributory factors and incident type

The HQ:SM:IP ratio shows some variation across incident types. It is to be expected that the broad range of fatal accidents types should vary in their precipitating events.

For example, the causal structure for 'slips, trips and falls on level' incidents differs from that for 'struck by something collapsing / overturning' incidents. Individual factors are relatively high for 'slips, trips and falls on level'. Poor housekeeping, personal clumsiness or weather conditions may cause such incidents, all of which are beyond the direct scope of HQ control. Alternatively, victims who are 'struck by something collapsing / overturning' are often the victims of external events which occur as a result of poor planning or design at HQ level. The individual on-site has limited control over structural aspects of his environment.

Table 9. Ratios x Incident Type

Incident	N	HQ	SM	IP
1. Contact with moving	2	33.33	50.00	16.67
3. Injured by falling object	7	27.71	41.02	31.28
4. Transport (excl. RTA)	20	25.09	48.38	26.53
5. RTA	3	48.48	36.36	15.15
7. Slips / falls on level	3	11.11	44.44	44.44
8. Fall from height	54	23.52	48.81	27.67
9. Struck by something	17	40.19	40.42	19.39
10. Drowning or asphyx	10	35.42	45.84	18.74
12. Fire or explosion	2	36.74	43.94	19.32
13. Contact with electricity	14	29.62	56.00	14.37

6.2.5 Factor Analysis

A factor analysis is an exploratory exercise that identifies underlying themes in the dataset. The format of the current questionnaire structures the data in such a way that items relating to HQ, Site and Injured Party are assumed to group together. However, an examination of the responses may indicate that certain items cluster together regardless of the organisational level at which they operate, revealing 'latent variables' (Kinnear & Gray, 2000, p.348) in the dataset. Thus, it may be possible to reveal patterns and trends that are organic to the questionnaire responses, free of the structures imposed by the questionnaire.

The analysis was performed on data for the periods 1991-1994 and 1998-2001. Even though this reduced the dataset from 132 to 93 cases, it was deemed more important to incorporate information gathered by the extended questionnaire. Responses to fourteen of the items were skewed beyond acceptable levels and were excluded from the factor analysis.

Three distinct factors were extracted from the remaining data, which combine to account for 54% of the variance in the dataset. The items that compose each factor are given in Table 10.

Table 10. Principal Factors Extraction with Varimax Rotation

Item	Level	Factor 1 (accounts for 26%)
B	HQ	Competence of dutyholders (PSDS, PSCS, designer, contractor)
C1	HQ	Failure to take adequate consideration of: design factors and features
E	HQ	Failure to learn lessons / be aware of spate of similar accidents
F	HQ	Failure to carry out adequate hazard identification and risk assessment
G	HQ	Failure to develop adequate Safety and Health plan/plans
I	Site	Failure to implement SSW
K	Site	Failure to identify hazards on site
		Factor 2 (accounts for 17%)
J	Site	Failure to communicate SSW to workers
M1	Site	Failure to supervise employees
M2	Site	Failure to supervise sub-contractors
		Factor 3 (accounts for 12%)
S3	Indiv	Unsafe act / risk-taking behaviour because of inadequate SSW
U	Indiv	Using initiative to solve problem (not trained / experienced for task)

Factor 1 is the largest, containing seven items. Factors 2 and 3 cannot be considered proper factors with only 3 and 2 items respectively. However, they do merit tentative interpretation in the interests of providing a comprehensive picture of the findings. The factors map on to the questionnaire to some extent, approximating the HQ, SM and IP categories. However, their precise composition and emphasis offer a new perspective on the dataset - the extracted factors do not follow the same pattern as that revealed for the contributory factors, where Site Management is twice as important as either Headquarter or Injured Party factors. The factor analysis identifies the HQ items as most predictive. That is, although inspectors identify site management factors as the major contributors, the pooled data reveals that Headquarter issues have more explanatory power. The percentage of variance explained by each of the extracted factors suggests that actions further up the organisational chain will have most impact on accident prevention.

A summary description of each factor follows.

Factor 1

The majority of items in this factor are from the HQ section of the questionnaire, representing failures at the planning and design stages of the construction project. These are elements that should be considered at the inception of a project. Consistent with the high percentage of variance explained, these failures have substantial impact across the breadth and duration of the project. They dictate the safety structures and procedures that are inherited at the Site Management and Individual levels. Failures in planning can filter through a project e.g. appointing an incompetent PSCS can lead to poor co-ordination and supervision of contractors during the construction stage, leading to unsafe behaviour on the part of individual workers. Ultimately, activities and policies at HQ level set the tone - unless safety is prioritised and allocated resources in the early stages of a project it unlikely to be prioritised by site managers or workers. Even if individual managers or workers are highly concerned with safety, they will not have the widespread power and influence of actors at the HQ level.

