Viability of Designing for Construction Worker Safety

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Abstract: Designing for construction safety entails consideration of the safety of construction workers in the design of a project. Research studies have identified the design aspect of projects as being a significant contributing factor to construction site accidents. Designing to eliminate or avoid hazards prior to exposure on the jobsite is also listed as the top priority in the hierarchy of controls common to the safety and health professions. Widespread implementation of the concept in the United States by engineering and architecture firms, however, is lacking due to perceived industry and project barriers. Given its absence from standard design practice, a question arises as to the viability of designing for safety as an intervention in the construction industry. This paper presents a pilot study that was conducted to investigate the practice of addressing construction worker safety when designing a project and to determine the feasibility and practicality of such an intervention. Through interviews of architects and engineers, the study found that a large percentage of design professionals are interested and willing to implement the concept in practice. Among the perceived impacts of implementation, project cost and schedule were mentioned most often along with limitations being placed on design creativity. The results of the pilot study indicate that designing for safety is a viable intervention in construction. The factors that impact the consideration of safety in the design of a project do not entirely prohibit its implementation or make its implementation extremely impractical and therefore not feasible. Additionally, the outcomes of implementation provide sufficient motivation to implement the concept in practice. The paper describes the key changes needed for implementation of the concept in practice which include: a change in designer mindset toward safety; establishment of a motivational force to promote designing for safety; increase designer knowledge of the concept; incorporate construction safety knowledge in the design phase; utilize designers knowledgeable about design-for-safety modifications; make design for safety tools and guidelines available for use and reference; and mitigate designer liability exposure.

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Introduction

An intervention identified as a breakthrough idea for improving construction site safety (Korman 2001) and which is gaining support in the construction industry is the concept of designing for construction worker safety. Designing for construction safety entails addressing the safety of construction workers in the design of the permanent features of a project. The design defines the configuration and components of a facility and thereby influences, to a large extent, how the project will be constructed and the consequent safety hazards (Gambatese 2000). When designing the structural steel frame for a building, for example, an engineer may choose to design steel connections in a particular fashion to facilitate safe worker access to make the connections. Anchorage points might additionally be designed into the surrounding steel members to provide locations for workers to anchor fall protection devices to further ensure safe access to the connections. Many other suggestions for how to design the permanent features of a project to facilitate safety during construction have been documented (Gambatese et al. 1997).

Studies by Whittington et al. (1992) and Suraji et al. (2001) reveal that a significant number of injury accidents originate from conditions upstream of the construction process during planning, scheduling, and design. Though the impact of the design on construction safety is evident and the potential benefits of its implementation are apparent, widespread application of this intervention in the United States construction industry is currently lacking. This state of practice brings up questions about the viability of designing for safety as an intervention in construction. Is designing for safety a concept that the construction industry can readily employ and, if implemented, would its impact be worth the effort? If the industry were to adopt the concept, what changes would need to be made in practice to facilitate its implementation? Little empirical evidence exists as to the answers to these questions. The Center to Protect Workers' Rights (CPWR) recently funded a pilot study to address the issue and explore whether designing for construction safety is a viable intervention (CPWR Small Study No. 01-2-PS). This paper presents results from that pilot study and offers strategies to facilitate the concept's implementation on construction projects throughout the industry.

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Previous Research and Implementation in Practice

Designing for construction safety as an intervention is supported by the hierarchy of controls common to the safety and health professions which identifies designing to eliminate or avoid hazards as the preferable means for reducing risk (Manuele 1997). Recognizing the importance of the design to construction safety, the American Society of Civil Engineers (ASCE) states in its policy on construction site safety (Policy Statement Number 350) that engineers shall have responsibility for "recognizing that safety and constructability are important considerations when preparing construction plans and specifications."

