Concepts of accident causation and their role in safe design among engineering students

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Safe design is a strong theme at present in Australia. To 'eliminate hazards at the design stage' is one of the five national priorities set out by the National OHS Strategy. The Australian Safety and Compensation Council have recently released both a guideline for safe design and an engineering education package. Safe design is not only about engineering decisions. Engineers are however an important group. This paper reports on a survey to evaluate perceptions of student engineers on topics relevant to the advancement of safe design including perceptions of: control versus fatalism; accident causation; and perceptions of the role played by engineers.

1 Introduction

Safe design is a strong theme in Australia at present. The National OHS Strategy (2002) set out five national priority action areas, one of which was to eliminate hazards at the design stage. The Royal Commission into the Building and Construction Industry discussion paper Workplace Health and Safety in the Building and Construction Industry (2002) raised the issue of safe design and the Royal Commissioners final report (2003) contained many safe design recommendations including using the role of government as a client as a point of influence. The Federal Safety Commission now takes carriage of the government model client approach. Recent guidance material on safe design includes the Australian Safety and Compensation Council's Guidance on the Principles of Safe Design for Work (ASCC 2006) and Safe Design for Engineering Students (ASCC 2006).

Common law has long recognized safe design duties. At common law, if a person can practicably reduce a foreseeable risk then they should do so. Those who have influence should use it to ensure safety downstream as far as can practicably be achieved. Since the 'snail in the ginger beer' case of Donohue and Stevenson in the 1930's, the law has developed to a point where all who influence a product to whoever might later be affected by that product owes a duty of care (1932 AC 562). Stevenson was the manufacturer of a ginger beer, which was sold to a distributor and made its way to a café. Donohue dined at the café with a friend who purchased the ginger beer. Donohue drank some of the ginger beer and subsequently discovered a decomposed snail in the beer then suffering shock and a stomach complaint. Donohue succeeded at trial, lost on appeal, and then succeeded in the House of Lords. The matter of significance was that Donohue had no contractual connection with Stevenson (the manufacturer). The House of Lords decision established clearly that the duty of care extended to whoever might reasonably be injured by the product regardless of the existence or otherwise of a contractual connection (Luntz & Hambly 2002, para. 2.2.7).

Over the past two or three decades occupational health and safety statutes in Australia (e.g. the Occupational Health and Safety Act 2004 (Vic) and its predecessors) have also specified duties for parties such as designers, manufacturers, suppliers, etc. Like the employers duties, these have generally been restatements of the common law principles.

The principles of managing risk within the statutes are hinged on the "elimination" of hazards at their source. The hierarchy of control problem solving model at the core of most occupational health and safety regulations expands on the "control at source" approach. The hierarchy of control model gives primacy to design-based solutions over worker-behavior modification.

Safe design is an approach to safety at work recognized broadly as being effective and also a responsibility on those who can influence decisions of this type. The US National Institute of Occupational Safety and Health (NIOSH) have coined the term Prevention through Design (PtD) and define PtD as: "Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment" (NIOSH 2007).

The *Principles of Safe Design for Work* (ASCC 2006) outlines five principles:
1. Duty of care follows control (i.e. if you can you should – the Donoghue and Stephenson principle)
2. Consider the effects of decisions throughout the lifecycle
3. Adopt a risk management approach including the hierarchy of control (see below)
4. Knowledge (of these principles, of risk management, of safe design solutions, etc)
5. Information transfer

In regards to risk management, the *Principles of Safe Design for Work* emphasize the hierarchy of control problem solving model (as is similarly found in most workplace safety regulatory instruments in Australian and in many other places):
1. Elimination. If you eliminate a hazard you completely remove the associated risk.
2. Substitution. If the hazard can't be eliminated, minimize the risks by substituting a substance or a process that has less potential to cause injury.
3. Isolation. You can make a structural change to the work environment or work process to interrupt the path between the worker and the risk.
4. Administration. You may be able to reduce risk by upgrading training, changing rosters or other administrative actions.
5. Personal protective equipment. When you can't reduce the risk of injury in any other way, use personal protective equipment (such as gloves or goggles) as a last resort.

