SAFETY, HAZARD AND RISK IDENTIFICATION AND MANAGEMENT IN INFRASTRUCTURE MANAGEMENT: A PROJECT OVERVIEW

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Safety hazards within transportation based projects can lead to serious injuries to company employees and the general public alike. Risks associated with such hazards must be managed in order to reduce the possibility of accidents and lighten injury severity. It is also envisaged that such a proactive risk management scheme would return significant cost savings associated with a reduction in compensation claimants and breaches in health and safety legalization. This paper presents the current progress of a 3 year PhD project at the University of Edinburgh set up to address the above situation. The project is funded by Carillion Plc and an EPSRC industrial CASE award. A case based reasoning methodology has been employed to create a prototype safety tool hosted via Microsoft Access program. The tool aids classification of work tasks using a system based on RIDDOR categories. The tool then searches a database to retrieve a selection of control measures / hazard mitigations that have been used in similar past work tasks. These suggested mitigations can either be accepted or declined by users and/or new mitigations can be added and uploaded to the database library for use in the next cycle.

Keywords: case based reasoning, risk management, safety, transportation. . .

THE PROJECT BACKGROUND

The current project investigating 'Safety Hazard and Risk Identification and Management in Infrastructure Management' is based at the University of Edinburgh (UoE). The research project is supported by the European Physical Science Research Centre (EPSRC) under their Industrial CASE scheme whereby financial contributions are made by both the EPSRC and the 'Transport Department' of Carillion plc. PhD Student Jennifer Campbell is undertaking the three year project, supervised by Dr Simon D Smith.

The project was inspiration by another Industrial CASE project where Gregory Carter (UoE) investigated the management of safety hazards on Carillion construction projects. One of the outcomes of Carter's work was the development of an online tool for the management of health and safety hazards and associated risks in construction.

The fundamental aspects of the earlier project were recognized as having significant potential within highways and transport projects. Transportation projects present very different risks to Carter's 'construction' tool (Carter and Smith 2006) .

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Previous work by Carter between 1999 and 2004 considered the UK construction industry as a whole and it has provided the background for the current project, which recognizes the unique nature of transportation construction and maintenance risks.

Current work proposes the development of safety- related tool can aid hazard identification in the work place as and facilitate decision support to select the best mitigations to ensure a safe system of work (Campbell and Smith 2006a, Campbell *et al.* 2007).

Four distinct academic milestones were identified by University of Edinburgh (UoE) and Carillion Transport prior to the start of the project. These key features are discussed in this paper in the sections entitled 'Scoping the Tool' and 'Developing the Tool' (see Figure 1 for more details).

Further aspects of the project, including the 'Think, Plan, Do' classification method and a Framework for Academic Collaborations and Strategies (FACS) were presented at ARCOM 22 (Campbell and Smith 2006b, 2006a)