Outside the United States, the European Union mandates consideration of safety in the design (CEC 1992). The United Kingdom's Construction (Design and Management) Regulations (HMSO 1994), established to comply with the EU Directive, place a duty on the designer to ensure that any design prepared avoids foreseeable risks to construction workers (MacKenzie et al. 2000). In Australia, the states of Queensland South Australia, and Western Australia place similar responsibilities on designers (Bluff 2003), and the New South Wales State government requires that a management strategy exist for the design process which includes consideration, evaluation, and control of occupational safety and health during construction (NSW Construction Policy Steering Committee 2000). Similarly, in South Africa, designers must ensure that their designs are safe and free of health risks (Republic of South Africa 1993). The South African Construction Regulations (Republic of South Africa 2003) state that designers shall modify the design or make use of substitute materials where the design necessitates the use of dangerous structural or other procedures or materials hazardous to health and safety, and that designers shall inform principal contractors of any known or anticipated dangers or hazards or special measures required for the safe execution of the work.

Lacking regulatory mandate, as is the case in the United States, implementation of the concept in practice will likely depend on the benefits received from designing for safety compared to the effort and resources necessary for its implementation. In terms of preventing injuries and fatalities, evidence exists that its impact is positive as illustrated by the following studies:

1. The European Foundation (1991) found that 60% of the accidents it surveyed could have been eliminated, reduced, or avoided with more thought during the design stage.
2. Gibb et al. (2004) reviewed 100 construction accidents and found that in 47% of the cases, changes in the permanent design would have reduced the likelihood of the accidents.
3. In a study of an intervention to prevent musculoskeletal injuries to construction workers, antecedents in design, planning, scheduling, and material specifications were likewise identified as probable contributors to working conditions that pose risks of such injuries during the actual construction process (Hecker et al. 2001).
4. In an effort aimed at linking the design for safety concept to construction site injuries and fatalities, Behm (2004) found that the design was linked to the accident in approximately 22% of 226 injury incidents that occurred from 2000 to 2002 in Oregon, Washington, and California, and in 42% of 224 fatality incidents in the United States from 1990 to 2003.
5. 50% of the 71 general contractors responding to a survey of the construction community in South Africa identified the design as an aspect or factor that negatively affects health and safety (Smallwood 1996). The contractors surveyed also ranked design as the highest out of all components identified that negatively affect safety.

While the merits of designing for construction safety are evident, implementation in practice throughout the United States is minimal to nonexistent. Numerous industry, project, and educational barriers to its implementation have been cited (Hinze and Wiegand 1992; Gambatese 1998; Gambatese et al. 2003; Hecker et al. 2004a; Toole 2004):

1. weak or absent regulatory requirements for architects and engineers to design for the safety of the construction workers;
2. OSHA's placement of safety responsibility on the employer (typically the constructor);
3. liability concerns among architects and engineers;
4. narrow specialization of construction and design;
5. limited availability of safety-in-design tools, guidelines, and procedures;
6. limited preconstruction collaboration between the designer and constructor due to the traditional contracting structure of the construction industry; and
7. the limited education architects and engineers receive on issues of construction worker safety and on how to design for safety.

Examples exist of companies both within and outside the United States that have developed and implemented design-for-safety processes. One example is the "Life Cycle Safety" (LCS) process developed by a large high-tech firm for the design and construction of a new semiconductor manufacturing facility in the Pacific Northwest (Hecker et al. 2004b). The LCS process consisted of trade contractor, designer, and owner focus groups during the programming phase to identify modifications to the plan of record that would improve the safety of those who construct, operate, and maintain the facility. Additionally, for each design package developed during the design phase, focused safety reviews were conducted by owner, construction manager, trade contractor, and environmental safety and health personnel at approximately the 30, 60, and 90% completion points in the design. Findings from a study of the process implementation and outcomes indicate that the involvement of trade contractors was particularly effective and that early consideration of suggested design modifications greatly impacted their implementation (Weinstein et al. 2004).

A design–build firm in Florida has developed its own design-for-safety program that involves three major elements (Angelo 2004). The first element is the participation of designers in an intensive but modified 10 h OSHA safety course. Second, warning symbols are added to project plans to alert the constructors of potential hazards that could result in electrocution, asphyxiation, falls, etc. Finally, safety-oriented design checklists are consulted for each project to help highlight potential hazards and suggest design modifications.

The international design firm of Foster and Partners, which is based in London, makes safety and health a facet of all of its programming and design activities (Istephan 2004). Translating both the Construction (Design and Management) Regulations and Foster and Partners' own design philosophy into practice, the firm utilizes a program involving multiple components: training, design reviews, integration of health and safety with quality assurance and other processes, the production and transfer of information, and feedback of lessons learned. An early start and planned timing of the firm's design reviews play a critical role in the effective application of its program.

