KNOWLEDGE TRANSFER OF SAFETY CRITICAL INFORMATION BY THE INTERNET

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Poor management and dissemination of existing safety knowledge threaten the UK construction industry. Skill shortages and the retirement of the 'baby boom' workforce are leaving companies no alternative other than reliance on young less experienced engineers. This paper demonstrates how and to what degree safety critical knowledge can be transferred to the IT and internet literate new generation. A project overview of a case based reasoning (CBR) safety tool as developed by the University of Edinburgh is presented. The tool aids classification of work tasks then searches a database to retrieve a selection of control measures / hazard mitigations that have been used in similar past work tasks. The CBR tool has been populated with data from infrastructure construction and maintenance tasks. The role of online surveys in past research is highlighted and a case study using online volunteers is presented. Volunteers with a range of engineering experience were asked to read a 'real life' method statement from a construction project and assign control measures with the aid of the CBR tool. Results and overall trends of the case study show what degree safety critical knowledge was successfully transferred. Lastly, the use of internet and CBR collaboration is argued for the purpose of education and training of engineers in the Construction Industry.

Keywords: knowledge management, risk management, safety, internet, case based reasoning.

UK CONSTRUCTION SAFETY AND SKILLS

The June 2000 Revitalizing Health and Safety Strategy Statement (Department of Environment Transport and the Regions 2000) contained the first ever UK targets for health and safety systems. This set out how the UK Government and Health and Safety Commission would work together to achieve a 66% reduction in the rate of fatal and major injury to construction workers by 2009/10. It is vitally important that this ongoing effort is not constrained by the dilution of tacit knowledge within construction companies in part due to the impending skill shortage (Egan 1998) and an aging and retiring 'baby boom' population from the 1950's. The increased pressure on younger, and perhaps less experienced, engineers has had an impact on how companies recruit and retain their new working population. Almost half (46%) of those partaking in a job satisfaction survey citing poor salary as motivators to leave their present employer with other factors including being undervalued and / or poor staff benefits (New Civil Engineer Magazine 2006).

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Current dynamics of the UK Constructions Industry demands existing skills and need of the new working generation be incorporated efficiently into company culture. The alternative risks future infrastructure projects, such as CrossRail and the 2012 London Olympic Games (Nce News Article 13 July 2006).

To this end, a web-based hazard management 'CBR Tool' has been developed at the University of Edinburgh to facilitate this knowledge management process. (Campbell and Smith 2006a, 2006b, Campbell, Smith and Forde 2007, Campbell *et al.* 2007, Campbell J.M and Smith 2007 - In press)

A project overview is included in this publication along with the phases involved in the populating the CBR Tool with real 'site data'. The CBR Tool Online Survey is highlighted as a method of achieving one of the last phases and preliminary results are discussed.

PROJECT OVERVIEW

Knowledge is gained through trying to understand the context of information within our society and experiences, in conjunction with the way in which we individually view the world; knowledge can be seen as the most valuable source of competitive advantage (Liaw 2005). With this in mind, the main aim of the project is to improve worker knowledge in the field of hazard identification and management.

It is proposed that the artificial intelligence methodology case based reasoning (CBR) can facilitate a learning paradigm by allowing existing tacit knowledge from the working population to be collected, shared and disseminated in the new generation of IT and internet literate generation of construction worker (Campbell and Smith 2007 - In press). This 'CBR Tool' includes a web-based user interface, allowing users to classify new work tasks and retrieve a dynamic list of control measures / hazard mitigations that were used in past examples of similar work tasks.

The methodology of Case Based Reasoning (CBR) originated in artificial intelligence research towards emulating human reasoning and decision making processes. 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 2006b). An example CBR cycle is presented in Figure 1 and 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. Cases are retrieved based on how similar these are to the current problem (Campbell and Smith 2006b).

