ACCIDENT PREVENTION ON CONSTRUCTION SITES: TOWARDS A NEW APPROACH

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Abstract: With an average of 150 deaths and 20,000 injuries reported to the Health and Safety Executive each year, the construction industry has one of the poorest safety records. This trend continues to rise despite availability of legislative provisions and guidelines. Although some causes of accidents are known, the underlying factors that bring about accidents are not yet well understood. Data available is inadequate in explaining the underlying interactive factors in accident causation on construction sites. Henceforth, this research design is presented with the aim of developing a better explanation of accident causation. It proposes the development of a methodology that provides a sound basis for accidents’ causation. In addition, it seeks to develop a series of tools for risk assessment analysis. These tools are based on recent technological developments in 3D Geographical Information Systems (GIS) and Virtual Reality (VR). Development of analytical tools to visualize accidents on site using 3D GIS will enable stakeholders in the industry to identify hazards and areas for effective preventive actions. Ultimately, it will result in the formulation of preventive health and safety policies that can assist industry reduce accident occurrence on construction sites.

Keywords: Accidents, Geographical Information System, Health and Safety, Risk Assessment, Virtual Reality.

INTRODUCTION

The construction industry has invested much time, effort and money in trying to improve its health and safety performance. This investment has had success in the past in achieving significant improvements in the industry’s record. However, these have not been maintained in recent years and now construction is one of the most dangerous industries (Health and Safety Executive 1988).

Accidents on construction sites are a major cause of avoidable ill-health; injury and death. DOH (1993). Nutt et al (1998) suggest that 20% of reported construction accidents could be attributed to poor site logistics. Every week, more than one person is severely injured or dies of accident cause CIRIA (2003). Accidents on sites are one of the most important factors in health service utilisation (DOH 1993). Efforts to improve Health and Safety on site have been of primary importance in an industry that continues to kill and maim its people every week.

Accident causation process is complex and is affected by several factors, which could be related to each other. Consequently, an accident prevention strategy requires a comprehensive understanding of this complex process. This paper reports on an ongoing research study, which seeks to account for the underlying causes of accidents on construction sites. It is suggested that this investigation will produce an informed basis for formulating a sound accident prevention strategy.

BACKGROUND

The construction industry’s safety record continues to be poor (Raymond 1995). In a typical decade, about 1500 people are killed on construction sites in Britain and 25,000 – 30,000 more are seriously injured. In addition, 300,000- 400,000 suffer injuries sufficient to keep them off normal work for at least three days (Davies and Tomasin 1996).

The Health and Safety Executive (HSE) (1988) published a study of accidents over a five-year period in the building and civil engineering industry entitled ‘Blackspot Construction’
which analysed 700 fatal accidents that had occurred over this period. It reported that between 1981 and 1985, 739 people were killed in the construction industry (Table 1.0).

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths</th>
<th>Major Injuries</th>
<th>Total</th>
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<td>128</td>
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<tr>
<td>82</td>
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<td>87/8</td>
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<td>3328</td>
<td>3471</td>
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<td>88/9</td>
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<td>3660</td>
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<td>93/4</td>
<td>88</td>
<td>2567</td>
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<tr>
<td>94/5</td>
<td>74</td>
<td>2582</td>
<td>2656</td>
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</tbody>
</table>

Note: 1. From 1986 the reporting year is April to March
2. Fatalities and major injuries to the employed and self-employed are included in the table but not the non employed
3. The continuity of major injury statistics was disturbed in 1986 by revised definition of a major injury
Source: Health and Safety Executive

The study showed that 90% of these accidents were judged preventable and that for 70% of them, action by management could have saved lives. HSE findings reported that the majority of the accidents could have been prevented by the application of reasonably practicable precautions.