The type of project delivery method can impact the extent to which safety is addressed in the design. The forms of project

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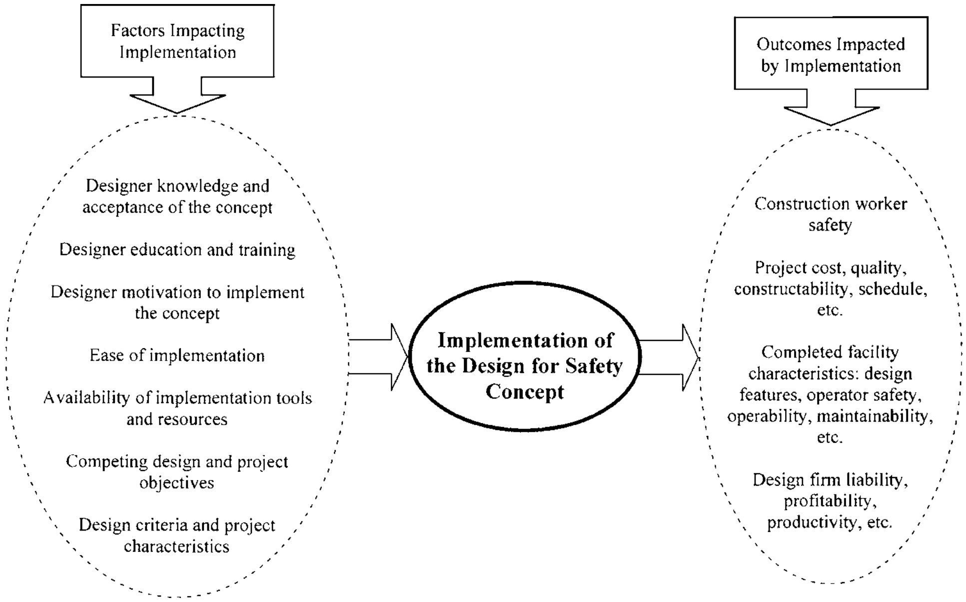

Fig. 1. Design for safety concept implementation factors and impacts

delivery essentially alter the roles played by the different parties and, most importantly, the allocation of responsibility (thus liability) is also redistributed. The design–build method forces a partnership between the design and construction teams which provides a natural motivation to address safety in the design. In the construction management (CM) agency approach, the owner shoulders more of the liability and this creates an environment where the construction manager can be more aggressive about safety in the design without having to evaluate the possible implications. The traditional general contract (design–bid–build) approach and the CM-at-risk approach keep the parties isolated, and there is no payback, presumably, for the designer to address construction worker safety. Variations of these can occur, especially when the owner addresses specific issues regarding safety in the contract.

The involvement of designers by project type (industrial, highway, residential, commercial, etc.) should make no difference as to their potential contribution to worker safety. Projects do vary, but this is largely driven by the owners. For example, owners in the industrial sector often have sizable budgets for construction and have become knowledgeable about the construction process and how to enhance safety. That motivation does not currently exist among owners with small budgets, as these owners often do not understand the construction process and rely heavily on the design team to get the documents prepared and the contract for construction awarded. That is why residential and commercial are the lagging sectors. Public owners, many with large construction budgets, do have the construction budgets to give them strong knowledge bases, but they are often hampered by the traditional selection of contractors through low-bid contracting requirements with no consideration given to the safety qualifications of the contractors. In the end, it is not the type of project, but more the size of the owner's budget and the ability to make changes from the traditional approaches to awarding contracts. The owner is the key to getting the designer involved in the safety process. Some owners, especially in the industrial sector, have seized the opportunity to improve safety, while others do not understand that they could make a difference or they continue to take the advice of legal counsel that cautions them against exposing themselves to liability by getting more involved in safety.

In the design–build method of project delivery, the designer is motivated to address worker safety issues in the design. In most of the other methods, the designer is a stand-alone entity. As an isolated party, designers often revert to their traditional role of not getting involved in safety. There is no solid basis for this stance. There is no clear evidence that designers who make their designs "safer" are more subject to lawsuits. The legal or contractual consequences of involving designers are an issue only if there is an injury. With a judicious effort on the part of the various parties, there should be fewer injuries, so the probability of a legal entanglement should be diminished with designer involvement.