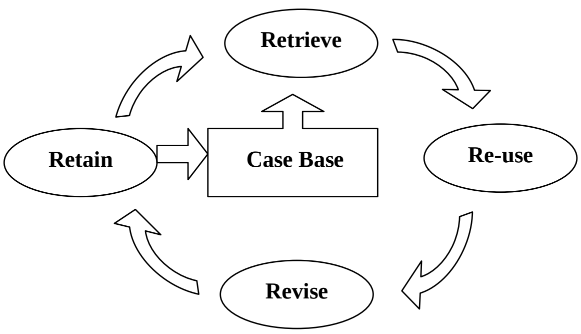


Figure 1: Simplified CBR Model (Campbell and Smith 2006b)

THE CBR TOOL

A method of extracting safety knowledge to populate the CBR Tool has been developed using five different phases. These are summarized below and have been discussed further by the same authors(Campbell, Smith and Forde 2007):

1. **Data Collection –** site visits were used to collect real data. The samples of method statements relating to the re-opening of railway track in Scotland were obtained by permission of Carillion plc.
2. **Designer –** Initial knowledge extraction by the CBR Tool designer using five method statements
3. **Differing Work Experience –** Two volunteers from different fields were asked to classify work tasks and assign control measure using the CBR Tool
4. **Mass Input** - Increasing the size of the library from 5 method statements to 26.
5. **Mass Input with Differing Work Experience** (combination of the phases 3 and 4) – Online survey where many volunteers are asked to classify work tasks and assign control measure using the CBR Tool

This paper will focus on the methods and preliminary results of the final phase – the CBR Tool online survey.

CBR TOOL SURVEY

Surveys are by no means rare in academic research and business applications. Non-engineering examples include using survey findings to develop targeted educational materials to help consumers (Kosa *et al.* 2006) and biodiversity data (Flemons *et al.*). There are numerous examples of online surveys being used to monitor patient care (Couper 2007, Fung, Rosenfeld and Reichel 2007).

Within the domain of the construction industry, the internet is largely used as a collaborative home for document sharing between project groups and partnering companies (Zhiliang *et al.* 2004, Forcada *et al.* 2007). There are demonstrably few applications where the internet has provided benefit to workers competence in hazard and risk identification and management in a real life scenario (Duffy, Wu and Ng 2003). To this end, an additional component was added to the CBR Tool: an online survey. This CBR Tool Survey gave access to research and examine five issues, namely:

1. Test the web architecture and ‘invitation’ strategy
2. Test the CBR functions in an internet setting
3. Size effects from increasing the size of the library by increasing the number of users and processed method statements
4. Differences in knowledge acquisition and risk perception
5. Comparing control and survey groups along with differing engineering work experience

As the online survey is ongoing, this paper will focus on the first two issues and give preliminary results.

Web Architecture and Invitation Strategy

Development and deployment of the CBR Tool for the internet was a gradual process using a laptop hosted prototype as a development tool. This was achieved by converting to a web based interface from a previous version using Microsoft Access (Campbell *et al.* 2007, Campbell and Smith 2007 - In press).

Hosting the CBR Tool on a computer server as opposed to a specific software package gives many advantages including version control and dissemination of upgrades. The database containing the case base / library and other data is held on a computer server and is accessed through a dynamic webpage using server query language (SQL) and browser interface engine Cold Fusion (an Adobe product). The Adobe product Dreamweaver was used to develop a dynamic web site and acts as an editing interface with Cold Fusion. Using an analogy of a driving a car instead of a web site, you can relate the resource of fuel as the case base of past solutions, and the drivers controls such as the accelerator as the web page. The Cold Fusion element can be viewed as the mechanical actions within the car that translate the driver's action into motion whilst the Dreamweaver package gives web developer tools to open the bonnet and view the engine. For the purposes of testing the system the survey is currently restricted to those with access to the University of Edinburgh (UoE) computer network as the database holding the 'case base' or library of past solution is hosted on a development server.

There are many different types of web architecture commercially available. The decision to use Adobe packages was based in the availability of the software through UoE's procurement and licensing schemes, the availability of a Dreamweaver training and contact with staff with past experiences using Cold Fusion.

The invitation strategy to entice volunteers to participate in the online survey was conducted by e-mail to all staff, researchers and postgraduate students in the School of Engineering and Electronics at the University of Edinburgh. The e-mail stated the researcher's need for volunteers, giving the aims of the project and directing the potential volunteers to the online home of the CBR Tool Survey. An Additional e-mail was sent by the Head of School to give weight to the research and encourage participation.