Raymond (1995) attributed accidents’ causation to several factors, which include:

1) **Lack of supervision by the line managers:**
   This view was identified by the HSE and supported by the unions. It was felt that the widespread use of subcontractors and self-employed labour led to problems of management and control. These issues were exacerbated by the new forms of contracting, which involved management remote from construction sites;

2) **Custom and practice in the industry:**
   The construction industry was not equipping workers to identify danger and take steps to protect themselves;

3) **Lack of coordination:**
   The lack of coordination between the members of the professional team at pre-construction stage has been found to be a contributing factor to accidents. As accident prevention on construction sites is a responsibility of everyone involved in the construction process, each duty holder in the process has a different and clear role. By working together through teamwork and collaboration with other duty holders, all parties can improve health and safety standards on construction sites.

   Different teams and individuals are involved at various stages. At each stage, designers from all disciplines have a contribution to make in avoiding and combating safety and health risks in construction. The development of detailed specifications may depend on a range of specialist teams. As the design evolves, decisions taken at early stages in the design process may be influenced by later decisions. Therefore a lack of pre-construction coordination between the professional teams would lead to decisions contradicting earlier or other professional teams decisions and this would inevitably lead to accidents on site. While it is noted that manpower training is also an important factor in accident prevention it is not a sufficient tool in accident prevention per say but rather a supporting tool.

   In addition, Davies and Tomasin (1996) put accident figures in perspective by linking them to the number of people at risk. Thus, comparisons of incidence rates, which are the number of fatalities and major injuries per 100,000 employed, provide a means of assessing the relative danger for people at work in various industries. In comparison to the manufacturing industry, the risk of a major injury is almost twice in the construction industry and the risk of a fatal accident nearly five times greater (Table 2).
Table 2.0. Fatal and major injuries in construction per 100,000 people employed

<table>
<thead>
<tr>
<th></th>
<th>81</th>
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<tr>
<td>Construction Industry</td>
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<td>9.7</td>
<td>11.6</td>
<td>9.8</td>
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<td>9.4</td>
<td>9.3</td>
<td>8.8</td>
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<td>Manufacturing Industry</td>
<td>2.0</td>
<td>2.4</td>
<td>2.2</td>
<td>2.7</td>
<td>2.4</td>
<td>2.1</td>
<td>1.9</td>
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<td>2.1</td>
<td>1.8</td>
<td>1.5</td>
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<tr>
<td>Major Injuries</td>
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Source: Health and Safety Executive.

In the HSE Self-Reported Work-Related Illness (SWI) survey of 2001/02, it was estimated that 137,000 people whose current or most recent job in the last 8 years was in the construction industry suffered from an illness, which they believed, was caused or made by this job. The corresponding prevalence rate, 5600 per 100,000 people working in the last 8 years, was statistically significantly higher than the average for all industries (HSE 2003).

An earlier SWI survey conducted in 1998/99, but restricted to people who worked in the last 12 months, indicated that the highest prevalence rate of self-reported musculoskeletal disorders, were ascribed to the construction industry. This rate is significantly higher than the average for all other industries.

Winkler (2003), in a report to Construction Productivity Network, pointed out that over a 12 year period between 1990 to 2001, the HSE statistics showed that the construction industry has made improvements regarding the number of fatalities, decreasing from over 150 in 1990 to just over 100 in 2001, with a low of 65 in 1999. Despite the overall fatalities figure reduction from 1990 to 2001, the number remains significantly high. For instance, accidents by fall, whilst not the largest single cause of death, are a significant cause of mortality on sites (CIRIA2003).

Moreover, while there has, reportedly, been some improvement in site safety in recent years, Davies and Tomasin (1996) suggested that statistics are unreliable due to under reporting and that the number of fatalities in the construction industry is only a tip of the iceberg. There are thousands of major injuries each year and even more minor injuries, which result in absence from work on more than three consecutive working days, which go unreported. The Health and Safety Executive recognises that only a fraction of non-fatal injuries are reported each year. In spite of this apparent improvement, it is clear that injury rate for the construction industry is still at an unacceptably high-level.