Two short case studies illustrate some of the principles of safe design:

One hundred and fourteen people were killed when a set of walkways in the Hyatt Regency Hotel, Kansas City, collapsed in 1981 (Kletz, 1993). Two walkways, one above the other, were suspended on slender rods. The original design consisted of a single continuous rod supporting both walkways. This design would have required the rod to be threaded all the way from one end to the point where the upper walkway was supported. In view of this awkward construction method, the builder made a design change to make the connection practical to construct. The level of discussion that occurred between the engineers and the builder seems to be a disputed matter. Owing to the discontinuous rod, the design change approximately doubled the load on the nut supporting the upper walkway (as it was now supporting also the lower walkway) and it was this connection that failed. There are some doubts as to whether the original design was suitable – but it is clear that the design change dramatically increased the load on the joint that failed. Further it is clear that better consideration of build-ability would have been useful.

On 4 May 1997, a Yass Shire Council employee suffered traumatic amputation to both arms while using a wood chipping machine. He had placed his hand into the chute to clear a blockage caused by some foliage and in so doing his glove had become caught on a twig. He was drawn into the chute and his arms came into contact with the blades. The case against the supplier was eventually decided by a majority decision of the NSW Industrial Relations Commission (Workcover Authority of NSW v Arbor Products International (Australia) Pty Ltd (2001) 105 IR 81). The decision emphasised the importance of safe design. The majority noted [44] … The distance between the external edge of the in-feed chute and the danger point of the feed rollers took insufficient account of the very real prospect of an operator acting inconsistently with any training or instruction manual or warning signs. The distance left insufficient margin for error or careless, inadvertent or even foolish behaviour on the part of the operator. This was particularly so in the environment of a waste transfer station where the machinery had a propensity to clog. There was a likelihood in this environment, that driven by the frustration of repeated blockages, the temptation for an operator to use his or her hands to clear the blockages would become overwhelming.

The messages from both these examples are about error proofing. In the first case it is concerned with error-proofing an assembly or construction method and the second is about using design to prevent danger than can otherwise arise from simple mistakes made by operators.

2 Aim

Safe design is concerned with good decision-making and many design decisions are made by people outside the "design community" of groups such as architects, engineers, etc. Hence the discussion about safe design should not be limited to the design community. However, engineers are nevertheless an important group. The aim of this research was to evaluate concepts of accident causation and perceptions of design duties among engineering students.

3 Methodology

Subjects were engineering students at an Australian university (unconnected with the authors) who voluntarily completed a written survey. These students had not completed any studies in occupational safety, risk management or similar. They responded to questions in the following areas along with some basic demographic data:

1. What proportion of accidents are preventable? (choose one)
   - Unsure
   - Hardly any
   - Less than half
   - Half
   - More than half
   - Nearly all

This question was originated by the NOHSC community survey (1999) as a measure of fatalism about accidents. For the encouragement of safe design it would be useful to find that decision makers viewed accidents as being preventable.

2. Accidents at work are usually caused by (each on a five-point scale)
   a. ... accident-prone workers.
   b. ... inexperience of the injured person.
   c. ... carelessness of the injured person.
   d. ... poor layout of workplace.
   e. ... lack of hazard control planning by management.
   f. ... poor equipment.

g. ... lack of training in how to behave safely.
h. ... unsafe working conditions.

The responses were on a five point scale (strongly disagree, disagree, neutral, agree, strongly agree). The question has been used before (Culvenor, Cowley & Harvey 2003) with the purpose being to gain a sense of whether there is a model of causation linked to design (i.e. layout, hazard control, equipment, conditions) or worker-behavior (accident-prone, inexperience, carelessness, training). For implementation of safe design it would be useful if student engineers concentrated on design-related points of causation rather than a victim-blaming way of thinking.

3. When designing an "item", it is an engineer's responsibility to design/allow for (each on a five-point scale)
   a. …workers/users who take short cuts when using the item
   b. …users/workers who don't have their mind on the job
   c. …uses to which the item could be put other than the original purpose
   d. …what will happen when the item is no longer needed
   e. …how the item will be refurbished
   f. …how safe the item will be to manufacture/build
   g. …access for workers who repair or maintain the item
   h. …information that will be needed to use the item safely
   i. …the item's purpose - e.g. capacity, power, size, output
   j. …keeping the design to budget
   k. …making the item reliable - e.g. avoiding structural failure, overbalancing, breakdowns, overheating, etc

These questions had not been used before. They sought to evaluate the extent that student engineers viewed safe design related considerations such as considering the effects throughout the lifecycle and the impact of less-than-ideal user behavior and possible modifications, alongside functional considerations.