Research Objectives and Methods

The purpose of this research study was to investigate designing for safety as a prospective intervention for improving the safety and health of construction workers. Drawing on the findings of previous research, examples of successful implementation in practice, and regulations enacted outside the United States, the hypothesis driving the research was that the practice of designing for safety is a viable means for enhancing construction site safety. For the purposes of the research, in addition to having a positive impact on safety, viability was considered to be related to the feasibility and practicality of implementation given the nature and characteristics of design practices and the delivery of construction projects. The researchers assessed the viability of the design-for-safety concept by considering the factors that impact implementation of the concept and the impacts resulting from implementation of the concept. These are listed in Fig. 1, which illustrates their relationship to the design-for-safety concept. Implementation of the concept is considered viable if: (1) the factors that impact implementation on a project do not prohibit, or substantially limit, its implementation; and (2) the outcomes of implementation are beneficial such that they provide sufficient motiva-

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tion to implement the concept. This combination suggests a concept that is both feasible to implement and effective in producing desired outcomes. If the concept is, for example, relatively easy to implement, requires minimal additional resources, and complements other project goals, designers will not be hesitant to employ it on a project. Additionally, if the outcomes resulting from implementation are positive, an incentive exists to make the effort to implement the concept.

To assess the viability of the concept, the research focused on designer knowledge and acceptance of the concept, their ability to address safety in designs, the feasibility of implementing promising safe designs, and the likely impacts resulting from their implementation of safe designs on a project. A survey research approach was selected for the study that consisted of in-person interviews of design professionals. The types of design disciplines included in the research study were limited to architecture, civil engineering, structural engineering, mechanical engineering, and electrical engineering. These are the primary disciplines involved in the design of construction projects and, by both dollar value and hours expended, their work constitutes the majority of the design effort undertaken on many projects.

Designers are employed by design firms that concentrate on one or more design disciplines, and by design–build firms that undertake both the design and construction aspects of the work. A sample of prospective design firm, design–build firm, and designer respondents was created using both convenience and random sampling from local telephone directories, the Internet, web-based professional association directories, and personal contacts of the researchers. A total of 40 different design professionals (19 architects and 21 design engineers) in western Oregon (Portland and surrounding areas) and northern Florida (Gainesville, Jacksonville, and surrounding areas) were selected. When selecting firms and design professionals for the study, consideration was given to firm type, size, and location, and designer discipline to ensure a survey sample representative of the construction industry. In addition, firms that design projects in each of the various sectors of the construction industry (residential buildings, commercial buildings, engineering facilities, and industrial facilities) were included in the study sample.

The research team contacted the 40 designers to request their participation in the survey on a voluntary basis only. Criteria used to determine designer participation were: designer willingness and availability to participate in the study; experience as a designer; knowledge about standard design practice; and current employment in the field of design. Out of the list of 40 design professionals contacted, 19 architects and design engineers volunteered to be interviewed for a total response rate of 46%.

Each of the 19 designers was interviewed separately. To assure comprehensive and consistent interviews, the researchers developed an interview questionnaire for reference during the interviews that comprised of a list of questions soliciting the following information:

- general background and work experience of the designer;
- the nature and extent of their current design-for-safety efforts;
- ideas for design changes that could be made to improve construction worker safety;
- the barriers that exist to addressing safety in the design;
- any foreseen limitations to designing for safety as an intervention in construction; and
- an assessment of the expected impacts of the intervention on projects.

In addition, the researchers presented the designers with a sample of promising design modifications identified in previous research studies and asked the designers to comment on the feasibility of implementing the design modifications.

The interviewees had varied backgrounds representing a variety of design disciplines, employment positions, and durations of work experience. Of those interviewed ($n=19$), eight were architects (42%), four structural engineers (21%), three civil engineers (15%), two mechanical engineers (11%), and two electrical engineers (11%). Nine of the designers interviewed were employed by design-only firms (47%) and the remaining ten were employed by design–build firms (53%). It should be noted that the design discipline of the designer may not correspond to their firm's primary design discipline. For example, a designer who is academically trained and licensed as a structural engineer may work for an architectural firm, providing the structural expertise required of that firm.

