

Prevention through Design (PtD): Current State of Implementation in the Design Industry

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A Growing number of studies indicate that designers possess the ability to impact on-site safety. Multiple countries across the globe have already included safety within the realms of designers. However, such a change is yet to be observed within the US, due to multiple reasons. Thus, this study aimed to identify knowledge, perceptions, and implementation patterns of PtD in the design industry. For this study, an electronic survey was emailed to 3,950 architectural firms. Complete responses from 69 architectural firms were accounted for the initial analysis. Preliminary results indicate that majority of respondents were small architectural firms (less than 5 full time employees) with 21 - 50 years of experience and yielded an annual revenue of less than one million dollar. Additionally, the majority of respondents were involved in private projects and mostly within the commercial sector. The study found that only 8.7% of the respondents were familiar with PtD and 11.9% of the firms were familiar with PtD. The study also indicated that even though respondents were in favor for creation of standard PtD implementation guidelines, they were averse to regulatory guidelines. The study also showed that despite the owners being perceived as one of the most receptive stakeholders for PtD, they were also perceived to lack the knowledge.

Key words: Prevention through Design, Construction Safety, PtD Implementation.

Introduction

The construction industry is accountable for the lives of three workers every workday (BLS, 2013) and has always been a source of concern. Scholars and practitioners have invested time and effort to improve the situation. A considerable amount of improvement is observed in the past few years in the form of decreasing number of fatalities in the construction industry. Still, the construction industry accounts for the highest fatality rate (calculated based on number of fatalities per 100,000 full time employees per year) among all other industry sectors (BLS, 2013) with an equally high number of injuries sustained by the workers. Thus, there is a continuous search for new methods and techniques to improve the current situation of construction workers' safety. One such approach is the Prevention through Design (PtD). American Society of Safety Engineers defined PtD as "addressing occupational safety and health needs in the design process to prevent or minimize hazards and risks associated with the construction, manufacture, use, maintenance, and demolition of a facility." This apparently intuitive concept of reducing construction workers exposure to hazards is not entirely new. The earliest reference of this concept can be found in the Accident Prevention Manual published in 1955 by the National Safety Council. Later in 1985, the International Labor Office (ILO) also recognized that the architects and engineers could actually play a significant role in the safety of construction projects. This concept supported by Szymberski (1997), claims that the ideal time to consider construction safety is during conceptual and preliminary design phases to be more effective.

A growing number of industry leaders throughout the world have recognized PtD as an effective means to enhance occupational safety. The acceptance of PtD in the US has been slow in comparison to some other countries such as United Kingdom, Australia, France, and others. National Institute of Occupational Safety and Health (NIOSH) led an initiative to encourage PtD starting in 2007. In support of this initiative, corporate houses such as Parsons, URS Corporation, and Jacobs Engineering have established PtD programs and Fluor, Kiewit, Mustang Engineering and Zachry Engineering have started implementing PtD programs. Some of the federal offices such as U.S. Department of Energy and the U.S. Army Corps of Engineers have also expressed interest in developing PtD programs.

Existing studies have established the association between decisions made during the design phase of construction projects with the fatalities in the construction jobsites. A study conducted by European Foundation (1991) showed 60% of the fatalities in construction jobsites could be associated with decisions taken during the design phase. A study from Australia also support the claims of the European Foundation (NSW Workcover, 2001). The study conducted by Behm (2005) analyzed several fatal accident reports and concluded that more than 40% of those fatalities could be linked to decisions taken during the design phase of the projects respectively. Because of the identified association between design and construction fatalities, many nations have modified their legislations to encourage and/or require the consideration of construction workers safety during the design phase of construction projects. United Kingdom has made it mandatory for construction companies, project owners, and architects to address safety and health during the design phase of projects in 1994 and companies there have responded with positive changes in management practices to embrace the move. Australia developed their Australian National Occupational Health and Safety (OHS) Strategy 2002–2012, which set "eliminating hazards at the design stages" as one of the priorities (Howard, 2008). In addition, France passed regulations, which mandate a holistic view of construction safety including the design and other European countries have since followed with similar regulations (Behm, 2005). Similar attempts to modify the legislation in the US has been defeated at the House of Representatives, Senate, and state governments (Behm, 2005). In the absence of any regulatory stipulation, to increase the involvement of the designers in the process of PtD, it needs to be promoted among the designers. Recent studies conducted by Behm (2004) and Toole (2005) have identified lack of understanding among the designers about their roles in the process of PtD. In addition, few who realize the benefit of PtD face objection from their counterpart in the industry (Behm, 2004; Toole, 2005). Any substantial improvement from the current state of adoption and implementation of PtD among designers will need a reality check about the status quo within the design industry. The following section discusses hierarchy of hazard control and how PtD fits into it.

History of Hazard Control

Breaking down a typical construction project into five phases such as (1) conceptual design, (2) detailed design, (3) procurement, (4) construction, and (5) commissioning, it is evident that the early involvement of the designers increase their ability to influence safety. Szymberski (1997) claimed that the ability to influence safety is greater when it happens early in the project lifecycle. A lot more coordination is required to make any changes in the later phases of the project lifecycle with subsequent higher costs. In conjunction with this view, NIOSH lists "eliminating hazards and controlling risks to workers to an acceptable level "at the source" or "as early as possible in the life cycle" as one of the missions of the PtD program. The term "at the source" in the previous statement is of much importance and has direct relationship with the hierarchy of hazard control.