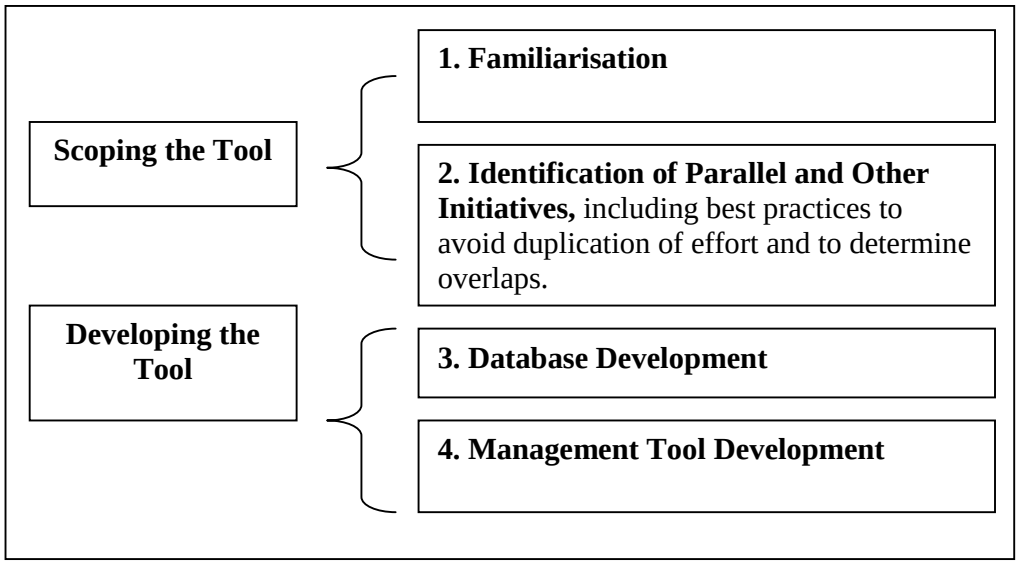

Figure 1: Project Milestones

SCOPING THE TOOL

The fundamental aim of the project is to improve hazard identification and management by aiding a worker's daily tasks of identifying hazards and applying the best mitigation. To achieve this, the knowledge and experience of existing workers needs to be tapped and utilized in the measurement of risk levels and subsequent management of mitigating control measures.

A series of site and office based visits and informal staff interviews were conducted in two projects in accordance with the first two milestones. These site visits were aimed as a brief introduction to the types of projects undertaken by Carillion plc, they include:

- The Term Maintenance Contract (TMC), awarded by Wolverhampton City Council in 2005 provides routine maintenance including patching, draining, kerbing and footway works, together with street lighting, sign erection and winter services. The project is worth £3 million a year for five years with an option to extend for a further two years.

- The £35m railway construction project at Larkhall-Milngavie was the first new branch line to open in Scotland for 25 years was funded by the Scottish Executive with support from South Lanarkshire. The project involved laying three miles of track from a junction near Hamilton Central to the new station at Larkhall, and a one mile extension of the Northern Suburban Line from Maryhill to Anniesland.

These visits and associated interviews suggested several different aspects for the safety related tool. Examples included acting as a 'one-stop-shop' for H&S information and streamlining hazard identification and risk management processes by reducing bureaucracy and improving document control.

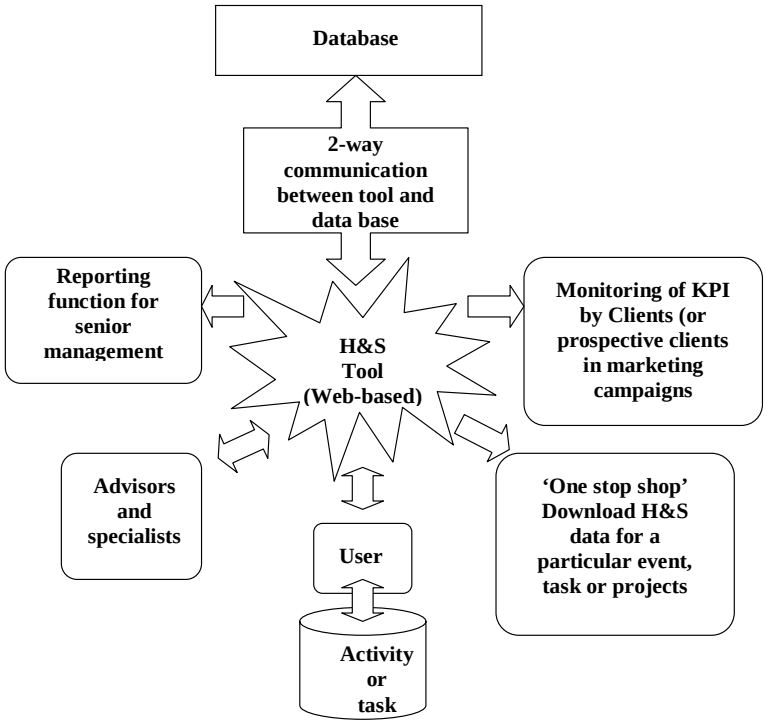

Figure 2: Systematic diagram Safety Tool (source: J. Campbell, 2007)