**COSTS OF ACCIDENTS**

Accident statistics represent not only the terrible human tragedies but also substantial economic and psychological costs. Accidents can result in the following:

- damage to plant and equipment,
- damage to work already completed,
- loss of productivity work time while debris is also cleared and damaged work rebuilt,
- reduced work rate until normal site working rhythm and morale are restored, disruption while investigations are carried out by the company safety department, the insurers, inspectors from HSE and sometimes representatives from the trade unions,
- legal costs and, in some case, fines,
- loss of confidence and reputation.
ACCIDENT CAUSATION

Accident causation is a complex issue, as there are usually several contributing factors that are the root causes of accidents on sites. Accounting for the interrelationship between these factors and their effects on accidents is a critical for an effective accident prevention strategy.

Data currently available on accident causation are, in many respects, inadequate for explaining the underlying and complex interaction of factors in the causation process. Prevailing construction accident reporting systems identify the types of accidents and how they occurred (HSE 2003). Although some of the causes of accidents are usually known (e.g. falls from ladders), the underlying factors causing the accidents are rarely accounted for i.e. temporal and spatial patterns. Overall, the combinatorial complexity of possible causes for accidents on sites is still unaccountable.

In a report to CIRIA (2003), it recently emerged that there is also increasing focus on the role of the designer in designing or mitigating risks both in the construction phase and during the operational life of the facility. In addition, it also became apparent that most accidents occur as a result of poor planning and design at the early stages of the construction project. HSE also published a new work plan, and announced its intention to get more involved at the planning and design stages of construction projects. Where safety risks are designed out and health issues of both contractors and end users are properly taken into account by designers, radical improvements can be realised in helping to reduce the emotional and physical cost of suffering, as well as the inevitable financial costs. The designers’ responsibility for safe design procedures and considerations applies to all design, construction and maintenance works and should not be seen as restricted only to design work specifically covered by the Construction Design and Management (CDM) Regulations 1994.

Overall, there has been a lack of appropriate support tools to assist designers and decision-makers to assess the risks of accidents and formulate effective preventive measures. However, in recent years, major efforts were devoted to the development of various IT support tools to deal with safety management on construction sites. The advances in computer technology are increasingly offering various communication and decision-support tools in health and safety management.

IT AND HEALTH AND SAFETY ON CONSTRUCTION SITES

According to Kibblewhite and Fidderman (1998), there are now more than 500 safety software products on sale in the United Kingdom. These products broadly deal with single aspects of safety management, such as auditing, or are component modular-based safety management systems.

- **Specific Software** addresses issues such as Control of Substances Hazardous to Health (COSHH) assessments, and personnel health and medical issues, such as the prevention of coronary heart disease.
- **General Software** permits users to enter details of workplace hazards, work areas, activities and tasks, persons and numbers at risk, probability factors, severity, control measures, and recommendations with implementation timescales. Some products include full employee health history, medical surveillance and occupational hygiene sampling records, along with workplace risk assessments.
- **Wide-ranging software** includes products that attempt to address every aspect of an organisations safety management system, from policy through risk assessment to auditing. In some instances, they will include allied areas, such as environmental risk assessments. Other software calculates absolute or relative risks, cites the levels
numerically or graphically, sets acceptance criteria; issues review dates and reminders for subsequent assessment, and sets priorities. Some systems will automatically link the assessment to administrative controls, including the issue of permit-to-work systems.

Despite these tremendous developments, there is still considerable debate about the utility of available computer-based decision-support systems in health management and prevention. One of the fundamental problems is related to the difficulty in the use of software, which has limited their widespread use in construction. Additionally, these tools suffer from their lack of multi-sensory capabilities, as the output of the analysis is often based on textual information. Above all, the design of software lacks understanding of the fundamental factors of accident causation.

Clearly, there is a need to improve our knowledge of accidents causation and to provide more intuitive and comprehensible media for analysing and visualising accidents. For instance, it was suggested that the application of Virtual Reality techniques would instil good safety practice by involving people in accident and fire scenarios (Kibblewhite and Fidderman 1998).

It is against this background that this research focuses on the development of IT tools that will enable the study of accidents and their prevention in construction projects. The proposed techniques would enable users to analyse factors that may lead to accident before the actual factors occur. By so doing, they put management a proactive position, enabling accident prevention planning measures. This would invariably bring down costs on the employer, designers and the health practitioners, and, above all, reduce accident occurrences on construction sites.