The failures described mainly fall under the jurisdiction of the client (e.g. ensuring the appointment of competent dutyholders) and designer (e.g. including information on Particular Risks in the preliminary safety and health plan).

Two SM-related variable clustered together with the five HQ variables. Their inclusion highlights the links between activities at various levels. A failure to carry out adequate risk assessment at the design stage can lead to a failure in identifying hazards on-site. The failure on the part of the PSDS to develop a safety and health plan hinders the implementation of a safe system of work at site level.

Factor 2

Factor 2 comprises three items from the Site Management section of the questionnaire. The combination of items specifically describes deficiencies in on-site communication. Item J represents a situation where an adequate SSW may have been devised at management level but is not relayed to operatives. Failure to supervise both employees and subcontractors also indicates a lack of effective interaction.

This factor represents the interface between the organisation and the individual. HQ may develop the ideal safety policy, but it remains ineffective until it is interpreted and activated at site-level. The agents of this process are the safety officers and site supervisors. They have responsibility for disseminating the SSW and monitoring all employees. The means by which safety-related information can be conveyed are varied; verbal interaction with operatives, regulation and disciplinary action, information and poster campaigns on-site, or by good example.

It is possible to trace this factor through the three organisational levels utilised in the questionnaire. Priorities and resource allocation set by HQ determine the level of concern for safety on-site. In turn, the level of safety supervision and communication on-site will have an impact on individual safety behaviour.

Factor 3

These two items describe behaviour at the individual level. They refer to actions and decisions of the worker on the frontline. The two items are clearly connected – the absence of an adequate SSW leads to unsafe behaviour (S3) in the form of the operative using their initiative to solve a problem (U). An effective SSW would ensure that workers were properly trained and that procedures were in place to deal with most eventualities.

The problem at this level is compounded by the fact that the operative may regularly act in an unsafe manner and never suffer a negative consequence. Theories of accident causation identify the difficulty of intervening at an individual level due to the stochastic nature of accident events.

So many factors operate at the individual level (e.g. personality type, personal relationships, time pressures), that it is more useful to aim at putting an adequate SSW in place. The development and implementation of good procedures is beyond the control of the individual worker. Thus, the unsafe behaviours described by this factor are in part the product of decisions further up the organisational hierarchy.

7. DISCUSSION

7.1 Site Management Contribution

The results of the current study reproduce the high proportion of SM failures found in previous research (HSE, 1992; HSA, 1998). Regardless of where error originates it is most likely to manifest itself at site level. A report by the European Foundation for the Improvement of Living and Working Conditions (1991) observes that ‘the site is the point of convergence for all malfunctions created upstream, and that it is where the price is paid for delays, errors and omissions in the study and planning phases’ (p.10). Hence, the site has become the obvious focal point in all considerations of construction safety.

The emphasis on site issues may be a function of the data sources. The HSE collected information from site personnel, and the HSA studies have obtained information from investigating inspectors. It might be expected that both groups focus on site issues. Inspectors visit the site in the course of a fatality investigation and it is aspects of the site environment that attract their attention e.g. unguarded openings, collapsed trenches. They quickly identify the immediate triggers in the event area but have limited access to information at other levels in the organisation. The safety and health plan, safety statements and safety representatives give some indication of HQ input, but the inspector cannot establish the relative priority assigned to the safety in comparison to other demands.

The most frequently cited SM factors for the period 1998-2001 were extracted so that they might be compared with the results for the 1995-1997 project. The items that occurred most often were:

- Failure to implement SSW
- Failure to identify hazards on site

The implementation of the SSW represents the translation of HQ policy into site-level safety procedures. While some hazard identification may have taken place at HQ level, the unique circumstances of every site configure to produce local hazards that could not be predicted at the planning stage. Both items represent tasks that are primarily the responsibility of site managers or supervisors.

The Safety, Health and Welfare at Work (Construction) Regulations 2001 require a Site Safety Representative on every site with more than 20 workers. HSA figures indicate that only 12% of construction sites had a safety representative in place in 2001. The role should increase awareness of the safety agenda among operatives. In terms of the SM items, the site safety representative has an interfacing role. They may provide managers and supervisors with information about local risks and concerns (identifying site hazards) and they may also act as intermediaries for the implementation of the SSW. McDonald et al. (2002) found that the presence of a site safety representative showed the strongest relationship with safety compliance. They recommend that all sites should have a safety representative and 'their role and functions should be reinforced as part of the safety management system' (p.4).

The phased introduction of the Safe Pass and Construction Skills Card schemes are further measures aimed at site-level failures. By 1 June 2003 all construction workers must have received the necessary training and been issued with a Safe Pass Card. Specific trades e.g. scaffolders, mobile crane operators, excavator operators, must be in possession of the relevant Construction Skills Card. The effect of these measures should be to raise the general standard of competence on construction sites.

