PREVENTION THROUGH DESIGN PRACTICE AND RESEARCH: A U.S. CONSTRUCTION INDUSTRY PERSPECTIVE

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ABSTRACT

Addressing construction worker safety and health in the design of a project, also referred to as prevention through design (PtD) and designing for construction safety and health, has seen expanded interest and activity in the U.S. construction industry. The positive influence that PtD can have on not only reducing construction site hazards and improving worker safety and health, but also improving quality and productivity, has motivated the construction community to explore and implement the concept. However, barriers to PtD's widespread implementation in the U.S. exist, including the lack of regulatory requirements for PtD to be incorporated into construction projects. Leaders in the PtD effort from across the U.S. participated in a recent workshop sponsored by the National Institute for Occupational Safety and Health (NIOSH) to develop a national strategy for studying and diffusing the PtD concept. As part of the workshop, attendees took part in focus groups related to construction industry practice and to PtD research. This paper presents the outcomes from the focus groups and discusses their relationship to the findings of PtD research described in previously published literature and the current and planned PtD activities in the U.S. construction industry.

Keywords: Construction, Safety, Design, Architect, Engineer

1. INTRODUCTION

Prevention through design (PtD) is a fundamental concept within the field of occupational safety and health. It is well known that when designing a work environment, it is better to design out the safety and health hazards than to simply protect the workers from, or warn them of, the hazards (Manuele 1997). Eliminating safety and
health hazards from the workplace provides workers a safe environment from the moment they step onto the job.

Application of the PtD concept in the construction industry can be challenging. Safety and health hazards for construction workers can be difficult to foresee given the nature and complexity of construction jobsites. The environment surrounding construction workers can change frequently as a facility gets built and jobsites often incorporate the work of many different trades and organizations each with different goals, priorities, and schedules. Depending on the contracting arrangement selected, the process used to construct the facility, and therefore some safety and health hazards that arise, may not be known until after the design is complete and construction services are contracted. There are impediments to the implementation of the PtD concept in construction that exist outside the jobsite as well. These include: designers traditionally limiting their focus to the safety of the facility end-users; a lack of education, training, and resources to assist architects and engineers to design for construction safety; perceptions of increased liability exposure to third-party lawsuits; the codes and standards to which designers prepare their designs; and the customs and culture of the construction industry. The absence of a legal requirement to apply PtD principles for construction workers in the U.S. is also limiting its application.

Although there are barriers to the implementation of PtD in the U.S. construction industry the benefits for PtD are recognized. Research has identified a link between the design and construction site injuries and fatalities. 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. 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 accident. In an effort aimed at linking the design for safety concept to construction site injuries and fatalities, Behm (2005) found that the design was linked to 42% of 224 fatality incidents in the U.S. from 1990 to 2003. Constructors recognize the impact of the design on safety and health as well. In a study in South Africa (Smallwood 1996), approximately 50% of the 71 contractors who were interviewed identified the design as an aspect or factor that negatively affects health and safety. The design was the highest of any component identified that negatively affected safety. Almost 90% of the contractors stated that there is a need for safety education at the university or technical college for architects and engineers.

It is clear that considering construction worker safety and health in the design of a project can eliminate jobsite safety and health hazards and therefore positively influence worker safety and health on projects. Other countries, such as those in the European Union and Australia, have recognized the beneficial impacts of PtD, taken formal action, and are leading the way through PtD legislation. Recognition of and interest in PtD throughout the U.S. construction industry is growing. However further efforts are needed to cause diffusion of PtD throughout the U.S. construction industry.
NIOSH Workshop

To facilitate and grow PtD in all industry sectors in the U.S., the National Institute for Occupational Safety and Health (NIOSH) began a national PtD initiative in 2006 (http://www.cdc.gov/niosh/topics/PTD/). The initiative is designed to promote the PtD concept and highlight its importance in all business decisions. The ultimate goal of the PtD initiative is to prevent or reduce occupational injuries, illnesses, and fatalities through the inclusion of prevention considerations into all designs that impact workers.