As a trial, a second strategy invited a contacting a small Scottish based consultancy (GlenClova Ltd) to partake the survey.

Internet Setting

The CBR Tool Survey can be accessed via the project web page located at www.total-safety.com . Volunteers can register for a username and password by completing an online survey designed to allow comparison between different users and work experience groups. Once logged in, the volunteer is introduced to the research aims of the 'online survey' and the survey method (Campbell, Smith and Forde 2007). These aims were to

- Establish relationships between work type / experience and knowledge acquisition
- Introduce a new hazard classification and gain volunteers opinion
- Enable calibration of a new classification method

The four sections of the online survey and their order are summarized below:

- **Part 1 - Background Knowledge**

Volunteers are instructed to download and read the method statement relating to the construction of 'Larkhall Station Car Park' as background knowledge to the work task. 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.

Details of the project relating to the method statement were not given to the volunteers in case this biased results. The £35m railway construction project at Larkhall-Milngavie is 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.

- **Part 2 - Role Play and Hazard Classification** (**Figure 2**)

Volunteers are asked to 'role play' or imagine that the construction of Larkhall Station Car Park had not started yet, and that they (the survey volunteer) are the person who will ultimately write the method statement from this viewpoint.

Concentrating only on 'unsafe' issues highlighted by the document, even if these dangerous situation were recognized and were avoided in real life, the volunteer is asked to assign 'Likely' , 'Unlikely' or 'Not Applicable' in the web interface CBR Classification screen as if the assessment of the work hazards and conditions is in 'real-time'.

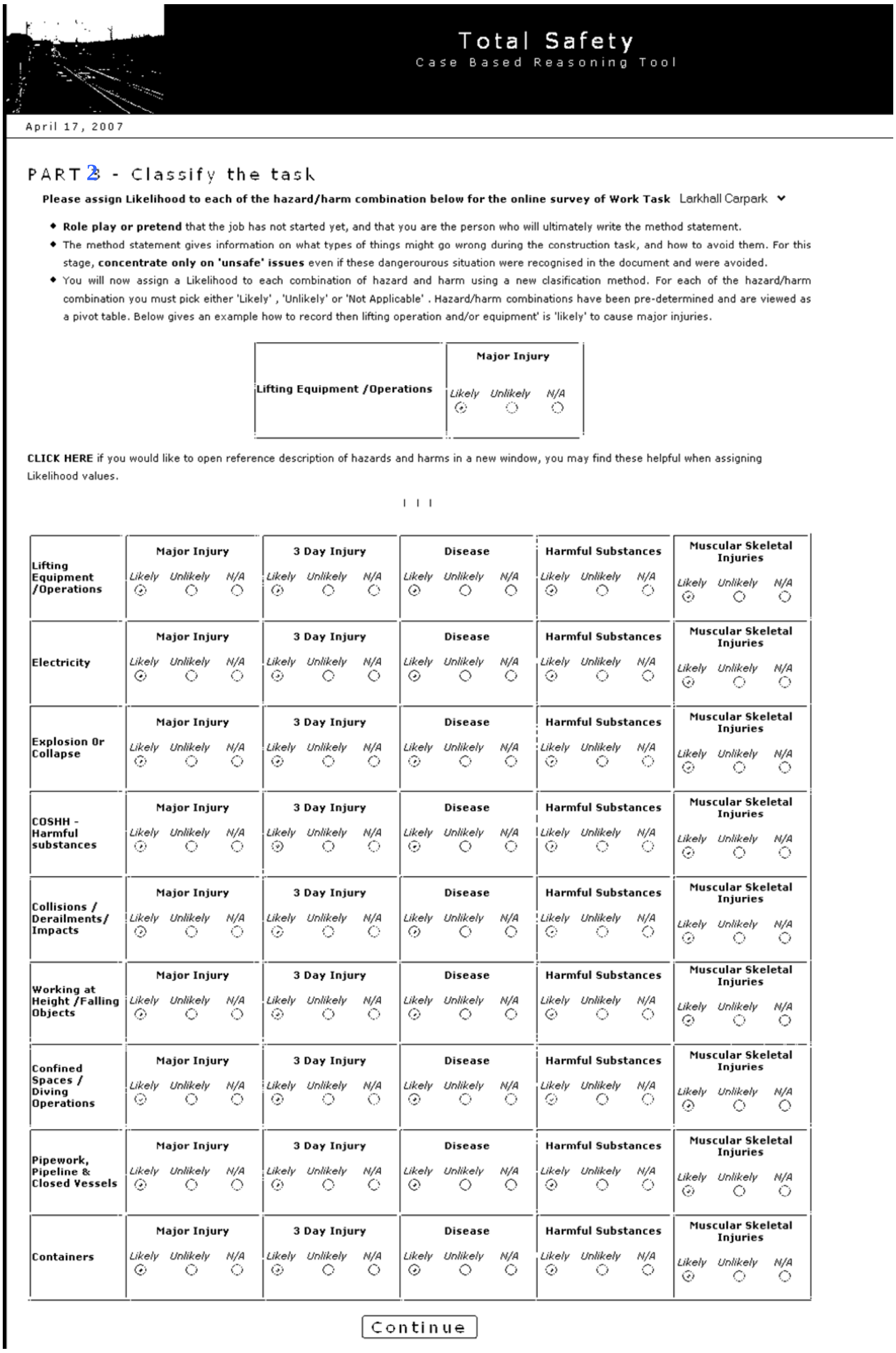
- **Part 3- Case Based Reasoning Tool** (**Figure 3**)