7.2 Headquarter Contribution

The results indicate that a substantial 28% of contributory factors were at the HQ level. Items in this section of the questionnaire focused on personnel concerned with the design and planning of the construction project e.g. clients, designers and dutyholders. The most frequently occurring items (in order) are:

- Failure to carry out adequate hazard identification and risk assessment
- Failure to take adequate consideration of design factors or features
- Competence of dutyholders (PSDS, PSCS, designer, contractor)

Consistent with the SM section, the largest factor in this section relates to the identification of hazards. The second factor is closely related – the designer can design out many of the hazards and risks once they have been identified. Failure to consider the implications of building design was identified as the most frequent failure in the 1998 study.

The HSE discussion document (2002) acknowledges that 'In general site conditions have been seen as exclusively the contractor's responsibility. Too often the designer's attitude has been that whatever the designer details or specifies it is up to the contractor to find a way to build it safely' (p.8). Carruthers (2002) refers to research conducted by the Institute of Civil Engineers in the UK which showed that '75% of all engineers working on design believed that more could be done to design out risks during construction'. There is enormous potential for the elimination of hazardous conditions at this stage. The HSE (1995) report for designers of smaller building projects states that 'it is only by considering health and safety issues from the earliest stages that designers can take full advantage of the opportunities for avoiding hazards on site' (p.2).

The third factor relates to duties of the client. The Safety, Health and Welfare at Work (Construction) Regulations 1995 state that clients must appoint a competent PSDS and PSCS. Guidelines are given for assessing competence. Clients are advised to ask about 'training, experience, track record and whether they have a health and safety management system in place. The degree of enquiry should be in proportion to the nature, size and level of risk involved in the project' (HSA, 2000). The client can set the tone of the entire construction project – their choice of dutyholders and contractor reflects their priorities with regard to safety and production.

Although the HQ category does not make the largest contribution, the factor analysis indicates that it is the category with most predictive power for the dataset, implying that improvements at this level will have the widest impact. The HSE (2002) estimates 'that 60% of fatal accidents are attributable to decisions and choices made before the work began' (p.26). This interpretation is also consistent with Reason's theory of accident investigation, which advocates the elimination of latent failures at an organisational level as the most effective means of reducing active failures and subsequent accidents.

7.3 Injured Party Contribution

The individual level factors most often cited as contributing to fatalities are:

- Unsafe act / risk-taking behaviour because of inadequate SSW
- Using initiative to solve problem (not trained / experienced for task)

These items map exactly on to Factor 3 extracted in the Factor Analysis (see Section 6.2.5 for a full description).

The general consensus in safety research represents a shift in emphasis away from the actions of the individual. Reason's theory suggests that there is limited value in attempting to anticipate every possible configuration of individual errors. The IP factor generally makes the least contribution to fatalities over the study period. A similar ratio applies to contributory factors for six out of the ten Incident Types. It is fitting that the factor making least contribution is also perhaps the least useful for the purposes of accident prevention.

7.4 Connections between levels

The authors of the 1992 HSE report on organisational, management and human factors in the construction industry note that management-level failures are regularly identified as a contributory factor 'without elaborating on the source of these failures or those pathways via which such failures are propagated' (p.11). This section attempts to identify the patterns by which unsafe behaviour is perpetuated through the system. Relationships between failures at different levels are important for accident analysis and particularly for the development of intervention strategies. Outlining how events at one level affect those at another suggests targets and routes for remedial action.

The HSE discussion document (2002) highlights the transfer of risk from one level to another – they posit that proposed reporting systems 'do not go far enough, because they do not address the situation where one party to the process can create or transfer risks to other parties' (p.13).

The failure to set up a SSW dominates the Site Management section. This failure may have its origin in several HQ factors. Incompetent dutyholders (item B) may not have the skills to develop a SSW. Under the 2001 regulations the PSDS is required to prepare key elements of the preliminary health and safety plan in writing. The PSCS extends the health and safety plan, and also organises the Safety File. The eventual system of work will be inadequate if these documents are not properly prepared. An alternative cause of the inadequate SSW may lie in the quality of the information provided by others to the PSDS or PSCS e.g. the designer may fail to highlight the safety implications of design features (item C1). The failure to set up and implement a SSW at site level has implications for individuals. The results reveal that operatives undertaking risk-taking behaviour due to an inadequate SSW is the most common contribution to fatalities at the IP level. Thus, an omission or error by an actor at HQ level influences the system of work at SM level such that individuals act unsafely in the absence of pre-arranged procedures.