4 Results and discussion

Twenty-nine students completed the survey. Most of the subjects were male (89%). The age range was 18-26 years with average of 21. Most students were studying full time (72%). Most subjects were local (i.e. not overseas) students (83%).

4.1 Proportion of accidents that are preventable

The overwhelming majority (over 80%) believe that more than half or nearly all accidents are preventable (Figure 1). The views compare very favourably with those in the general community in 1999 as shown by the data in Figure 1. However, community expectations about accident prevention may be changing over time.

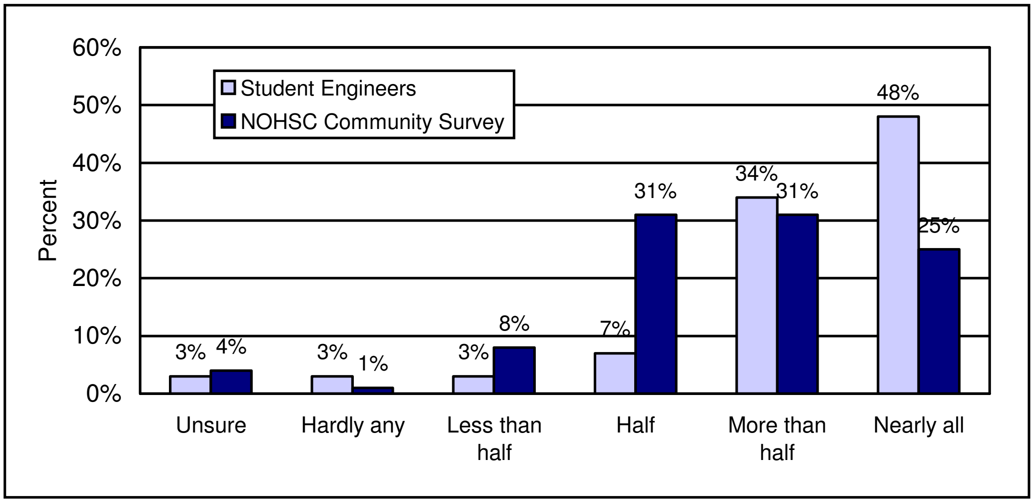

Figure 1: Proportion of accidents that are preventable – student engineers v community data (NOHSC 1999)

4.2 Concepts about causes of accidents at work

The responses to the question about the causes of accidents at work unfortunately do not show any trend (Figure 2). There seemed to be a tendency to agree with most of the statements. Positively, issues like unsafe working conditions, poor equipment and layout and lack of planning were identified by most (70%+). Unfortunately though it is also popular to attribute accidents to lack of training, carelessness, and inexperience. Positively "accident-proneness" is the least popular although it is troubling that it resonates as a cause of accidents in the minds of about half respondents.

