33 IT TOOL FOR CONSTRUCTION SITE SAFETY MANAGEMENT

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Abstract
The construction industry remains to be one the most dangerous industries in which to work. Hazard identification is fundamental to construction safety from statistical, legislative and risk management perspectives. However, from a practical standpoint, all site-based activities are made up of a series of tasks executed by construction operatives. Association of hazards with tasks becomes important to both managing construction safety and communicating safety and hazard awareness down to the people who are actually exposed to the hazards. In practice, projects are always faced with time, cost and manpower constraints so tasks also need to be prioritised in terms of risk so that limited site resources can be focussed upon the tasks that expose operatives to the greatest danger. This paper discusses a web-based construction site safety management tool intended to address these issues.

Keywords: *construction safety, hazard identification, risk assessment, information technology*

INTRODUCTION

Globally, the construction industry has a poor safety record and is disproportionately dangerous compared to other industries. Statistics from the Health and Safety Executive (HSE) show that U.K. construction workers are approximately five times more likely to be killed and two times more likely to be seriously injured compared to the average for all industries (Whitelaw 2001). U.S. construction workers are over three times more likely to be killed than the all-industry average and one in six construction workers can expect to be injured every year (Kartam 1997). In 1998 the U.K. average annual fatal accident rate per 100,000 employees was 5.6, while the E.U. average was 13.3 (Whitelaw 2001).

A potential key to improving construction safety is reducing the occurrence of hazardous events. The authors are developing an IT tool for construction site safety management that has at its heart a database containing combined knowledge and experience of personnel within the company. The key issues addressed in this system are hazard identification, task/hazard relationships and risk quantification.

Other research has attempted to integrate safety into construction schedules. The systems work by linking safety information, obtained from databases, to activities in the schedule. These proactive systems allow management to plan and respond to general safety issues. However, contractors still need to produce method statements for all construction activities within the schedule, which involves creating a detailed methodology stating the specific tasks that operatives will need to perform in order to complete a particular activity. The authors will present a system capable of linking hazards to tasks so that a complete risk assessment can be produced automatically when a methodology is devised. It is method statements that communicate safety issues to site foremen and operatives who actually have to carry out specific tasks and encounter specific hazards.

Improving levels of hazard identification and linking hazards to construction activities should result in improved safety awareness and reduced accident rates. The use of historical accident data will enable a more reliable and objective quantification of risk to take place. Risk can be linked to tasks via the task/hazard relationships to allow task safety-significance to be established. It is hoped that this can be used to prioritise tasks in terms of risk and help safety managers to focus limited resources on the tasks that have the greatest potential for harm.

IT IN CONSTRUCTION

Other Construction Safety Research

Systems have been developed that incorporate health and safety into construction critical path method (CPM) scheduling software (Kartam 1997, Coble et al 2000). The aim of these systems is to introduce health and safety considerations as early as possible during the project. Such incorporation of safety within the construction schedule allows advance planning to take place, e.g. preordering special equipment and materials to deal with a hazard or arranging safety training for future work (Coble et al 2000). These systems rely on safety database systems. Information sources of these databases can include data from health and safety professionals, research results from field studies, existing databases and computerised standards and regulations from safety institutions such as the HSE in the U.K. and the Occupational Safety and Health Administration (OSHA) in the U.S. This safety information is then linked to the CPM project files. Many project CPM networks contain thousands of activities so the safety information is accessed via links on the schedule rather than being superimposed directly onto the network. The results of this type of research are proactive safety systems that give management advance warning of general safety issues, which allows effective planning and response.

Other safety systems being developed address the issue of health and safety training. Training software is aimed at site foremen and operatives so it must be designed for their needs. Thus most training topics are based on video clips supplemented by voices, while the software itself makes use of text, voices and icons so that semiliterate and illiterate people can still use them. One system (Aranda 2000) involves users navigating a construction site from a 'first-person' perspective, i.e. through the eyes of the 'virtual operative'. The user identifies hazards and can suggest what needs to be done to improve safety.