The design experience of those interviewed ranged from three to 33 years (mean=20.7 years; median=23 years). In addition to their design experience, the interviewees were asked how much construction experience they possessed. Construction experience was defined as actually performing construction work, e.g., carpentry, roofing, plumbing, etc. The construction experience of those interviewed ranged from zero to ten years with a mean of 1.7 years. However, only seven of the 19 designers interviewed had any construction experience. For the seven designers that have construction experience, the mean number of years of construction experience is 4.6 years and the median is 3 years.

The size of the firms represented by the interviewees ranged from small to large. Twelve interviewees (63%) answered the questions regarding design fee revenue and whether the firm's revenue was generated from design or construction. The total annual design fee revenues ranged from $75,000 to $500 million, averaging approximately $155 million/year. Six firms (32%) reported design fee revenues in excess of $100 million per annum. In four of the twelve firms, 100% of the revenue came from design services. The remaining eight firms provide design and construction services, with the split between design and construction revenue on average being fairly equal.

Results

Factors Impacting Implementation of Concept

Two factors that are crucial to implementation of designing for safety in practice are the designer's knowledge and acceptance of the concept. Safety will not be considered in the design if the designer is not aware of the concept or how to implement it, or does not accept it as part of design practice. The designers were identified as either "knowledgeable" or "not knowledgeable" according to whether they were able to describe the general nature of the concept, had received some on-the-job training or classroom education on safety or the design-for-safety concept, and demonstrated a general understanding of the concept and the related barriers and benefits during the course of the interview. During the interview, the designers were asked specific questions about their understanding of the concept and their safety education and training. The interviewer also made an assessment of the designer's knowledge of the concept based on a qualitative evaluation of the respondent's overall understanding of the concept gained during the face-to-face interview.

Of the 19 designers interviewed, four (21%) were judged to be knowledgeable of the concept. When asked directly about their understanding of the concept, three respondents (16%) referred to

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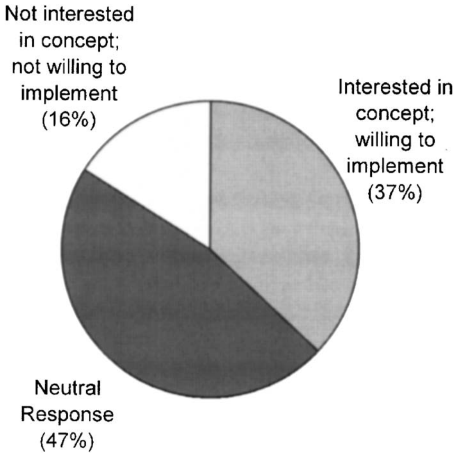

Fig. 2. Designer interest in implementing design-for-safety concept ($n=19$)

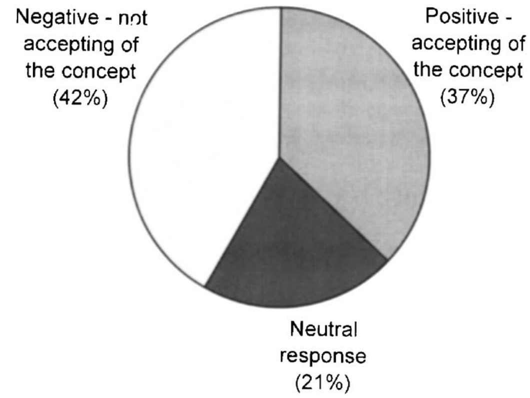

Fig. 3. Designer acceptance of design-for-safety concept ($n=19$)

the American Institute of Architects (AIA) contract documents which state that safety is the contractors' responsibility. Four respondents (21%) indicated that they had heard of the United Kingdom's CDM Regulations (HMSO 1994).