AIMS AND OBJECTIVES

The aim of this research is to put forward a methodology for accident prevention on construction sites. The proposal utilises the state of the art technology for accidents prevention on sites, by meeting the following objectives:

- Provide a better understanding of the contributing factors to accidents on sites;
- Foster the early involvement of stakeholders in the formulation of health and safety policy at the early stages of the design process;
- Develop an analytical model for the identification of potential hazards, at the design stage;
- Produce tools, which enable the visualisation of the analysis in real-time;
- Evaluate the potential for further development exploitation of the analytical tools.

The research design proposed puts forward a new methodology to provide a better explanation of accident causation for construction activities on sites and to identify aspects where more effective prevention efforts should be directed. In addition, it proposes to develop a series of tools for risk assessment analysis. A new opportunity has arisen with the technological developments in 3D Geographical Information Systems (GIS) and Virtual Reality (VR), which assists in the analyses of accident patterns e.g. type of accident, location on site, time, day and date of accident, type of person injured, injury sustained etc. It is suggested that the rehearsal tools help various stakeholders to identify hazards and to assist in the formulation of preventive measures, which assist them in the elimination of the risk of accidents and injuries on construction sites, at the early stages of the design stage.
METHODOLOGY

The research design will begin with an in-depth review of related work in this area, in particular health and safety research and work relating to the application of geographical information systems in health and safety applications. It will require a detailed analysis of accident statistics and their associated spatial-temporal factors that are collected and collated by the Health and Safety Executive.

An analytical model, within a 3D GIS environment, will be used to intuitively organise and display the accident data, according to its spatial and temporal aspects. This innovative approach offers an extra dimension of information that is often important in understanding accident causation or grasping obscure relationships between contributing parameters, which include:

- population or people involved, e.g. age or gender, training;
- type of injury and cause(s), e.g. falls or chemicals;
- temporal such as diurnal and seasonal;
- location, e.g. trench, roof; and
- other factors, e.g. time of day or costs or other factors not accounted for such as human and organisational issues, as well as regulatory or safety considerations.

By combining 3D GIS and Virtual Reality technology, it is possible to provide decision-makers with robust analytical tools to visualise accidents on site in real-time in the 3D GIS environment. It provides real-time and realistic evaluation of spatial and temporal data to assist in risk assessment. This approach will improve understanding of analyses and will enhance the handling of queries related to accident data, at the design stages. The prototype produced will allow those concerned with site safety to build-up real world scenarios at the design stage and translate them into dynamic 3D simulations to assist in the identification of hazards and thus, determine appropriate and effective preventive measures. In addition, users will be able to visualise and evaluate the results of a risk assessment in a 3D, which will facilitate better communication for all involved in the management of health and safety in the construction process.

CONCLUSION

It emerged that most accidents occur as a result of poor planning and design at the early stages of the construction project. All the stakeholders in the construction process have a responsibility for safe design and construction procedures. Therefore, considerations should apply to design, construction and maintenance works and should not be seen as restricted only to design work specifically covered by the CDM Regulations 1994.

Clearly, a new approach is needed to overcome the identified limitations with current tools and techniques in accidents’ prevention. This paper presented an innovative methodology that seeks to identify the underlying causes of accidents and their interrelationships. It proposed that the link between construction tasks, spatial, and temporal aspects of accidents requires to be fully understood. The research also advocated the need for new tools in the form of 3D GIS and VR, which could support more effectively the decision-making process about potential hazards on site.

The benefits from this research work will be wide-ranging, as it has the potential to be used by all those involved in the construction process. It will contribute to creating a working team to design out health and safety problems from the onset stages of the projects. It will be used by a variety of stakeholders within the construction industry, including designers to enable them to design projects that are safer to construct, maintain, renovate and demolish;
managers to enable them to identify and thus manage hazards and their associated risks more effectively, estimators to enable them to include costs for appropriate safety measures, site operatives to raise their awareness of health and safety issues and insurance assessors to quantify the risk of accidents on site.

REFERENCES


HSE (1988), Blackspot Construction: A study of five years fatal accidents in the building and civil engineering industries, HMSO.