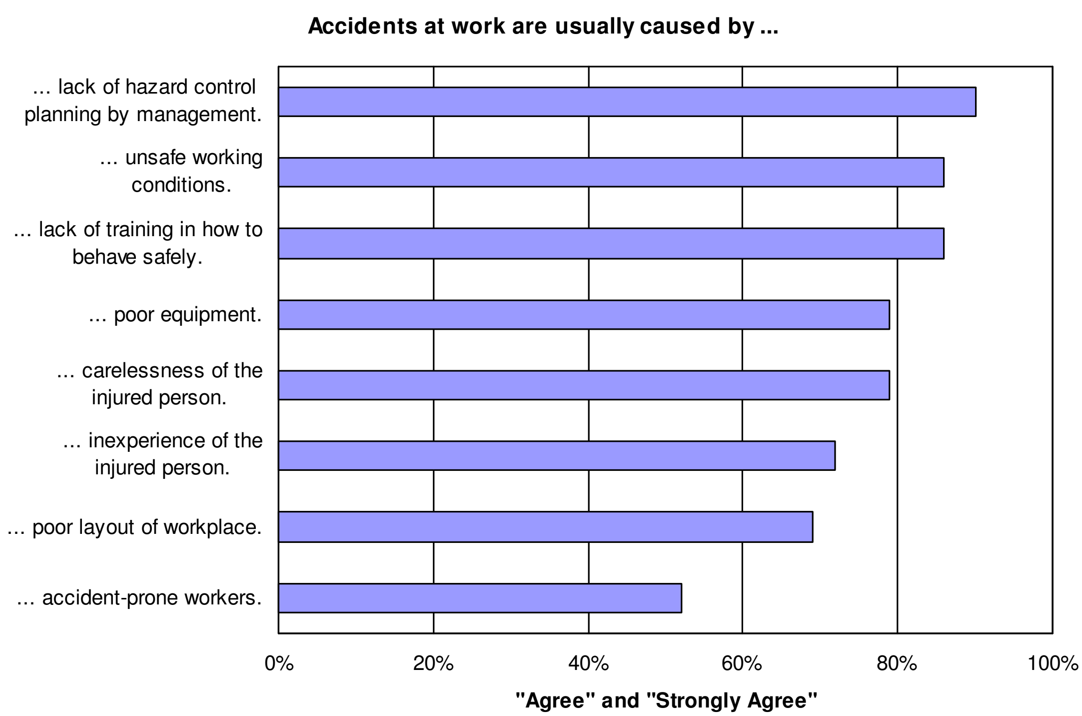

Figure 2: Causes of accidents

4.3 Responsibilities as an engineer

In regard to an engineer's responsibility, making the item reliable, keeping it to budget and meeting the items intended purpose featured strongly among responses (Figure 3). Some safe design points feature strongly, for instance how safe the item will be to build, ranks first alongside making the item reliable. Other safe design issues such as providing access for maintenance and repair, and providing information about safe use feature strongly (80%+). Providing information for safe use is not the best kind of safe design (not needing information is preferred) but nevertheless it is important and this is also well recognised as a design responsibility. Less well recognised are important issues such as what happens at the end of the items life, the other uses to which it could be put, and catering for users whose mind wanders or who take short cuts.