As an initial step in the initiative, NIOSH hosted a Prevention through Design Workshop in Washington, DC, from July 9-11, 2007 to launch the initiative. The workshop attracted approximately 225 participants from diverse industry sectors and disciplines. The workshop spotlighted the success of PtD in several industries in the U.S. and internationally; engaged participants in industry-centered breakout sessions to identify opportunities and barriers and to develop recommendations for each industry; and included cross-industry breakout sessions to map out the top over-arching issues for PtD in Research, Education, Practice, and Policy. The output from the workshop will be used to develop a strategic plan that highlights actions and milestones to institutionalize the PtD concept throughout the U.S.

Much can be learned about diffusing PtD in the construction industry from the input provided during the focus group (breakout) sessions at the workshop. This paper presents a summary of the input related to the construction industry that was provided during the Construction Industry and Research sessions along with an evaluation of its merits. An evaluation of the input is also provided with respect to previous PtD research and current and planned PtD activities in the U.S. construction industry.

2. FOCUS GROUP (BREAKOUT) SESSIONS

The second and third days of the NIOSH PtD Workshop were devoted to a large extent on focus group sessions. On the second day, the focus group sessions were organized according to eight work industry sectors (Agriculture, Forestry and Fishing; Construction; Healthcare and Social Assistance; Manufacturing; Mining; Services; Transportation, Warehousing and Utilities; and Wholesale and Retail Trade). Those interested in the construction sector, approximately 85 attendees, gathered together in one room to discuss PtD in construction. This group, which amounted to approximately one-third of the conference attendees, consisted of employees of large engineering/construction firms, large owner firms, academic researchers, design professionals, and national occupational safety and health organizations. The participants were asked to address questions related to four functional areas within construction: practice, policy, research, and education. For each functional area, the participants were asked to discuss and respond to the following questions:

a. How can PtD practices, policy, research, or education address specific goals or important areas identified within the construction sector?
b. How can we overcome barriers and use drivers to promote PtD practice, policy, research, or education in the construction sector?

c. What PtD practice, policy, research, or education opportunities are there for immediate action and how do we move forward on these opportunities?

As a means for discussing each functional area, the participants were separated into small focus groups using the Café method (World Café Community 2002) of group discussion. A total of 12 tables were set up for the discussion (three for each of the four functional areas). The discussion at each table focused on a particular functional area (practice, policy, research, or education). Each focus group was asked to discuss the questions related to the functional area of interest at that table. After allowing time for discussion, the participants were asked to move to another table (not a table covering the same functional area) to participate in discussion with a different group of participants. A total of four tables were visited by each participant. This process permitted the participants to provide input on all functional areas and allowed for “cross-pollination” of ideas. A table “host” was present at every table to facilitate and record the discussion that took place. The records taken by the table hosts were then organized and reviewed by a rapporteur who wrote a summary report on the breakout session.

On the third day of the workshop, the focus group sessions were organized according to functional area: Practice, Policy, Research, and Education. This format allowed practitioners from different industry sectors to come together to share ideas within a particular functional area. For the Research functional area, the research-related input from all industry sector discussions gathered on day 2 of the workshop was collected and organized. From this information, seven topic areas were identified as important to PtD research and were used to facilitate further discussion of PtD research during the breakout session. The seven topic areas were:

1. The economics/business case for PtD
2. Design-related causality of occupational injuries and illnesses
3. The development of PtD devices, tools, and processes
4. Worker, machine, structure, and environment interaction
5. Diffusion, sustainability, and the communication of design innovations
6. Methodologies for PtD research
7. Leveraging PtD methods and technologies from other industry sectors

Participants in the breakout session were asked to consider each of these topics and to provide input and guidance for conducting PtD research in these areas. The Café method of group discussion that was used for the focus group sessions on day 2 was used again for the Research functional area discussion. Similarly, a rapporteur collected, organized, and summarized the input provided during the Research functional area discussions.
3. RESULTS

Construction Sector Focus Group Responses

The Construction sector focus group sessions provided valuable insights into the needs, challenges, and opportunities for PtD in the construction industry. A summary of the input is provided below. The Construction sector rapporteur’s report (Behm 2007) provides a more detailed description of the focus group results.