Simple inference tests (Chi square) were conducted to evaluate the relationship between various designer characteristics and their knowledge of the concept. The findings in which the correlation was found to be statistically significant ($p<0.05$), and in which only a moderate or borderline relationship exist but which are of interest ($p<0.10$), are as follows:

1. Respondents who stated that they have been asked to address construction worker safety in the design phase are much more knowledgeable of the design for construction safety concept than those respondents who have never been asked to address construction worker safety in the design phase ($p=0.004$).
2. Respondents who stated that they believe that the nature and culture of the construction industry precludes them from addressing construction worker safety in the design phase are less knowledgeable of the design for safety concept than those respondents who do not believe the nature and culture of the construction industry precludes them from addressing construction safety in the design phase ($p=0.05$).
3. Respondents who have construction experience are slightly more knowledgeable of the design for construction safety concept. Respondents who do not have construction experience are less knowledgeable about the concept ($p=0.08$).

Acceptance of the design-for-safety concept was evaluated in several ways. One question elicited their acceptance of the concept by asking about their personal willingness to address construction worker health and safety in the design phase of a project. Fig. 2 summarizes the responses to this question. Seven of the respondents (37%) said that they were interested and willing to implement the concept, while 47% gave a neutral response, and only three respondents (16%) expressed negative interest.

Acceptance of the concept was evaluated through two interview questions that related to the designers' involvement in and comfort level with the topic of construction worker safety. In response to the question "Have you ever been asked your opinion about construction worker health and safety issues?," eight of the 19 designers (42%) stated that they have been asked to give their opinion about safety. Most of the designers stated that they provided general suggestions while on-site and during safety meetings. Additionally, when asked, "Do you feel comfortable talking about construction worker safety issues?," 95% of the designers (18 of 19) felt comfortable discussing safety issues.

The level of acceptance that each respondent exhibited toward the concept was also rated as "positive," "neutral," or "negative" by examining the following:

1. the responses to the list of design modifications that required the respondent to comment on the feasibility of implementing the various design modifications;
2. the response to a question that asked the respondent to describe their understanding of construction worker safety; and
3. the interviewer's qualitative evaluation of the respondent's overall acceptance of the concept gained during the face-to-face interview.

As with the assessment of knowledge of the concept, this evaluation of acceptance was subject to the interviewer's judgment. Fig. 3 shows the results using this rating. The designers were fairly evenly distributed between those who accepted the concept (37%) and those who were not accepting of the concept (42%), while the remainder (21%) exhibited a more neutral response. Regarding the relationship between acceptance of the concept and various designer characteristics, the findings in which the correlation was found to be statistically significant ($p<0.05$) are as follows:

1. respondents who stated that the nature and culture of the construction industry precludes them from addressing construction worker safety in the design phase are less accepting of the concept than those respondents who do not believe the nature and culture is a barrier to addressing safety in the design ($p=0.02$) and
2. respondents who work in design-only firms mention liability as a barrier to designing for construction worker safety more frequently than those respondents who work in design–build firms who mentioned liability as a barrier ($p=0.04$).

Previous research identified numerous barriers to the implementation of the concept. The research participants were asked, "What barriers or limitations do you see in addressing construction worker health and safety in project design?" The most cited response to this question (mentioned by seven of the 19 designers) was that it would possibly interfere with the constructor's means and methods. Five (26%) of the designers mentioned increased liability as a barrier. The following barriers were each mentioned four times: designers have limited or no construction experience; time constraints to create the design ("designers have enough to deal with"); and designers have no control over who gets the bid (constructor hired separately).

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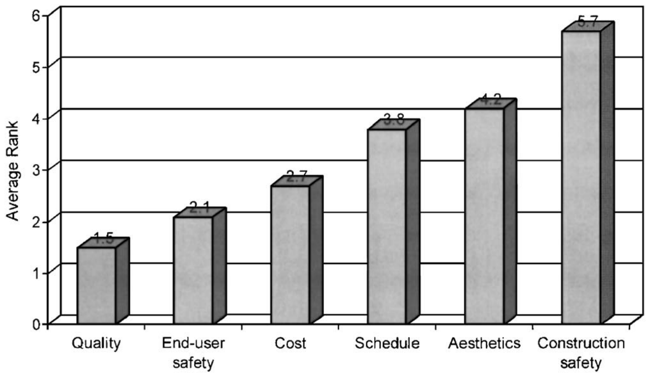

Fig. 4. Rank of priority given to project criteria (1=highest priority, 2=second highest priority, and so forth; lower ranking indicates higher priority)

Two questions were aimed at specific barriers that have previously been identified and are considered significant. One question asked: "Do you believe that addressing construction worker health and safety in the design phase will increase your liability exposure?" The issue of liability is of concern as 16 of the respondents (84%) answered that they believed their liability would increase. In response to a second question, "Do you believe that the nature and culture of the construction industry precludes you in any way from addressing construction worker health and safety in the design phase?," the designers did not hold this in the same regard. Only four respondents (21%) felt that the nature and culture of the construction industry was a barrier.