These phases and site visits aided in the creation of the schematic diagram of the safety-related tool (Figure 2) and the main interactions within the intended tool environment. The main features being 2-way communication between a database holding information on hazards, risks and best practice data and a web-based user interface. This will enable specific hazard and risk data to be downloaded / displayed based on specific user requests along with capacity to upload relevant changes with regard to type of task, hazards identified and mitigations. The tool's artificial intelligence function will consider any new information to make a better suggestion in the next cycle of user requests. The use of prescribed entry templates and registered users will enable accountability and logical audit trails for document control.

There is also scope to expand the tool function in collaborative and commercial settings such granted access for prospective or current 'Clients' to view strategic safety information or Key Performance Indicators or succinct management of safety critical information given to the Client at the end of the project.

TOOL DEVELOPMENT

The development of the Tool features is threefold: the methodology, the data and the hosting platform. The development of the tool envelopes milestones 3 and 4, Database Development and Management Tool Development, and based at the University of Edinburgh Campus.

Methodology: Case Based Reasoning (CBR)
The methodology of Case Based Reasoning (CBR) was chosen to facilitate the dynamic 2-way communication between a database and user interface.

Case Based Reasoning (CBR) originated in artificial intelligence research towards emulating human reasoning and decision making processes and presents solutions to given problems by selecting similar 'cases' within a stored library. Cases are retrieved based on how similar these are to the current problem. Figure 3 shows the basic journey of a 'case' from being retrieved from the case base or library, to being re-used or revised depending on the current problem, and finally being stored for use in the next cycle.

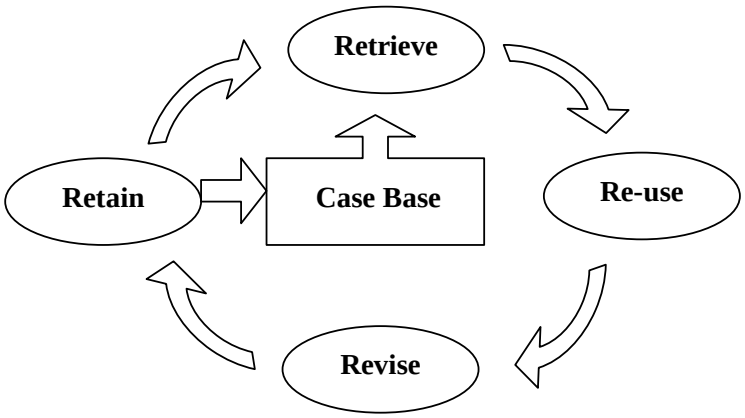

Figure 3: Simplified CBR Cycle (Campbell and Smith 2006a)

Artificial intelligence strives to replicate human thought processes and / or learning methodologies and as such Case Based Reasoning (CBR) is not alone in the field:

- **Expert Systems** are a form of 'rule-based' paradigm. Summarized as 'if 'A' occurs, then perform action 'B'. The number, details an interactions of 'A' occurrences and 'B' actions are collated from human 'experts.
- **Artificial Neural Networks (ANNs)** were inspired by biological processes in the human brain. ANN's can allow dynamic structuring of data based on information flowing through the 'network' in terms mapping, interconnection and relationships. Back propagation techniques can also be used to recognize patterns in unfiltered data (Zhang and Fuh 1998, Ung *et al.* 2006).

CBR methods are analogy based and proving to be a popular research paradigm for many different research areas including transportation applications (Khattak and Renski 1999, W.Sadek 2001, Campbell and Smith 2006a).