Similarly, the impact of inadequate hazard identification may be identified at the three levels. The IP section highlights the dangers of operatives using their own initiative because they are not properly trained for a task. If hazards are identified in advance by site management or HQ, measures can be taken to ensure that operatives are selected and trained to deal with specific dangers. Ideally, information on hazards should move in both directions – designers and clients should alert project supervisors to the risks inherent in the design, dutyholders should make contractors aware of the hazards (ideally at the tender stage), who in turn should ensure that their employees and sub-contracted employees are suitably trained. Equally, operatives should alert site management to local hazards (through the safety officer), and contractors should advise designers on the 'buildability' of their designs.

7.5 Particular Risks

The 1995 regulations present a non-exhaustive list of Particular Risks in the construction sector. The most common incident types in the current research correspond with some of the Risks on the list.

- 'Falls from heights' (54 fatalities) are identified as a Particular Risk where working at a height is likely to be aggravated by the presence of another significant hazard.
- 'Transport, excluding RTA' (20 fatalities) is not specifically mentioned on the list of Particular Risks
- Many of the incidents included in the 'Struck by something collapsing / overturning' category (17 fatalities) are relevant to the 'Risk of burial or engulfment'.

- ‘Contact with electricity’ (14 fatalities) includes incidents that are covered by the category ‘Work near high voltage power lines’.

The analysis of these incidents at multiple levels offers additional information about the particular circumstances in which such risks culminate in fatal injury. ‘Falls from height’, ‘Transport, excluding RTA’ and ‘Contact with electricity’ maintain the overall pattern of contributory factors, with SM factors predominating. These all concern elements that are installed for the purposes of the construction project e.g. scaffolding, machinery, and power lines. Policy with regard to these fixtures will be issued from HQ level, but their translation into on-site fixtures may diverge from the ideal - it is at site level that the scaffolding is actually erected, the machinery is activated etc. The predominance of SM failures suggests that site-level monitoring and regulation are the most useful means of targeting these problems.

The HQ contribution to Particular Risks relates to issues such the selection of sub-contractors or the provision of resources. The design of the building and the planning of the project sequence may aggravate the risk of a fall from height if operatives ‘work on or adjacent to fragile roofing materials’ or where ‘the nature of the work or other restrictions make it impracticable to provide standard scaffolding or other suitable and sufficient means of support’ (HSA, 1999).

The ‘Struck by something collapsing / overturning’ category has a different ratio of contributory factors. HQ and SM factors are more important than the IP contribution. These incidents often involve trenches or walls collapsing, that is, structural elements of the site that are beyond the control of the individual worker. In such situations the worker has little opportunity to react or take preventative action. Efforts to prevent this Particular Risk should include adequate hazard identification and risk assessment at the design and site management stages.

The HSE (2002) discussion document notes that the types of incidents that lead to injuries and fatalities in the construction industry ‘are foreseeable and preventable. We have known for years how to prevent them, but they often happen in the same old ways’ (p.4). This is borne out by the finding that ‘falls from heights’ consistently account for almost 50% of construction fatalities. In the UK, fatalities among scaffolders, roofers and steel erectors were all above the HSE's intolerable risk criterion for the period 1993-1998 (Brabazon et al., 2000).

The circumstances of such incidents are not complex, usually involving a fall from scaffolding or roof, or through fragile roof materials. Enforcement actions confirm that extent of the problem – 'scaffolding safety and unguarded openings are major factors leading to prohibition and improvement notices' (HSA, 2002, p.12). The prevention of falls from heights does not require sophisticated engineered defences. The preventative measures are simple, but remain under-utilised.

7.6 Legislation

The statistical analysis revealed that the contributory factors for fatalities did not alter significantly after the implementation of the 1995 regulations. There are several possible interpretations of this outcome.

Firstly, this result is compromised by the poor quality of the data for the period prior to 1995. The number of cases for each of those years is not sufficient to permit robust conclusions.

The new allocation of responsibilities was introduced in mid-1996. It will have taken time for the regulations to filter through the system and be fully implemented. This is illustrated by the fact that, despite the regulations, dutyholders were appointed at only 55% of sites where fatalities had occurred in the period 1998-2001. If similar levels of uptake apply to other aspects of the regulations, it may not be the case that the regulations are ineffective, rather that they have not been effectively utilised.

A comparison of Figure 10 and Figure 11 below indicates that deficiencies in site management account for the same percentage throughout the study timescale, whereas there was a marginal rise in the percentage HQ contribution since 1996.

This increase may be a function of the increased consciousness of HQ factors brought about by the 1995 regulations. Previously, inspectors' attention was not directed toward failures on the part of clients, designers or project co-ordinators. The 1995 regulations widened the scope of the investigative process to take account of these elements. Thus, awareness of, and subsequent attributions to, HQ failures may have increased with the new regulations.