The CBR tool analyses the results from previous part of the survey and generates a list of suggestions to avoid the dangers of the construction task.

Users are asked to look through this list and decide whether or not information in the original method statement agrees with the CBR Tool suggestions. Volunteers are given the opportunity to search a library of existing mitigations using a key word search if they feel the generated list missed out important factors. Lastly volunteers can add new mitigations the library if they feel additional mitigation information is missing from the previous steps

- **Part 4- Feedback Questionnaire**

The feedback questionnaire is aimed to help improve the survey methods and fine tune the calibration of the CBR tool.



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Case Based Reasoning Tool

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PART 2 - Classify the task

Please assign Likelihood to each of the hazard/harm combination below for the online survey of Work Task Larkhall Carpark

- **Role play or pretend** that the job has not started yet, and that you are the person who will ultimately write the method statement.
- The method statement gives information on what types of things might go wrong during the construction task, and how to avoid them. For this stage, **concentrate only on 'unsafe' issues** even if these dangerourous situation were recognised in the document and were avoided.
- You will now assign a Likelihood to each combination of hazard and harm using a new clasification method. For each of the hazard/harm combination you must pick either 'Likely' , 'Unlikely' or 'Not Applicable' . Hazard/harm combinations have been pre-determined and are viewed as a pivot table. Below gives an example how to record then lifting operation and/or equipment' is 'likely' to cause major injuries.