Future Trends in IT

Previous questionnaire-based research (Froese and Waugh 1991, Waugh et al 1996) has attempted to gain an insight as to what the role of computers will be in project management and construction in future years. Their first conclusion was that projects would be carried out by fewer organisations working in larger partnerships. In the future, computers will be interconnected to the same degree that telephones are now. Both inter- and intra-organisational information access and communication will increase in future years. Computer speed and power will, and has already been seen to, increase dramatically. This will have profound implications on managing information exchange and information processing. Many computer programs of today are stand-alone applications that 'own' their own data. Results from both sets of questionnaires indicated people thought that in the future applications will: (1) be able to exchange all forms of data with other applications on demand; and (2) operate with bodies of information that they don't 'own' such as project databases. Web-based applications will also become more popular.

A recent magazine article (Fleming 2001) heralded Bluetooth as a technology that could revolutionise the construction workplace. Bluetooth is a wireless technology that communicates to other Bluetooth enabled devices via short-range radio links. On site, people will be able to share information with less effort and more effectiveness than conventional methods. This technology, combined with palm-top computers, will enable network access anywhere.

RESEARCH INTRODUCTION

Objectives

The overall objective of this research is to reduce on-site accident rates. If this happens then accident costs will naturally be reduced.

Specific objectives that may help achieve the primary objective are to:

1. Improve the level of hazard identification on-site.
2. Base risk calculations upon historical accident data contained within a central database.
3. Better integrate the contents of risk assessments into method statements so that operatives and supervisors have a better understanding of the hazards, risks and control measures associated with specific tasks.

Rationale and Approach

Hazard identification is fundamental to construction safety. There are three reasons for this. Firstly, the fatality of a construction worker can be considered as the peak of a statistical triangle that has at its base many hazards (Figure 1). For every hazard there is a probability that a hazardous event, sometimes called a 'near-miss', will occur. Likewise, there is a probability that some of these events will result in an accident. The proportion of accidents occurring decreases as the severity of the accident increases until we reach the peak of the triangle as defined by the occurrence of a fatal accident. Thus, the key to improving construction safety is reducing the occurrence of hazardous events, which have the potential to cause accidents.