PtD Practice. With regards to PtD practice, some standardized tools are available and utilized, including the Construction Industry Institute’s (CII) Design for Construction Safety Toolbox (CII 1996) and variations of the Construction Hazard Assessment Implication Review (CHAIR) process developed in Australia (Workcover 2001). Individual firms who currently have PtD processes in place also utilize design reviews, constructability reviews, checklists, and risk assessment processes and forms.

A PtD practice issue commonly cited by the focus group participants was that of liability exposure. Unlike in Europe and Australia where PtD is mandated via legislation, in the U.S. architects and engineers commonly resist incorporating PtD for construction based on advice from legal counsel. When responsibility for safety is contractually placed on the constructor, it is believed that additional liability will be assumed if a designer implements PtD concepts into their designs. To mitigate this fear, opportunities exist to work with innovative firms to understand how the liability issue was overcome. Additionally, firms could work with attorneys and insurance companies to discover methods to eliminate the liability risk or minimize it to an acceptable level.

The participants provided several suggestions regarding ways to increase awareness and acceptance of PtD in construction. Case studies must be developed and geared towards owners and designers. A set of case studies from across the multi-faceted construction industry is needed, as is a prescribed methodology to incorporate PtD and measure its effectiveness. Linking PtD with sustainability was also suggested. The concepts of sustainability and PtD were identified as very congruent and should be able to co-exist. Opportunities to partner with the U.S. Green Building Council (USGBC) which developed the popular Leadership in Energy and Environmental Design (LEED) rating system should be sought. Additional assistance in spreading PtD throughout the industry could be provided through: a “hot list” of design suggestions, identifying tangible benefits designers will receive if they implement PtD concepts, demonstrating ease of use, and collaboration with and education of key professional organizations such as the American Institute of Architects (AIA) and Construction Users Round Table (CURT).

PtD Policy. Looking at PtD from the broader view of policy, the focus groups identified a need to define what “prevention through design” means in the construction sector. Some of the questions raised that should be clarified by a common definition were: Is it design or is it re-design? Are all engineering controls considered under the umbrella of PtD? If someone designs a better scaffold, for example, is that PtD or is PtD about seeking methods to reduce work at height through better project design, or are both examples of PtD? NIOSH or another national organization should develop and put forth
a definition of PtD in construction so that all parties within the industry have a common understanding of PtD. The participants voiced their opinion that governmental agencies should take a lead in PtD by changing standard contracts to make its use a requirement on government projects. However, the participants also believed that governmental regulation of PtD in construction is not a viable short-term strategy.

**PtD Research.** When asked to focus on PtD research in construction, the focus group participants agreed that the research needs to be applied rather than theoretical. Studies to measure PtD’s impact and effectiveness were identified as a high priority. Measuring PtD effectiveness can be difficult because of the impacts of other safety program elements that are implemented on projects in addition to PtD. Individual, in-depth case studies may be the most feasible means for understanding the impact of PtD on a project or a firm. Case studies should begin in the project’s conceptual design stage and follow PtD through the completion of construction. The following research study topics were suggested: analyses of the link between PtD and the sustainability movement; investigation of issues surrounding liability; and how to diffuse PtD throughout the construction industry.