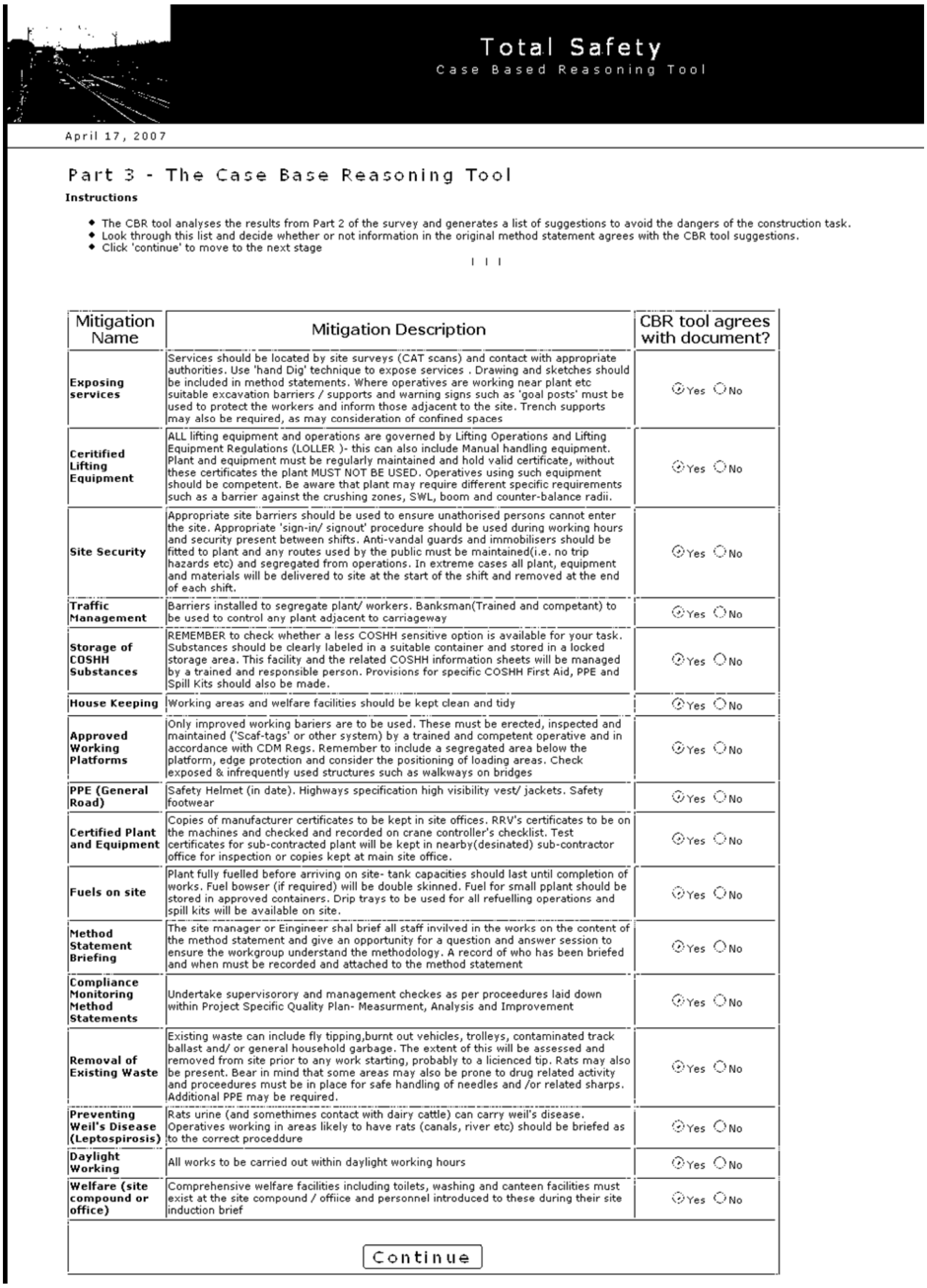
	Major Injury
Lifting Equipment /Operations	Likely Unlikely N/A

CLICK HERE if you would like to open reference description of hazards and harms in a new window, you may find these helpful when assigning Likelihood values.

	Major Injury	3 Day Injury	Disease	Harmful Substances	Muscular Skeletal Injuries
Lifting Equipment /Operations	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Electricity	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Explosion Or Collapse	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
COSHH - Harmful substances	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Collisions / Derailments/ Impacts	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Working at Height /Falling Objects	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Confined Spaces / Diving Operations	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Pipework, Pipeline & Closed Vessels	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A
Containers	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A	Likely Unlikely N/A

Continue

Figure 2: Online Survey- Part 2, Classifying the Task (source: J. M. Campbell, 2007)



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Case Based Reasoning Tool

April 17, 2007

Part 3 - The Case Base Reasoning Tool

Instructions

- The CBR tool analyses the results from Part 2 of the survey and generates a list of suggestions to avoid the dangers of the construction task.
- Look through this list and decide whether or not information in the original method statement agrees with the CBR tool suggestions.
- Click 'continue' to move to the next stage