Using a CBR methodology has many advantages over the Expert Systems and ANNs. In Expert Systems, solutions, relationships and input criteria tend to be 'hard-wired'

and inflexible due to onerous knowledge extraction processes. This process is often work intensive for all participants;

- knowledge facilitator(s) researching and creating suitable scenarios,
- busy and expensive group(s) of 'experts',
- Those who transcribe / translate conversations or 'know how' conveyed during group work / surveys / one-on-one interviews into computer lingo
- modelling specialist(s) who must correctly interpret this data and produce a final product.

Lastly, validating Expert Systems can be difficult due to a low number or quality of experts and their judgements, resulting in perhaps a longer data gathering exercise to train the model than original intended, or even a complete re-design of the model relationships. The time and resource constraints resulted in an unacceptable risk to the project and resulted in this methodology being unviable.

ANNs, unlike Expert Systems, allow relationships and interaction to be redesigned in accordance with the information available, making ANNs a good tool to recognize pattern in data. However, the main disadvantages to using this method is three fold and given below:

- ANN's cannot detect when they are working outside their range of competence or using 'bad' quality data outside their range of experience
- ANN's cannot communicate with human decision makers in human terms to explain their output, nor can they easily explain their decision processes (Johnson, Picton and Hallam 1993).
- High validation maintenance when learning post-certification (Kurd and Kelly -In press, due 2007)

ANNs can be viewed as a 'black box' with little visibility of the why a particular answer is chosen by the system. This can present problems within the industrial setting if users fear that the new tool will replace their job, or even worst, workers may become complacent in the belief that the new system is infallible leading to legal culpability issues for the tool designers and maintenance operators.

Expert Systems and ANNs are generally digital and require hybridization with fuzzy logic or linguistic terms to convey any real meaning to users. Unlike Expert System and ANNs, the case oriented and analogies based techniques of CBR are able to deal with qualitative data, thus negating the need to combine with fuzzy logic systems. Additional benefits include:

- Users can incorporate their own 'expertise' into a stored library
- Solution can adapt and allow change
- Unlimited number of users
- Self learning with minimum calibration

The main advantages of CBR are the transparency it offers a safety tool along with the ability to continually learn and calibrate itself with user interactions. In this way, a CBR methodology can easily be pitched to workers as a knowledge aid running parallel to their daily task of identify hazards and decide on control measures, rather than an alien artificial intelligence engine with the aim of replacing high skilled

workers. It is proposed that CBR methodology can stop worker wasting time effort and resources 're-inventing the wheel'.

The CBR function will search and retrieve a selection of control measures / hazard mitigations that have been used in similar past work tasks from a Case Base or library of past events. These suggested mitigations can either be accepted or declined by users and / or new mitigations can be added and uploaded to the database library for use in the next cycle. The library or 'case base' was populated with safety critical extracted from paper site documents called method statements.

A flow chart of the envisaged processes involved in the CBR Tool is given in Figure 4.

Data: Method Statements

Many documents are used on UK construction and maintenance sites relating to safety including the 'Health and Safety Plan / File' and accident reports. Method statements are prepared by competent workers who are responsible for the planning and completion of individual work tasks. Method statements can be viewed as a work task recipe and demonstrate that someone in the organization has given consideration to safety practice. They are an excellent source of safety knowledge as they can capture how the person preparing the method statement perceived the characteristics of the work. Unlike accident reports that focus on specifically 'what went wrong' when there is an incident, method statements can be used to effectively capture the 'null' reports and encourage an more optimistic view of 'what was right'. A five phase knowledge extraction process was used to populate the case base:

1. Data Collection
2. Designer
3. Differing Work Experience
4. Mass Input
5. Mass Input with Differing Work Experience (combination of the phases 3&4)

The data collection phase is self explanatory whilst Phases 2 to 5 demonstrates the evolution of the knowledge extraction and re-use as the CBR Tool becomes more widely used and the designer becomes less involved. Further details of this work are currently in press (Campbell, Smith and Forde 2007).