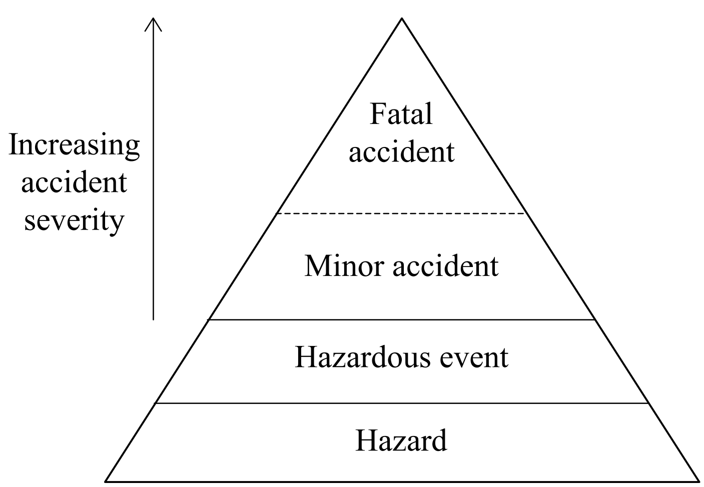

Figure 1: Statistical triangle showing progression from hazard to fatal accident

Secondly, the Construction (Design and Management) Regulations 1994 (CDM Regs) (HSE 1994) and the Construction (Health, Safety and Welfare) Regulations 1996 (HSE 1996) are the main pieces of legislation in the UK relevant to construction safety. These regulations placed new duties upon clients, designers and contractors to take account of health and safety and manage it effectively through all stages of a project. CDM Regs require risk assessments to be produced for all construction activities during both design and construction phases of a project. The core requirements of risk assessments are to identify hazards relevant to particular activities, to evaluate their risk and to identify suitable hazard control measures. Contractors also have to prepare method statements for all site construction activities appearing in the CPM network. Among other things, these documents detail the methodology for the planned work and the associated risk assessment, as required by the CDM Regs. In practice however, method statements and associated risk assessments are sometimes considered to be separate documents. The situation can arise where risk assessments are attached to the method statement as an appendix simply to comply with legislation without detailed consideration as to whether the contents of the risk assessment reflect the hazards encountered in the planned work. Such ‘cutting and pasting’ of risk assessments can mean that hazards relating to particular work may not be properly identified in the risk assessments.

Thirdly, identification, estimation, evaluation, response and monitoring are the five stages of the risk management process (BS 8444, 1996). A hazard must be identified before it can be managed. The problem is that any individual is unlikely to possess all the knowledge and experience required to identify every hazard associated with a particular construction activity. This means that risks cannot be estimated and evaluated and that hazards cannot be responded to. Furthermore, the individual may not be able to identify suitable responses to the hazards that have been identified.

From the three arguments given above it is clear that hazard identification is of paramount importance in improving construction safety. However, simple identification of a hazard and adding it to a project risk log will not alone improve safety. The hazard needs to be linked to specific tasks carried out by operatives because it is these people who are exposed to the hazards. At every stage of the work, supervisors and operatives need to know what control measures they need to protect them from hazards associated with particular tasks. In practice, however, no construction company can afford to respond to every single possible hazard that may present itself. The companies need to focus their limited resources on the hazards where the risk is greater than cost of risk response. In fact the CDM Regs make allowance for this and state that workers’ health and safety must be protected so far as is **reasonably practicable**. This term is interpreted as the *“degree of risk in a particular activity or environment balance against time, trouble, cost and physical difficulty of taking measures to avoid the risk”* (Horner 1998). In summary the authors believe that a successful site safety management system will need to address hazard identification, hazard/task association and risk quantification.

SITE SAFETY TOOL

Overall Design Structure

The system is being developed as a Dynamic Data Driven (DDD) website. It is being developed using Allaire ColdFusion (CF) (Forta 1998), a commercially available web application server. The system has a three-tiered structure (Figure 2). The first tier is the client side of the system, or user interface, and is accessible to users via a standard web browser. Individual web pages are produced using the ColdFusion Markup Language (CFML), which was modelled on the Hypertext Markup Language (HTML). The second tier contains the CF server. When the browser requests a CFML page from the CF server, the server processes the CFML code and connects with backend systems, e.g. databases or excel files. The CF server then dynamically generates the page in standard HTML format that can be viewed by the client on any standard Internet browser. The third tier consists of a central safety database, which does not have to be on the same server so long as CF knows where to find it. CF connects to the database, created in Microsoft Access, via Open Database Connectivity (ODBC). CF is an ODBC client, which means that the database language used is Structured Query Language (SQL). All of this means that the user has the power to view, update, insert or delete data from the database using a familiar and simple web-based interface. Currently there are four applications within the tool, which will now be discussed.