**PtD Education.** Lastly, the focus group participants provided input on PtD education. Education efforts should cover two aspects: continuing education and university education. Creating PtD education workshops for Continuing Education Units (CEUs) required for Professional Engineer and Registered Architect licensure renewals is necessary to diffuse the PtD concept among practicing architects and engineers. Challenges to doing this include the fact that each state has its own engineering licensing system and the difficulty of developing adequate educational materials for the various design and engineering specialties. With regards to education at the university level, the participants felt that this was needed but not a priority at this time compared to other issues. One of the most compelling factors discussed was that entry-level architects and engineers will commonly focus on learning what their employers and clients want them to practice, not on suggesting major changes in policies and processes. Given that practicing design professionals typically do not incorporate PtD in their design work, an educational effort aimed at colleges and universities may be ineffective until the industry standard changes to incorporate PtD in practice at some level.

**Research Functional Area Focus Group Responses**

The Research functional area focus groups identified PtD research opportunities and needs for all industries, many of which are applicable to the construction industry. A summary of the focus group results is provided below. The Research functional area rapporteur’s report (Gambatese 2007) provides a detailed description of the results.

**The Economic/Business Case for PtD.** Anecdotal evidence suggests that PtD can improve productivity, quality, and cost; however further research is needed to fully understand and quantify the economics of implementing PtD. Research is needed that examines the costs associated with both the process of PtD and the manufacture and construction of specific safe designs. Research should be conducted that addresses the
economic impacts of not integrating safety early into the design process. Addressing safety issues through retrofitting has been shown to be quite expensive. Further documentation of the expense is needed. When economic evaluation is conducted at an industry-wide level, assessments should consider human, environmental, and social costs and benefits. Making a business case for PtD is usually done at the individual company level and should include both direct and indirect costs and benefits. It may be that a business case study does not indicate a positive return on investment while societal economic evaluations suggest a benefit to society as a whole. Both types of analyses provide valuable insights into the PtD concept and are needed. Developing an appropriate benefit-cost model and comparing the expected benefits to the costs is needed in order to provide a means to assess PtD from a financial perspective.

**Design-related Causality of Occupational Injuries and Illnesses.** Research is needed to determine how to effectively assess design-related causality and to determine the connection between specific design features and worker injuries and illnesses. This is a very important first step. Understanding injury and illness causality allows for analyzing and re-designing work environments, tools, and systems to eliminate the associated hazards. To facilitate this research, better surveillance data on worker injuries and illnesses is needed. The research should consider both the frequency and severity of injuries and illnesses when identifying new designs.

**The Development of PtD Devices, Tools, and Processes.** Additional tools and processes are needed that assist design professionals with hazard recognition and design optimization in a wide range of contexts. Research is needed to investigate and develop new designs that create a safe and healthy work environment. Including the views and input of the workers affected by the designs and the manufacturers of the products is an important aspect of this research. The designs should consider not only the controlling system but also all sub-systems so that some sub-systems are not negatively impacted.

**Worker, Machine, Structure, and Environment Interaction.** In addition to developing tools and processes to implement the PtD concept, research is needed to understand how to design to account for human interaction with machines and their work environment. The ways in which workers approach, operate, and view machines can impact the hazards which they experience. Workplace dynamics and organizational culture have also been shown to influence worker safety and health. Research is needed to understand these impacts in the context of PtD, and could be accomplished through ethnographic studies aimed at creating and developing products and services that better meet worker needs. Once implemented, maintenance of the tools and continuance of a positive PtD climate will be concerns. Research should be conducted to address how to maintain PtD throughout the lifecycle of a project or within an organization.

**Diffusion, Sustainability, and Communication of Design Innovations.** Research is needed to determine what avenues are available to disseminate PtD information and to measure their effectiveness. This research should be followed up by implementing successful communication strategies so that actual diffusion of the information occurs. Research related to this topic should also consider bringing in a global perspective.
Research is also needed to explore what drives the design community to act and how best to create this demand. The research should involve worker organizations, educational institutions, compliance organizations, and professional groups associated with the design communities to determine how each of these can affect the demand.