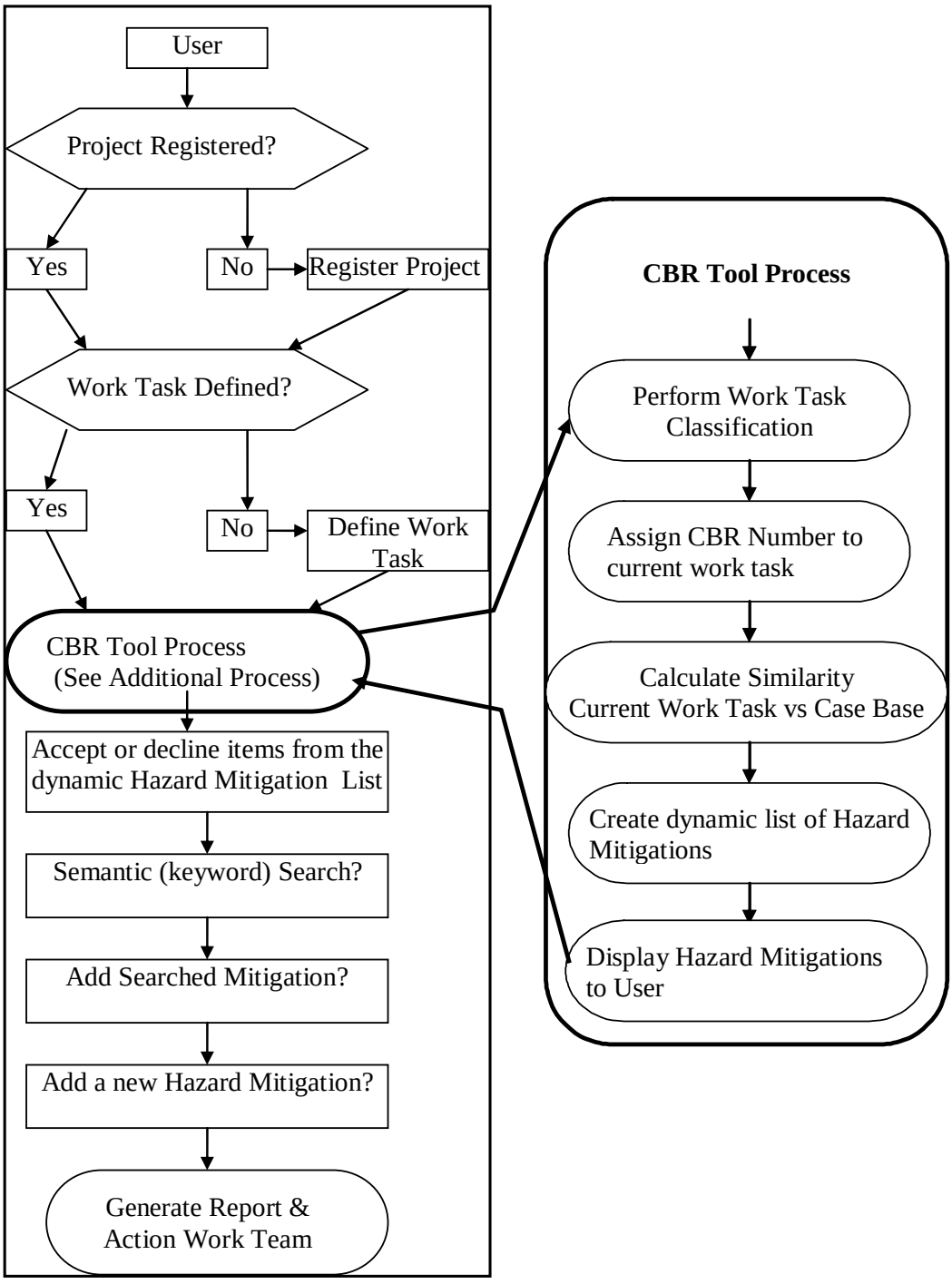

Figure 4: Process flow chart for CBR tool

The first feature of the CBR Tool process is registration of new projects and the scoping and classifying of work tasks. In addition to titles and descriptions, the prescribed input templates can accommodate both commercial information such as project references / work order numbers and specific details such as managerial details (project /work task manager and safety co-ordinator), along with estimations on projected cost, duration and man hours.The user classifies a new work task by assigning either likely, not likely or not applicable for each of the 45 pre-determined hazard harm categories. The hazard harm classification events themselves are based on RIDDOR dangerous occurrences and major injuries categories (Campbell *et al.* 2007). The Case Based Reasoning (CBR) function generates a list of mitigations

based on a case base or library of other method statements. The user can then accept of decline the suggestions, search the case base using a semantic (or keyword search), or even add completely new mitigations. This new case is uploaded to the Case Base or library where the information can be used by the next user. A report is generated containing the salient factors of the decision making process, listing possible hazards and the methods employed for their control – this forms a basis for the method statement to be actioned by the work team.