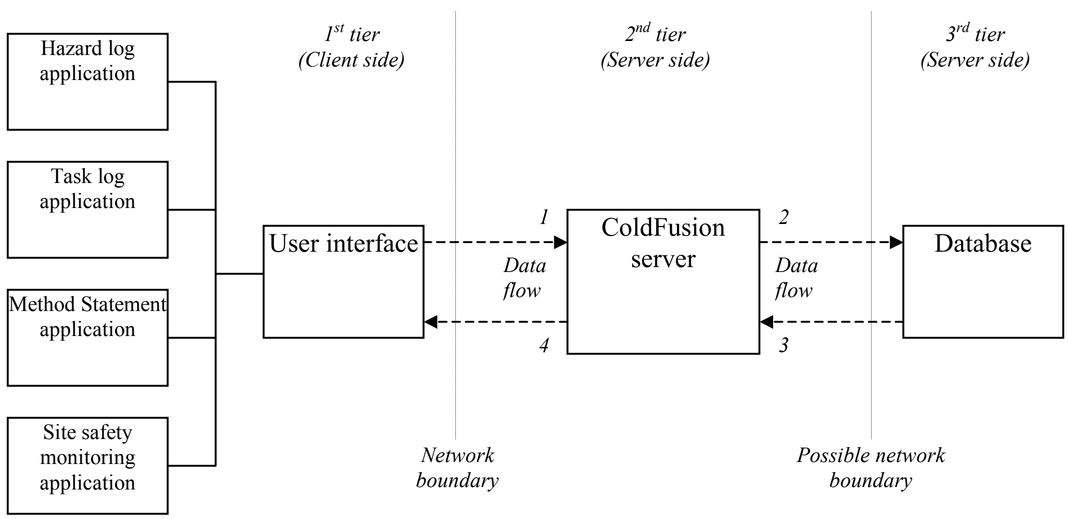

Figure 2: Structure of our IT tool

Site Safety Monitoring Application

This application enables safety managers to enter accident reports to the central database. Data such as times of occurrence and severity are entered into the database. The accidents are linked to hazards that contributed to the accident (Figure 3). Therefore, once the database becomes populated with enough accident reports, each hazard will have accidents associated with it. Risk is accepted as being a *"combination of the probability of a hazard occurring and the consequence(s) of that hazards occurrence"* (Baker 1997) so risk can be calculated based upon the mean accident frequency and severity of the accidents linked to a particular hazard.

Figure 3: Screenshot of one of the accident reporting pages

Hazard Log Application

This application contains a list of all identified hazards. The safety manager can update and add new hazards to the list. Figure 4 shows two screenshots from the hazard log. Upon selecting the hazard the safety manager can view its current risk rating, calculated from accident data, and also view the risk history, i.e. how the risk level has changed over time on the particular construction site and also for the 'all-site average' for the company as a whole. Safety performance for the site could be related to the rate of change of the risk level with time, although this feature has not been developed yet. Hazard control measures can be viewed, which can also be updated inserted into the database as knowledge is advanced, e.g. if new fall protection personal protective equipment (PPE) is developed that prevents back injuries then a control measure stating it should be used will be updated to hazards relating to falls. From that point onwards, every risk assessment for any site that the company is involved with containing a hazard relating to falls will have that control measure listed next to the hazard.