Figure 10. Contribution: Fatalities 1991-1996

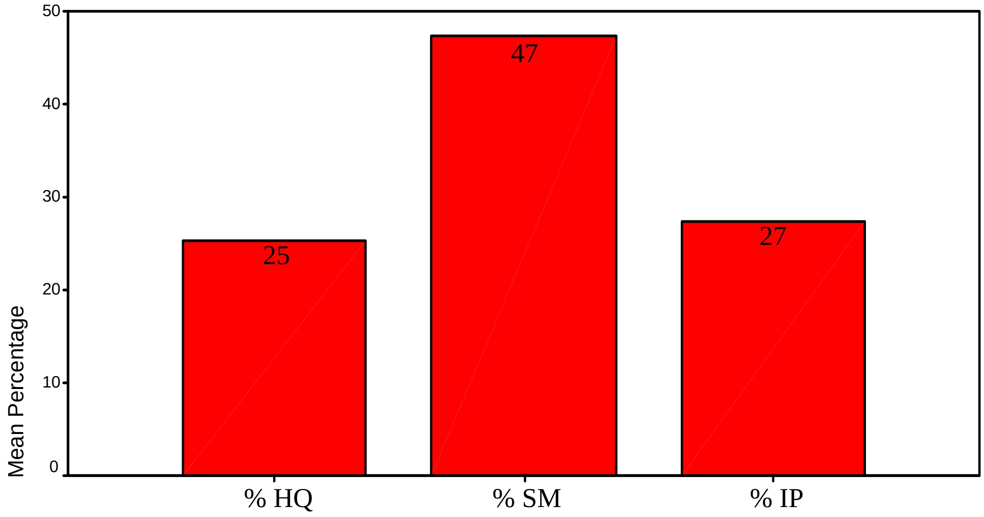
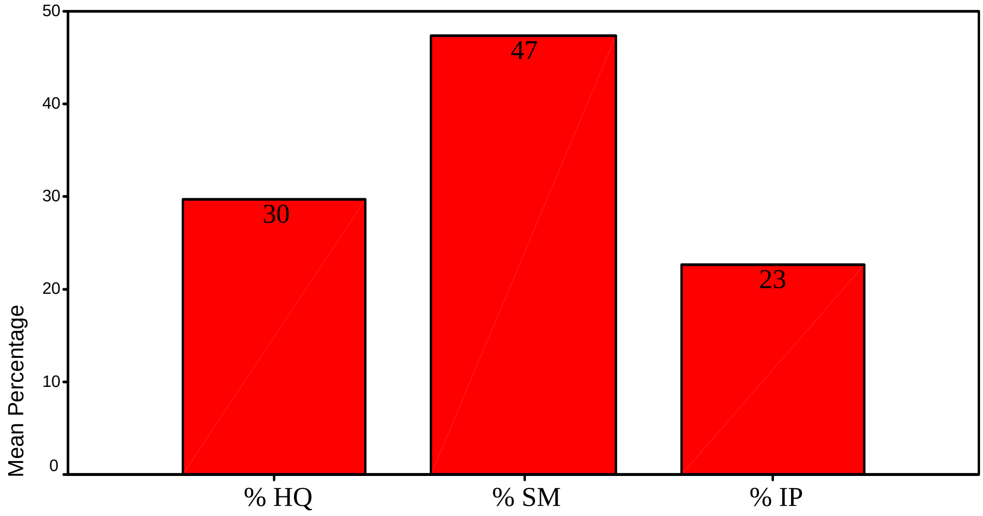


Figure 11. % Contribution: Fatalities 1997-2001



7.7 Limitations of the Current Study

The quality of data available for the period 1991-1994 is a clear limitation of the current research. Analyses have been conducted and results discussed on the basis of very few cases. This shortcoming should moderate the interpretation of the results and any subsequent conclusions, particularly those that compare data for pre- and post- 1995 Regulations.

The use of the extended questionnaire meant that data from the 1995-1997 study had to be omitted from certain of the analyses e.g. factor analysis. This was unfortunate as the entire dataset (bar one fatality) was available for this period. However, the value of examining the new information on the revised questionnaire outweighed this disadvantage.

While HSA inspectors provide a balanced overview of the accident circumstances and causation, they cannot offer the insight into the site safety culture that might be provided by site personnel. There may be social dynamics or local conditions that contributed to the accident, but are beyond the scope of the HSA investigation process.

7.8 Recommendations

This report is intended as a resource for those with responsibility for the development of regulations and policy. It is beyond the remit of this report to make direct suggestions to the construction industry.

However, there is one issue that may usefully be considered at a theoretical level. Having confirmed a consistent pattern for the contributory factors in construction accidents, the question arises - at which level should we direct legislative change and intervention strategies in order to maximise safe performance?