Motivation to design for safety, another factor impacting implementation in practice, is reflected in the priority given to safety compared to other project criteria. One interview question asked the designers to rank the following project criteria in terms of priority when designing a project: cost, schedule, quality, aesthetics, end-user safety, and construction worker safety. As shown in Fig. 4, quality of work was the highest ranked criterion among the designers interviewed. This was followed by final occupant safety and then project cost. Construction worker safety was ranked last in importance among those priorities mentioned.

When asked about the nature and extent of their education and training with respect to safety and designing for safety, only two respondents (11%) stated that they have had coursework that included addressing construction worker safety, but not specifically designing for safety. This low percentage is expected based on the findings of a previous study that found the majority of civil engineering programs at universities lack any coursework in construction safety (Gambatese 2003).

Impacts of Implementation of Concept

When implemented, designing for safety will impact a project in a variety of ways. Several of the interview questions asked about the potential impact of designing for safety, where impact was defined broadly and could be related to any aspect of a project, the design process, or the overall construction industry, including safety and other project characteristics. The impacts mentioned most often were increased project cost (74%) followed by extending the schedule due to lower productivity (47%). Four respondents (21%) felt that it would limit the design creativity and therefore decrease overall quality. The only positive impact cited was from one respondent who mentioned an increase in productivity as a result of designing for safety. In a recent survey of 97 designers in South Africa (Smallwood 2004), the designers anticipated similar impacts. It is interesting to note that an impact on construction worker safety was not mentioned by the respondents. While this may be because the impact on safety was "too obvious" and therefore not a response worth mentioning, it perhaps provides another indication of a designer's mindset about construction worker safety and their top priorities on a project.

Design-for-Safety Implementation

The extent to which the designers currently implement the design for construction safety concept and address construction worker safety in their projects was also examined. Nine designers (47%) indicated that they make design decisions that improve construction worker health and safety without giving any indication of how or when safety is addressed. Perhaps the designers address safety on an informal basis as part of other design processes rather than as part of a formal design-for-safety process. They may also address safety when redesigning elements of the project as part of a value engineering change or during the construction phase to accommodate the construction means and methods. When asked a similar question specifically about the design phase, "Have you ever made modifications to a design in the design phase to eliminate a potential safety risk that would impact construction worker health and safety?," eight respondents (42%) answered "Yes." A smaller percentage of designers (21%) stated that they have previously been asked to address construction worker safety and health in the design phase.

Three of the designers (16%) stated that they have worked with or hired a construction health and safety consultant in the design phase. Utilizing consultant services can help overcome deficiencies in safety education and training. This is perhaps a future service that OSHA can provide to design firms through its consultation program to assist with implementation of the design-for-safety concept.

Included with the questionnaire was a list of example design modifications that were collected in previous studies. When asked to comment on the feasibility of implementing the design modifications, the designer provided the following responses:

1. Design modification: Indicate on the contract drawings the locations of existing underground utilities and mark a clear zone around the utilities. Include the source of information and the level of certainty on the location of the utilities. Designer responses: Ten respondents stated that they already provide this information to some extent. Most do not mark a clear zone or provide a level of certainty for the location of underground utilities. Four respondents noted that this was not part of a design professional's work and this work should be completed in the field.
2. Design modification: Design parapets to be 1.07 m (42 in.) tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance. Designer responses: Five respondents responded positively to this design modification. Four responded negatively. Five stated that overall costs would increase if this modification were implemented. Three said that this would help with building aesthetics by hiding maintenance equipment usually found on top of buildings. One responded that this design modification would negatively impact aesthetics.
3. Design modification: Design columns with holes at 0.53 m (21 in.) and 1.07 m (42 in.) above the floor level to provide support locations for guardrails. Designer responses: Six re-

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spondents stated that this modification is possible. Two mentioned this would not add cost. Four responded that they would not implement this design modification. Three designers mentioned a potential concern with the structural integrity by drilling holes in the steel.