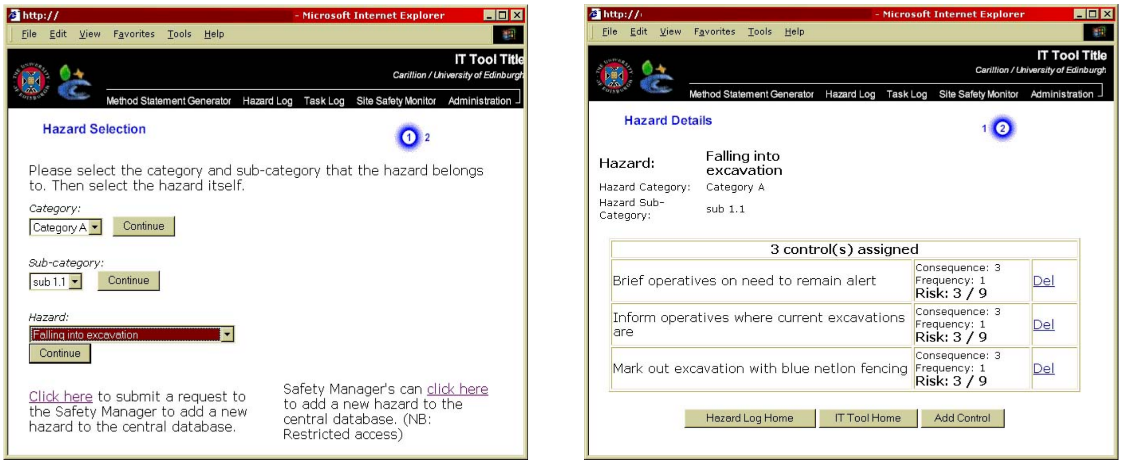

Figure 4: Screenshots of the hazard log application

Task Log Application

This is the application where tasks are associated with hazards. The application contains a constantly updated list of all possible construction activities. Upon selecting a task the associated hazards can be viewed (Figure 5). The associated hazards can be deleted or hazards can be added from the list contained in the Hazard Log. We believe it is a this point, where people consider the practical nature of the task and the dangers it involves, that new hazards will be identified and incorporated into the database. If one individual identifies a new hazard as being relevant to a task then all sites benefit not just the one on which the individual works.

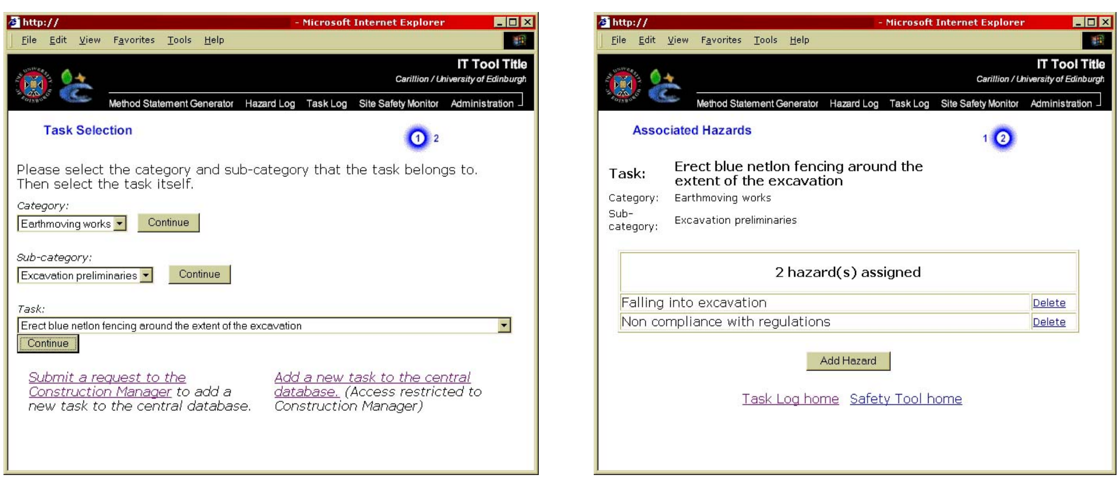

Figure 5: Screenshots from the task log application

Method Statement Application

This application will be used to create method statements. From the operatives' point of view, the most important part of these documents is the methodology section, which detail the work to be done. The user will select tasks to be included in the methodology and numerically sequence them to establish the actual methodology (Figure 6). Due to the relationships set up in the structure of the database, a risk assessment will automatically be generated based upon the selected tasks. Note that although the creation of the risk assessment is automatic the content is obtained from the safety database, which contains the constantly updated knowledge and experience of the whole company. It is important to appreciate that the content is not derived from 'hard wired' computing code, i.e. algorithms, logic and conditional statements, in decision making systems that can sometimes cripple their effectiveness, applicability and flexibility.