The knock-on effect of errors has been a recurring theme through the current report, suggesting that remedial action should focus on HQ level factors, thereby pre-empting errors further along the project chain. Using Reason’s terminology, Suraji et al (2001) describe how ‘pathogens may originate from project conception, be transmitted through the project development and design phases, and subsequently result in inappropriate system states during construction operations’ (p.338). Suraji et al.’s own model illustrates how responses at one level determine the constraints experienced by personnel at subsequent levels. In the current study it is possible to connect errors at different levels e.g. failure to design out hazards at HQ level, leading to oversights at SM level, leading to unprepared operatives at IP level. The potential for intervention at HQ level is supported by the outcome of the factor analysis - a HQ level factor accounted for most variance in the dataset.

It is only actors at the HQ level who have the authority and resources to prioritise safety, to create a climate in which acceptable safety standards can be set and achieved. Concern for safety at this level has widespread impact throughout the project. However, most campaigns aim to change individual operative behaviour (IP level). Regardless of how successful the intervention, the effects are local to the participant and are subject to influence from higher levels e.g. pressure to increase productivity may cause safety procedures to be disregarded.

This is not to remove all responsibility from the individual worker, who is often directly responsible for an accident. But the emphasis on individual failures 'results in a reliance on short term solutions rather than any attempt to uncover more fundamental management or organisational problems' (Whittington et al, 1992, p.4). The remedy targets a specific event or operative, such that no effort is made to uncover the underlying cause of the accident. HSE research (2001) observes that 'changes at the direct level alone will not deliver the degree of change being sought, nor would the improvement be sustained' (p.0.11). Further, Reason (1990) highlights the impossibility of anticipating the infinite number of possible failures that can occur at the individual level. It is more effective to eliminate failures at the HQ level – the number and type of possible errors increase as the project progresses to the construction phase.

Several recommendations may be made in relation to future research.

The precedent set by the HSA in commissioning reports in 1998 and 2002 is positive. Analysis of the HSA fatality data is a valuable exercise and should be carried out at regular intervals. Collating and reviewing the available information reveals trends and common causes in Irish construction fatalities. The bank of data may also act as a baseline, facilitating the evaluation of any legislative changes or safety campaigns.

The HSA records fatality information on the SAFE system. A review of the literature has suggested several categories that might usefully be recorded and included in future research. Data on the size of the company that employed the deceased, and the size of the site where the fatality occurred would facilitate the identification of high-risk situations. It would also be useful to create taxonomies for some data, similar to the 16 categories under which incident type is recorded. Although a detailed system for recording trades exists, it may be more practicable to develop a summary taxonomy with categories for general labourer / electrical workers / woodworkers / scaffolders etc. In the current study, the variety of trades recorded was such that no trade, apart from the 'general operative' category, had sufficient numbers to permit meaningful analysis.

The SAFE system is limited to a description of the fatality – it does not incorporate any causal analysis. The RIDDOR system in the UK (HSE, 2001) is similarly deficient – 'data have generally been gathered to determine the profile and extent of accidents and data collection has focussed on parameters which are readily quantified and categorised' (p.6.2). Merely gathering data is not sufficient – a more in-depth interpretation is required in order to establish how accidents may be prevented in the future.

But a causal analysis is a complex exercise, requiring an assessment of the interaction of multiple factors at multiple levels – who is qualified to make causal attributions? Particularly in the event of a fatality, personnel in the construction industry may fear blame and prosecution and consequently offer biased interpretations of events. The HSE has developed a causal classification for inspectors entering data on their FOCUS system. These are broad categories e.g. 'failure to control risk' and 'inadequate supervision'. The authors of the HSE report on 'Improving Health and Safety in Construction' (2001) note criticism that these groupings are 'too generic to be instructive' but they advocate the system on the basis that it 'enables system failings to be compared across accident types whereas a more detailed assessment would become task specific' (p.7).

Perhaps a causal analysis of fatal accidents could be incorporated into the SAFE system. Indeed, the questionnaire used in the current study provides a starting point for such a development, offering a list of contributory factors that span the entire construction project. Building causal information into the database would facilitate regular analyses, with minimum time and effort. Lessons learned could be incorporated into future HSA strategy.

7.9 Concluding Comments

The results of this project further establish the pattern of contributory factors whereby site level factors contribute twice as much to fatalities as headquarter or individual factors.

Contrary to the hypothesis, the ratios did not alter with the introduction of the Safety, Health and Welfare at Work (Construction) Regulations 1995. It is perhaps fair to conclude that the ratios are unlikely to change radically. The precipitating event for most fatalities and the immediate investigation will always occur at site level, so that site-level failures will continue to dominate accident analyses. The main point to take from the current research is an increased awareness that events on-site are manifestations of events and decisions at other levels.

The research design should not be over-interpreted – it is not sufficient to examine levels of the construction industry in isolation. McDonald et al. (2002) note that 'the most acute problem may lie less with the commitment of the individual workers or management, and more with the failure of the system for regulating and managing safety to provide effective channels to translate safety aspirations and initiatives into effective outcomes' (p.74). The discussion for this project reveals that errors can be traced through the entire system e.g. failure to identify hazards. As such, any attempt to improve safety must be comprehensive, improving performance within levels, while enhancing communication and co-operation between levels.