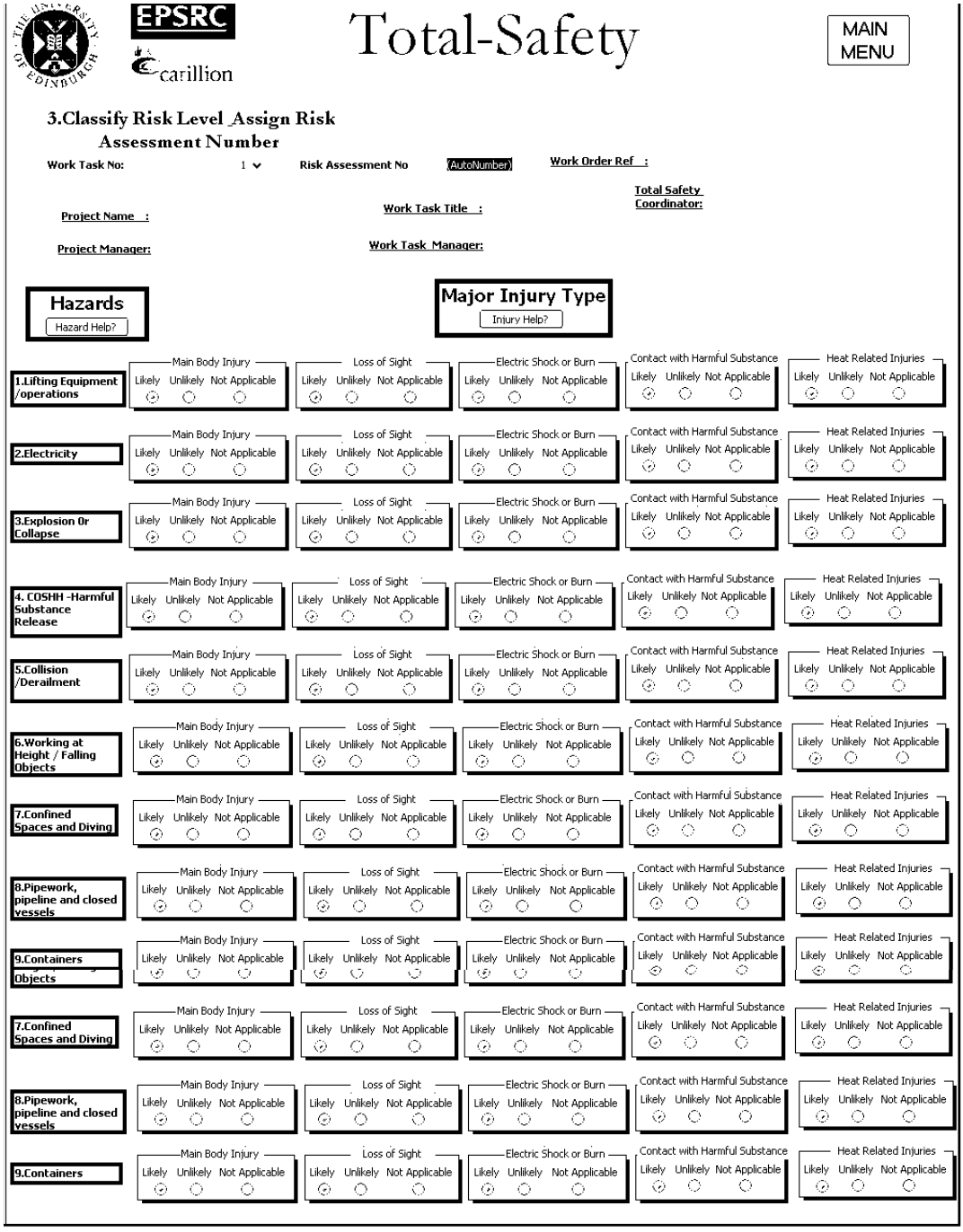

Figure 5: Classifying Work Task Using RIDDOR-based categories (source: J. Campbell, 2007)

It is proposed that later stages of this ongoing research theme will include investigation into small, light hand-held devices that will allow this process to become mobile on site. feature. This additional feature will allow site personnel to add

(electronically) whether the control methods in the report were effective or if a different method had been used if others were infeasible. Thus how workers' actually carried out the given task is added to the Case Base and incorporating the 'revise' phase in the CBR cycle in Figure 3.

Finally, both work tasks and projects can be 'close out' after feedback and completion to ensure an auditable trail of safety management ownership.

Hosting Platform: Microsoft Access and Internet Technology

Many hosting platforms are available to facilitate this new 'CBR Tool' including held locally computer programs and databases or distributed computer programs / systems. High costs associated with ongoing maintenance and upgrading of a locally held version of the 'CBR Tool' lead to the decision to use internet technology to host the user interface and a centrally held database. A database is a structured collection of information whereby computer programs may easily query and search the information for specific items or groupings. In addition, common 'querying' language can be used on commercially available software such as Microsoft products Excel / Access or bespoke applications. Total Safety, a locally held prototype version of the 'CBR Tool', was created using Microsoft Access. This interim phase using Microsoft Access allowed relatively easy changes in visual layout and database design in the development in later versions of the tool.

The addition of a prototype version to the initial milestones has given many advantages including aiding CBR Tool calibration and significantly reducing timescale for testing of case studies (Campbell *et al.* 2007) in line with a PhD timescale.