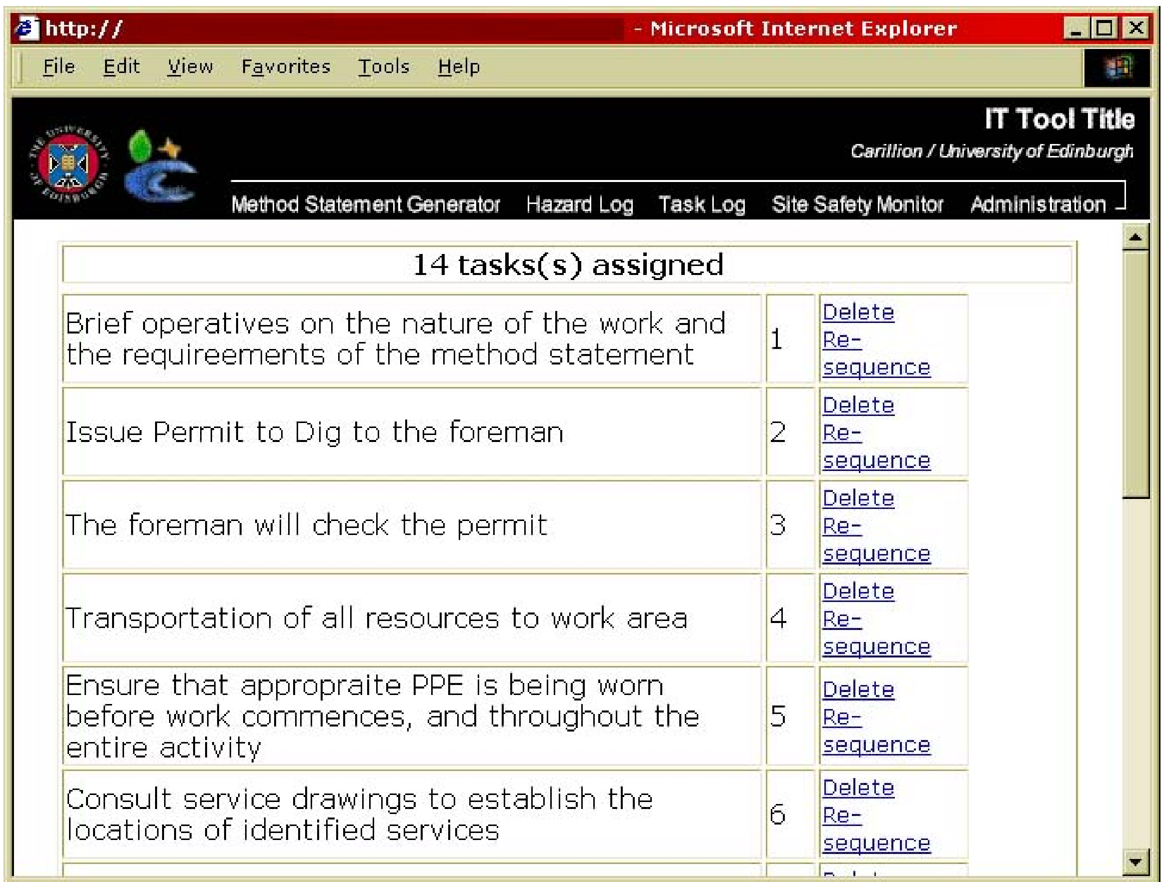

Figure 6: Screenshot of method statement application showing a partial methodology

Safety-significance of the tasks within the methodology can be established. Safety-significance is being investigated as a way of prioritising tasks in terms of risk, although this work is still in the early stages of development. Based upon the task/hazard relationships and accident data contained within the database the system ranks tasks in terms of their total associated risk. This should enable Safety Managers to focus limited resources on the tasks that expose operatives to the greatest degree of risk.

CONCLUSIONS & FUTURE WORK

Hazard identification is fundamental to construction safety. An effective safety management system needs to address task/hazard relationships and risk quantification as well as hazard identification for it to have any practical use.

Future IT systems are likely to be web-based applications that make use of information stored on databases that they do not 'own'. The site safety tool discussed in this paper is based upon these principles.

Safety-significance is proposed as a possible way of prioritising tasks within a methodology, which will enable Safety Managers to focus limited resources on reducing risk.
The authors have discussed a prototype site safety tool. This tool needs to be tested on site to validate existing features and to allow further development. Risk calculations depend heavily upon historical data and so data collection is of paramount importance. An extended period on site is scheduled for the end of March.

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