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Websites

www.cif.ie

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APPENDICES

FAO: Investigating Inspector

13 September 2002

Dear Inspector,

RE: Survey of Fatal Accidents: 1991-2001

The aim of this research project is to trace health and safety trends during the selected period, and identify contributing factors. This is a follow up to a previous HSA project which included data from 1995-1997.

As an investigating inspector for a fatality during the past four years, I would be grateful if you would complete the attached survey(s).

I have included the following where available:

- Brief outline
- Initial fax to the Department for Enterprise and Employment
- Investigation report

Please return the completed questionnaire by the 27 September 2002. It would also be very helpful if you could include a copy of the accident report, if it is not enclosed with this letter. Alternatively, you may provide details of where the report is located on the HSA network.

Please do not hesitate to contact me if you require further information.

Thank you in advance for your assistance.

Yours sincerely,

Marie Dalton
Research Assistant, HSA

Tel: 01 6147088
Email: Marie_Dalton@hsa.ie

Enc. F39/99

Appendix 2 – Study Questionnaire

D = definite contribution to the accident
P = possible contribution to the accident

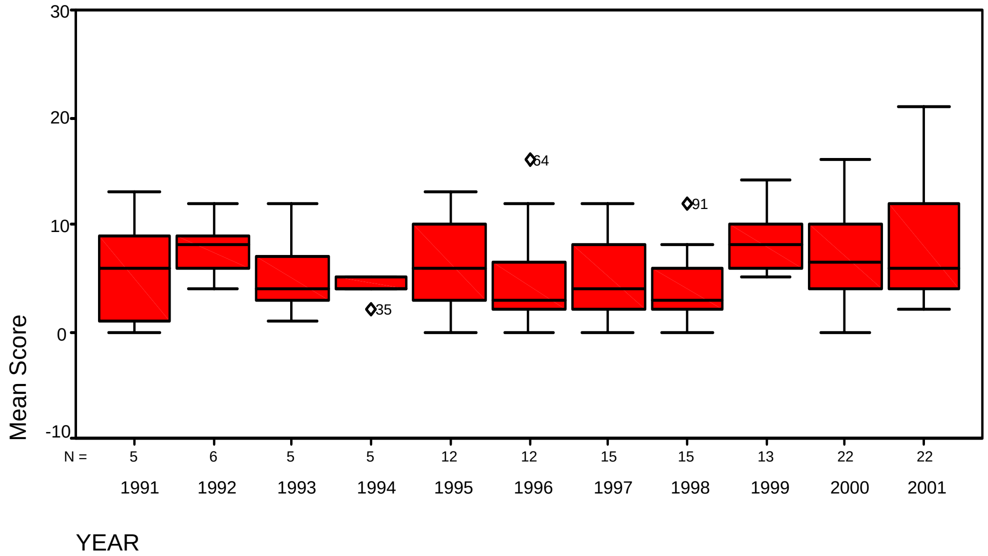
(D and P may appear more than once in each section)

FACTORS RELATED TO HEADQUARTER RESPONSIBILITIES		
A	Was PSDS/PSCS appointed (Is CR1 form available)?	Yes / No
		D or P
B	Competence of dutyholders (PSDS, PSCS, designer, contractor)	
C	Failure to take adequate consideration of:	
	(i) design factors or features(including temporary works) e.g. fragile roof lights, propping/shoring systems	
	(ii) personal protection equipment (PPE)	
	(iii) project timescale	
D	Poor system for controlling maintenance of plant (own or SC's) e.g. cranes, MEWPs	
E	Failure to learn lessons / be aware of spate of similar accidents	
F	Failure to carry out **adequate** hazard identification and risk assessment e.g. public access etc.	
G	Failure to develop adequate Safety & Health plan/plans	
H	Other HQ factor	
FACTORS RELATED TO SITE MANAGEMENT		**D or P**
I	Failure to implement a safe system of work (SSW)	
J	Failure to communicate SSW to operators	
K	Failure to identify hazards on site	
L	Failure to take appropriate action on recent safety incident	
M	Failure to supervise:	
	(i) employees	
	(ii) subcontractors	
N	Poor control/planning of multiple/linked tasks	
O	Failure to ensure supervisors/operatives trained or authorised for task	
P	Provision of wrong equipment for task (or correct equipment not used)	
Q	Other issues relating to:	
	(i) unauthorised access	
	(ii) scaffolding	
	(iii) ladders	
	(iv) excavations	
	(v) electricity	
	(vi) PPE	
R	Other site management factor	
FACTORS RELATED TO INJURED PARTY		**D or P**
S		