FINAL STAGES

This paper has given an overview of current work towards developing a safety- related tool to aid hazard identification in the work place and describes the advantages of Case Based Reasoning to facilitate decision support in selecting the best mitigations to ensure a safe system of work. The reasons behind our choice of electronic media and using internet technology within the project is also highlighted along with an intermediate phases of the prototype tool Total Safety.

The project completion is due in November 2007. It is proposed that the final 'CBR Tool' will be hosted on the World Wide Web and modification of the prototype's code and functions are already under way. The Adobe application Dreamweaver will be used to create web pages where as ColdFusion, another Adobe application, will act as the 'middle man' between these pages and a server-side version of the database (Campbell J.M and Smith 2007 - In press). In addition, development of an online survey component is underway. The results from this survey and other upcoming case studies will further investigate the effect of sample size and running time on the database along with increased number of users with differing work experience.

Testing and calibration of the tool continues to be an iterative process and heavily relies on actual Carillion projects and case studies. Other infrastructure contractors or agencies may be considered to trial the tool on other projects.

The final aspect of the project is to ensure that the tool developed can be actually used by Carillion staff on 'transport projects'. A roll-out strategy is still under development however this phase may be delayed if project timescale warrants as it is dependent on

a fully working IT tool being developed in the previous phases and full support from Carillion plc

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