4. Design modification: Design perimeter beams and beams above floor openings to support lifelines. Design connection points along the beams for the lifelines. Note on the contract drawings which beams are designed to support lifelines, how many lifelines, and at what locations along the beams. Designer responses: Four designers stated this modification was possible, while four said it was not possible. Six respondents identified an increased cost associated with this modification, and two identified extra time in the design phase. One designer stated that they are starting to provide this design feature for the owner, but that it was not feasible because they would need constructor input. One designer would do this but only if hired by the constructor after the design phase.
5. Design modification: Design window sills to be 1.07 m (42 in.) above the floor level. Window sills at this height will act as guardrails during construction. Designer responses: This was the most contentious modification among the respondents with nine responding negatively toward this suggestion. Architects, in particular, felt that this would negatively impact design quality. Some thought this was excessive and unnecessary. Three respondents stated that this is feasible, but that it is owner driven.
6. Design modification: Provide permanent guardrails around skylights. Designer responses: Five designers responded that this was a feasible modification, while seven stated that they would not do this or that it was not feasible. Six respondents stated that there would be an increase in cost to implement this design modification.

Conclusions and Recommendations

Designing for safety is an intervention that is gaining interest in the construction community, but which has not become part of standard design practice. The results of this study indicate that designing for safety is a viable intervention in construction. Barriers currently exist which limit its implementation including: the structure of the construction contracting process; a lack of knowledge and acceptance of the concept; designer education, training, and construction experience; competing project objectives; and motivation to implement the concept. However, none of the barriers are insurmountable. With continued research and dissemination of information on designing for safety, designer knowledge of the concept will increase. New design tools and resources can be created to assist designers in addressing safety in the design. Alternative project delivery methods can be used to access the constructor's knowledge to highlight safety hazards and facilitate implementation of design modifications. Owners can motivate designers through contractual requirements and monetary incentives. Owner acknowledgment of the importance of designing for safety can place it as a higher priority compared to other project parameters. The means by which these barriers can be overcome are known and have been implemented to successfully address safety in the design of a project. In fact, designing for safety is currently being practiced, and examples exist of how the barriers have been overcome. The factors that impact the consideration of safety in the design of a project do not entirely prohibit its implementation, or make its implementation impractical.

Viability is also predicated on whether the outcomes of implementation are such that they provide sufficient motivation to implement the concept. Previous studies show that eliminating hazards and facilitating the use of safety measures through the design of the project will positively impact construction safety. The interviews with design professionals, most of whom have not implemented the intervention, suggest that designers foresee negative impacts with respect to other project criteria such as cost, schedule, design creativity, and liability exposure. When implemented in practice, however, designing for safety has resulted in positive impacts to construction cost, schedule, productivity, and quality (Gambatese et al. 1997; ISTD 2003). Furthermore, if the entire life cycle of a project and sustained purchasing of construction services are considered, the potential benefits are expanded as design changes which initially may be costly become long-term benefits as a result of lower construction costs and improved safety during operation and maintenance. In addition, the potential impacts cannot be terribly obstructive since the criteria that the designers perceived to be impacted are not ranked by the designers as the highest priorities on a project. Thus, substantial motivation to implement the design-for-safety concept exists with many positive impacts.

The study results reveal that there are some key changes which are vital to successful implementation in practice and which will have significant initial impact on both the implementation and the outcomes of designing for safety. These keys to implementation are: a change in designer mindset toward safety; establishment of a motivational force to promote designing for safety; increase designer knowledge of the concept; incorporate construction safety knowledge in the design phase; utilize designers knowledgeable about design-for-safety modifications; make design for safety tools and guidelines available for use and reference; and mitigate designer liability exposure. In addition, constructors need to look for the changes made in designs to make construction safer, and take appropriate action when the design facilitates safe performance of the work.

The viability of designing for safety as an intervention for improving construction worker safety provides an incentive to move forward in several ways. Implementation of the concept in practice should be promoted to increase its use in practice. Continued exposure will increase designer knowledge of the concept and initiate the development of best practices for its implementation. Most importantly, continued consideration of safety in designs will lead to fewer construction worker injuries and fatalities.

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