Mitigation Name	Mitigation Description	CBR tool agrees with document?
Exposing services	Services should be located by site surveys (CAT scans) and contact with appropriate authorities. Use 'hand Dig' technique to expose services . Drawing and sketches should be included in method statements. Where operatives are working near plant etc suitable excavation barriers / supports and warning signs such as 'goal posts' must be used to protect the workers and inform those adjacent to the site. Trench supports may also be required, as may consideration of confined spaces	Yes No
Ceritified Lifting Equipment	ALL lifting equipment and operations are governed by Lifting Operations and Lifting Equipment Regulations (LOLLER)- this can also include Manual handling equipment. Plant and equipment must be regularly maintained and hold valid certificate, without these certificates the plant MUST NOT BE USED. Operatives using such equipment should be competent. Be aware that plant may require different specific requirements such as a barrier against the crushing zones, SWL, boom and counter-balance radii.	Yes No
Site Security	Appropriate site barriers should be used to ensure unathorised persons cannot enter the site. Appropriate 'sign-in/ signout' procedure should be used during working hours and security present between shifts. Anti-vandal guards and immobilisers should be fitted to plant and any routes used by the public must be maintained(i.e. no trip hazards etc) and segregated from operations. In extreme cases all plant, equipment and materials will be delivered to site at the start of the shift and removed at the end of each shift.	Yes No
Traffic Management	Barriers installed to segregate plant/ workers. Banksman(Trained and competant) to be used to control any plant adjacent to carriageway	Yes No
Storage of COSHH Substances	REMEMBER to check whether a less COSHH sensitive option is available for your task. Substances should be clearly labeled in a suitable container and stored in a locked storage area. This facility and the related COSHH information sheets will be managed by a trained and responsible person. Provisions for specific COSHH First Aid, PPE and Spill Kits should also be made.	Yes No
House Keeping	Working areas and welfare facilities should be kept clean and tidy	Yes No
Approved Working Platforms	Only improved working bariers are to be used. These must be erected, inspected and maintained ('Scaf-tags' or other system) by a trained and competent operative and in accordance with CDM Regs. Remember to include a segregated area below the platform, edge protection and consider the positioning of loading areas. Check exposed & infrequently used structures such as walkways on bridges	Yes No
PPE (General Road)	Safety Helmet (in date). Highways specification high visibility vest/ jackets. Safety footwear	Yes No
Certified Plant and Equipment	Copies of manufacturer certificates to be kept in site offices. RRV's certificates to be on the machines and checked and recorded on crane controller's checklist. Test certificates for sub-contracted plant will be kept in nearby(desinated) sub-contractor office for inspection or copies kept at main site office.	Yes No
Fuels on site	Plant fully fuelled before arriving on site- tank capacities should last until completion of works. Fuel bowser (if required) will be double skinned. Fuel for small pplant should be stored in approved containers. Drip trays to be used for all refuelling operations and spill kits will be available on site.	Yes No
Method Statement Briefing	The site manager or Eingineer shal brief all staff invilved in the works on the content of the method statement and give an opportunity for a question and answer session to ensure the workgroup understand the methodology. A record of who has been briefed and when must be recorded and attached to the method statement	Yes No
Compliance Monitoring Method Statements	Undertake supervisorory and management checkes as per proceedures laid down within Project Specific Quality Plan- Measurment, Analysis and Improvement	Yes No
Removal of Existing Waste	Existing waste can include fly tipping,burnt out vehicles, trolleys, contaminated track ballast and/ or general household garbage. The extent of this will be assessed and removed from site prior to any work starting, probably to a licienced tip. Rats may also be present. Bear in mind that some areas may also be prone to drug related activity and proceedures must be in place for safe handling of needles and /or related sharps. Additional PPE may be required.	Yes No
Preventing Weil's Disease (Leptospirosis)	Rats urine (and somethimes contact with dairy cattle) can carry weil's disease. Operatives working in areas likely to have rats (canals, river etc) should be briefed as to the correct proceddure	Yes No
Daylight Working	All works to be carried out within daylight working hours	Yes No
Welfare (site compound or office)	Comprehensive welfare facilities including toilets, washing and canteen facilities must exist at the site compound / offiice and personnel introduced to these during their site induction brief	Yes No

Continue

Figure 3: Online Survey-Part 3 Case Based reasoning Tool (source: J. M. Campbell, 2007)

Preliminary Results

Initial results using the current invitation strategy were disappointing solely on the few numbers of volunteers willing to undertake the survey. These six volunteers from the University of Edinburgh included two engineering lectures, one non-engineering undergraduate and two PhD Students and one studying an engineering discipline. All members from the small consultancy volunteered, one being the company administrator (the only female) and the other being a contractor currently working in the oil industry.