	Unsafe act / risk-taking behaviour (i) because of exceptional time pressures (ii) because of habitual violations (e.g. correct method may take longer) (iii) inadequate SSW (iv) other	
T	Miscommunications between operatives on site (e.g. banksmen)	
U	Using initiative to solve problem (not trained/experienced for task)	
V	Other injured party related factor	

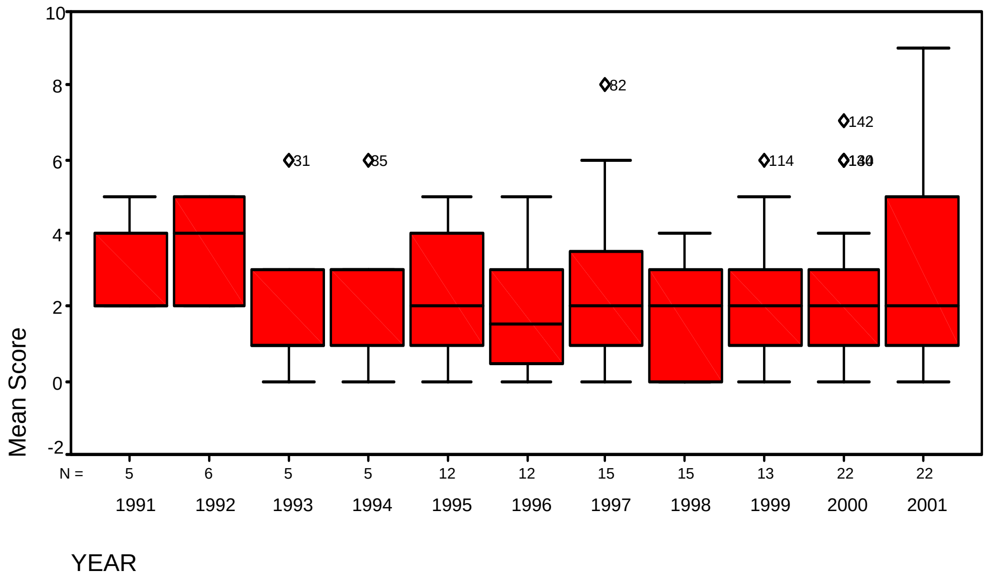
3.1 Boxplot representing SM contribution to fatalities 1991-2001

Figure 2. Site Management factors 1991-2001



3.2 Boxplot representing IP contribution to fatalities 1991-2001

Figure 3. Injured Party factors 1991-2001



3.3 Bivariate correlation: Year x HQ x SM x IP

		YEAR	TOTALHQ	TOTALSIT	TOTALIND
YEAR	Pearson Correlation	1	.129	.130	-.031
	Sig. (2-tailed)	.	.154	.152	.734
	N	159	123	123	123
TOTALHQ	Pearson Correlation	.129	1	.665**	.214*
	Sig. (2-tailed)	.154	.	.000	.018
	N	123	123	123	123
TOTALSIT	Pearson Correlation	.130	.665**	1	.336**
	Sig. (2-tailed)	.152	.000	.	.000
	N	123	123	123	123
TOTALIND	Pearson Correlation	-.031	.214*	.336**	1
	Sig. (2-tailed)	.734	.018	.000	.
	N	123	123	123	123

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.4 Independent Samples T-Test: Ratios pre- and post 1995 regulations

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TOTALHQ	Equal variances assumed	1.371	.244	.647	121	.519	.4271	.65971	-.87899	1.73313
	Equal variances not assumed			.708	61.255	.482	.4271	.60344	-.77949	1.63363
TOTALSIT	Equal variances assumed	.253	.616	-.172	121	.864	-.1417	.82470	-1.77436	1.49105
	Equal variances not assumed			-.178	54.890	.860	-.1417	.79752	-1.73998	1.45667
TOTALIND	Equal variances assumed	.049	.825	-1.052	121	.295	-.3969	.37713	-1.14355	.34972
	Equal variances not assumed			-1.128	58.789	.264	-.3969	.35197	-1.10126	.30743

3.5 Independent Samples T-Test: Ratios for employees and self-employed

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TOTALHQ	Equal variances assumed	1.993	.161	2.103	108	.038	1.3642	.64873	.07834	2.65012
	Equal variances not assumed			2.323	68.671	.023	1.3642	.58716	.19278	2.53568
TOTALSIT	Equal variances assumed	5.258	.024	2.577	108	.011	2.0470	.79437	.47238	3.62153
	Equal variances not assumed			3.004	78.377	.004	2.0470	.68139	.69053	3.40339
TOTALIND	Equal variances assumed	3.918	.050	.458	108	.648	.1760	.38386	-.58489	.93687
	Equal variances not assumed			.521	73.651	.604	.1760	.33762	-.49678	.84876