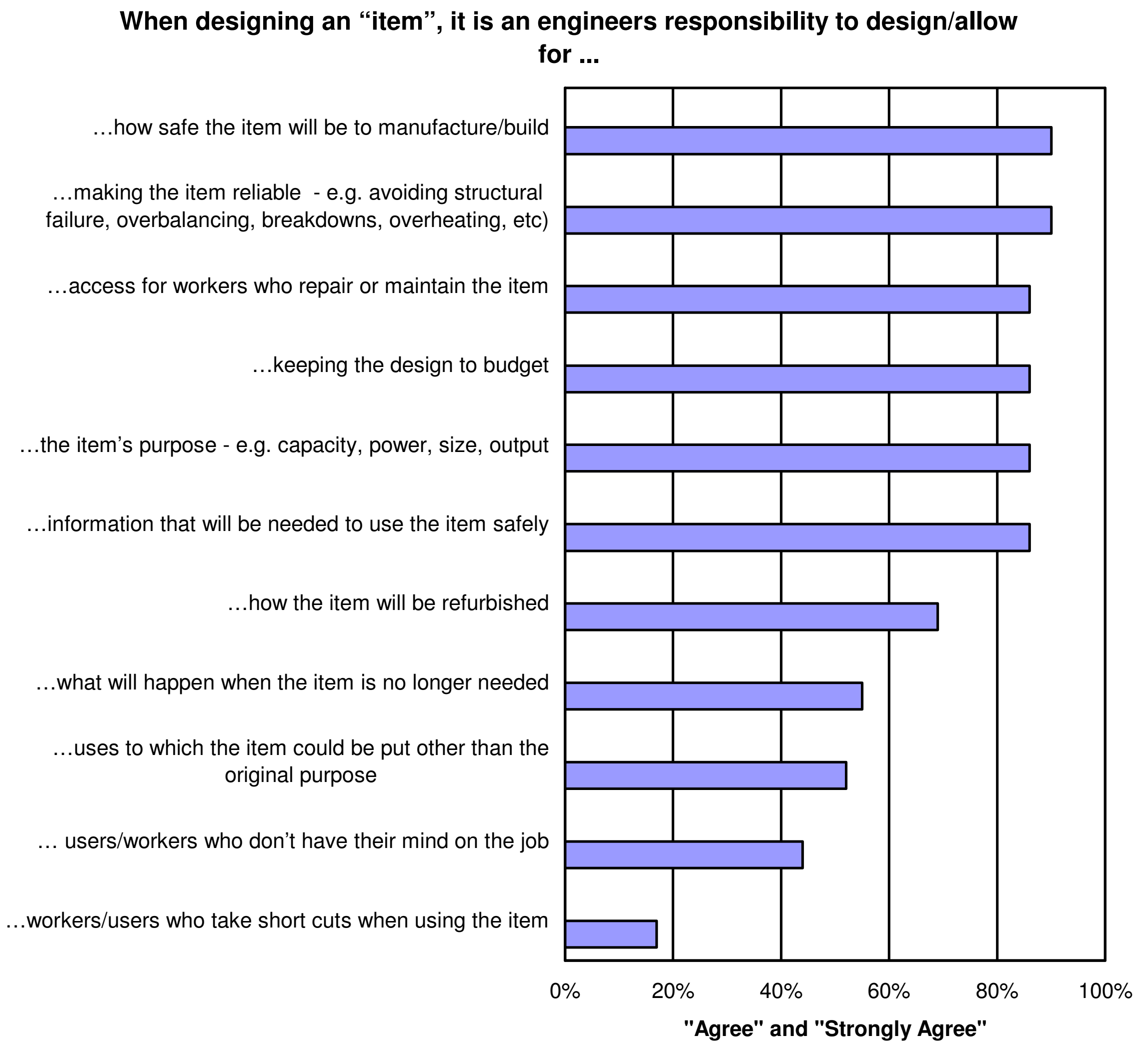

Figure 3: Engineers' design responsibilities

5 Discussion

Many workplaces, facilities, equipment, processes and environment in modern society are either conceived, designed, approved or commissioned by engineers. Accordingly, engineers are central to the creation or control of associated health risks and safe design as a principle is at the core. Their role is reflected by the recent resource publication by ASCC (2006b).

For student engineers to eventually be effective agents of change and promoters of safe design they need to view accidents as controllable, to recognise design solutions as paramount through a clear model of causation and to embrace their role in safety throughout the lifecycle and adopt a design for the user philosophy.

Emergent from this student survey are positive indicators including the result that accidents are viewed as controllable. Little progress would be made if fatalism was strong. In terms of a model of causation, the subjects positively accepted design-based causation but it unfortunately did not emerge as being highly favoured over a victim blaming approach. In terms of responsibilities we see some similar themes emerge. For instance, although it is a strong legal principle, the student engineers do not universally accept that designing for "workers who take short cuts" or "workers who do not have their mind on the job" are part of the considerations they should make. This would seem linked to a trend to accept victim blaming to some degree.

It would be worthwhile strengthening the emphasis on the engineer's ability to consider possible user behaviour, to find out about actual and possible user behaviour, and to design with this in mind. We can see in the recently produced education material (ASCC 2006) material, exercises and activities that target these issues.

6 Conclusions

It is positive that student engineers view accidents as being controllable. They also embrace design related issues as being genuine causes of accidents. In terms of responsibilities they positively accept that they should consider safe construction and manufacture, access for maintenance and the provision of information for safe use. Where ground needs to be made up is in developing clarity of thinking about accident causation, causing a design for the user approach to be foremost in their mind and extending their considerations in design to the whole of life. Safe design as a legal responsibility is well established. The need to consider user behavior that is less-than-ideal for example is one of the necessary considerations. The aspects of safe design thinking of this type need significant strengthening based on this small study. Widespread implementation of the educational material *Safe Design for Engineering Students* (ASCC 2006) would be a useful step forward. However a better understanding through ongoing monitoring of perceptions about safe design is necessary in understanding the need for education to progress safe design.

7 References

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