33 potential volunteers applied for a username and password yet only 8 completed the survey within a two week trial period. Each volunteer classified the work task (see Figure 2) differently and thus assigned CBR values ranging from 46 and 91. No

appreciable similarities could be found within age groups but examining work experience and gender highlighted some interesting factors:

- Both lecturers use of gave the lowest CBR values of 46 and 51. These volunteers had experience of over 10 years in academia and between 5 and 10 years respectively.
- Both the contractor and one of the PhD students gave a CBR Value of 59. The contractor had the most experience with between 2-5 years experience in consultancy, over 10 years experience in health and safety and over 20 work experience in general contracting.
- Surprisingly, both the non-engineering undergraduate and one the PhD student from an engineering background assigned a CBR Value of approximately 71. The PhD student had between 2-5 years consultancy experience and the other volunteer had made comments that the area of risk assessment was ‘alien’ to them.
- The only female gave the second highest CBR Value of 87. This person was the administrator within the consultancy with over 10 years experience in contracting matters.
- The highest CBR Value of 91 was gained from an engineering PhD student with between 2-5 years consultancy experience.

These CBR Values are used by a search function to present volunteers with list possible control measures from the case base / library. Volunteers then assessed whether the issues presented by the CBR Tool agreed with information they had understood to be in the method statement. The list of control measure generated in the study ranged from 17 to 65 measures. Results were as follows:

The CBR Tool suggested a total of 244 mitigations for the eight volunteers, 65% of these were accepted by volunteers as matching information in the original method statement. The number of mitigations declined by the volunteer range from 0 to 36.

Both the lecturers were presented with 23 and 22 control measures and opted that only 6 and 5 of these measures were evident in the original document (22% and 27%). The four issues the lecturers agreed upon as being evident were entitled ‘Exposing services’, ‘Identifying hidden services’, ‘Method Statement Briefing’ and ‘Fuel Spill Kits’. Issues they did not agree on were whether issues of ‘House Keeping’, ‘Safety Briefings’ and ’Limited Shift Hours’ were in the method statement. Interview with these individuals will be held to ascertain why so many control measures suggested by the CBR Tool were de- selected as many were stated in ‘risk assessment’ and COSHH pages at the rear of the document.

Non-lecturing volunteers opted that between 16 and 30 control measures were evident from the method statement document corresponding to 44%-100% where they felt the listed control measures were evident in the method statement (the average being 80%).

CONCLUSIONS AND OPPORTUNITIES FOR IMPROVEMENT

This paper has highlighted the problem relating to knowledge transfer between the construction industries retiring workforce and the new generation of IT and internet literate engineers. To this end, current research into web based CBR Tool and associated architecture has been introduced. The CBR Tool aids classification of work tasks then searches a database to retrieve a selection of control measures / hazard mitigations that have been used in similar past work tasks.

An online survey has been identified as an interim phase in the development of the CBR Tool and preliminary results are promising:

- Volunteers were able to use the online CBR Tool survey despite differences geographical location and work experience
- The method of using CBR for knowledge extraction is credible with an average of 80% of mitigations suggested by The CBR Tool being agreed as correctly identified by volunteers.
- Volunteers with more academic work experiences appear to be more optimistic about in the likelihood of site dangers whilst those with contracting / consultancy experience appear to more pessimistic. There also appears to be differences in how lecturing staff have approached the survey task.
- Those with 2-5 years work experience appear to have a range of optimism of site dangers (CBR Values are between 58&91). These finding suggest that managers should consider work experience when delegating risk-based tasks to engineers with less than 5 years work experience.
- More investigation into gender differences is required to assess whether males are more risk tolerant that females within a construction safety setting.

This paper has also highlighted several opportunities for further research and improvement of current methods. Research is already underway to improve the 'invitation strategy' by moving the CBR Tool to more accessible sever space, allowing access from out with the University of Edinburgh computer network system. The next stages in the project development include:

- Development of a managerial framework is underway to strategize a method of deploying the CBR tool in a corporate setting and ensuring data integrity.
- Exploring differences in knowledge acquisition and risk perception by comparing control / survey groups with larger number of volunteers and differing engineering work experience.

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