**Methodologies for PtD Research.** Conducting PtD research is a complex venture often involving numerous stakeholders trying to study a new process and measure an outcome that may not be directly quantifiable. There is a need to establish PtD research methods that account for these factors and result in reliable research findings under practical research limitations and resources. Research is also needed to develop evaluation metrics, measure the performance of specific designs, identify benchmarks for safety and health performance, and assess the performance relative to the benchmarks. The research should consider performance not solely related to worker safety and health, but also to other outcomes such as cost, quality, and sustainability. There is a need to conduct simple, small studies that focus on specific designs. While these types of studies may not be groundbreaking nor considered high profile research, they can contribute to a significant safety and health issue, and when combined, can provide a magnified impact. Efforts should also be made to coordinate studies under a common funding program such that they complement each other and combine to create a greater impact than each could have on its own.

**Leveraging Methods and Technologies from Other Industry Sectors.** Innovation often occurs in an industry sector as a result of the integration of ideas, tools, and technologies from another industry. Research studies are needed to: identify existing PtD practices in each industry sector; evaluate the practices in terms of their transferability to other industries; and develop the practices for application in other industries. Conducting this research requires that connections be made between industry sectors to enable the communication of ideas and experiences. One way in which this can be accomplished is by creating a national clearinghouse of PtD information. Access to such a clearinghouse would allow researchers to learn from other industries and keep from duplicating research efforts.

**4. CONCLUSIONS AND RECOMMENDATIONS**

The responses provided by the focus groups point to important activities and research that need to be undertaken to diffuse PtD into the construction industry. It is clear that without continued research and dissemination efforts, acceptance and implementation of the PtD concept in the construction industry will be slow to take place. Moving forward to accomplish the identified research requires efforts on numerous fronts. Questions still remain regarding PtD’s impact and the most effective tools for its implementation. Using previous and on-going research as the starting point, additional research should be conducted to validate the impact of PtD on construction worker safety and health and on other project properties such as cost, quality, and schedule. Since PtD knowledge may be incorporated into the design in various ways, assessing the impact of PtD should be conducted in conjunction with the development of PtD processes and tools used for
implementation. Parallel efforts are also needed to educate and train design professionals to assist and promote the implementation of the design processes and tools.

The growth of PtD in the U.S. construction industry is expected to take place. The responses from the focus group sessions suggest the paths, or “trajectories”, it should and will take in its development. Paths which PtD will take have been identified in previous scholarly work. Toole and Gambatese (2007), for example, identify four trajectories through which PtD concepts will evolve in the construction industry. These are: increased prefabrication, increased use of less hazardous materials and systems, increased application of construction engineering, and increased spatial investigation and consideration. The activities suggested by the focus groups can be “mapped” to coincide with the identified trajectories and enhance their effectiveness.

There was much enthusiasm within the Construction sector for PtD. However, numerous challenges exist and among those, the liability issue must be resolved at a national level. While not an issue in other countries where PtD is legislatively mandated, liability is commonly the biggest obstacle to PtD implementation in the U.S. Additional work needs to be done to investigate the probability and magnitude of added third-party liability exposure when designing for construction worker safety and health. Once this is understood, work should be conducted to develop tools and contracting strategies that can be implemented at the project, organization, and industry levels to mitigate the liability. This effort most likely will involve the participation of insurance representatives and construction legal counsel along with professional design associations.

Comprehensive PtD research will require multiple studies over an extended period of time. Like research in many other fields, occupational safety and health research is commonly conducted by independent organizations and researchers who are often working independently and occasionally in collaboration. Communication of investigative efforts, barriers, and findings takes place through publications, presentations, and in some cases informal contact. The autonomous nature of research efforts, along with the often lengthy time period between performance and publication of the research, can inhibit timely, comprehensive, interconnected research of a particular topic. Studies that are undertaken may overlap or result in knowledge gaps. Effective performance of PtD research can benefit from a concentrated effort that integrates and coordinates the individual activities of separate efforts. When study is required on multiple fronts, this allows for planning and conducting integrated research studies and ensures that all research needs are addressed without duplication of efforts. Because of the many and varied PtD research needs remaining, such a combined effort is suggested for continued research on the topic.
5. REFERENCES