Typically, the hierarchy of hazard control has been used to determine the feasibility and practicality of effective hazard controls. The levels in order of highest to the lowest are (1) elimination, (2) substitution, (3) engineering controls, (4) administrative controls, and (5) personal protective equipment. The measure of control at the highest level is the most effective. Elimination and substitution recognized as the most effective measures that are difficult to implement at a further stage in the project lifecycle. However, if the project is still in the design phase it is relatively inexpensive and simpler to incorporate hazard control measures. To implement these higher-level effective controls, the involvement of the designers is necessary. Again, there are certain materials used in construction projects that are hard to eliminate or substitute. In those cases, engineering controls in the form of changed equipment or procedures may be required to eliminate or reduce the hazards. Implementing higher-level controls has the obvious benefits of reduced fatalities and injuries. Reduced accidents will affect the bottom line of the construction projects by saving workers compensation payment, lesser insurance premiums, and fewer injury related lost workdays. Above all, it will improve the social quotient of sustainability by improving the moral of the workers due to fewer accidents. The long-term benefit of PtD can be realized during the operations of the facilities. In addition, the time and cost involved in retrofit actions, which are often required for the safe maintenance and operations of the facilities will be considered during the design phase itself.

Application and Implementation

The Prevention through Design (PtD) concept is not widely accepted in the US design and construction industry, yet is an effective approach for making the work environment safer by providing alternative design solutions. There are many examples of PtD applications in the industry. One of many examples is designing skylights domed in structure, the addition of strengthening wires, or designing guardrail protection around skylights. Another example is the alternate parapet wall design (39") which acts as fall protection during construction and maintenance stages, and further saves money and time that would normally be spent on temporary guardrails. Steel design has been one of the chief areas for PtD implementation. Through the design phase, several PtD applications can be exercised in ways such as identifying anchorage points, allocating guard rail holes in vertical steel elements, avoiding hanging connections and eliminating sharp corners (NIOSH, 2013; Toole, 2013; Toole & Gambatese, 2014).

The implementation of the PtD as a full program has been led by large design-builders such as URS Corporation, Jacobs Worley Parsons, and Bechtel. On project level, several owners such as Intel, the Southern Company and the U.S Army Corps of Engineers have been implementing or requesting to implement PtD on several projects (Behm, 2005). It is also worthy to mention that PtD has been implemented in other industries. For example, in mining industry, they have altered the machine designs to reduce the noise exposure of mining machine operators in coal mining (Kovalchic et al. 2008). Another example would be applications in the healthcare industry (Freiherr, 1996; Quinn et al., 2011). Several tools are used during PtD implementation. These tools include but not limited to safety manuals, constructability (safety) reviews, Checklists, prefabrication options and others. Recently, there have been several attempts to develop a more dedicated CAD based and Building Information Models (BIM) based software to address PtD. One of the current examples is "Design for Construction Safety Toolbox, Version 2.0", developed by the Construction Industry Institute (CII). These tools, along with the use of BIM, can ease the transition phase for the Architecture, Engineering, and Construction (AEC) industry and further develop the PtD implementation (Lew & Lentz; 2010; Ku & Mills, 2010).

Challenges and Barriers

Each new concept and principle faces some barriers and challenges before their practical application because of lack of knowledge. Similarly, PtD is facing some challenges that slow its adoption in the AEC industry. Three main barriers have been consistently identified throughout the literature. First is the designer's fear of liability toward worker safety and the exposure to third party lawsuits. Second is the increase in design fees due to the extra time that designers spend to incorporate safety measures in the design. However, it is worthy to mention that some research studies foresaw cost savings in the long term due to increased productivity and decreased overall project life cycle costs. Third is the lack of the designers' safety expertise that is articulated in identifying and installing safety measures and alternatives during the design phase (Toole, 2005; Toole & Carpenter, 2012; Malcolm, 2008; Rajendran & Gambatese, 2012). Gambatese (2013) has identified several other barriers. These barriers include the lack of regulatory requirements in the U.S, which differ from other countries such as UK, Australia, and Singapore. In those countries, there are regulations in place that obligate the designers to address construction safety during the design phase. The fragmented culture of the AEC industry is an impediment since it limits the dissemination of knowledge of construction safety and makes it a discipline where only contractors are knowledgeable about and liable for its implementation. Another identified barrier is the lack of easily accessible tools for the PtD implementation through different types and sizes of businesses. Finally, yet most importantly, is the lack of education and training among the AEC industry professionals and AEC academic curriculum regarding the PtD concept and implementation (NIOSH, 2014; Gambatese, 2013).

Training and Education

Training and education are the main driving forces behind the successful implementation of PtD. National Institute for Occupational Safety and Health (NIOSH) has driven most of the current efforts for training and education. As a part of the National Occupational Research Agenda (NORA) research project, NIOSH has developed educational modules on several design topics such as structural steel, reinforced concrete, mechanical/electrical systems, and architectural features. NIOSH is also working with authors of course textbooks to insert PtD content and NIOSH case studies in some of these textbooks. Although addressing PtD concepts in academic design programs has been scarce, it has recently been added at some universities like University of Alabama at

Birmingham. NIOSH has also developed a professional course for active industry professionals through several outlets such as East Carolina University where they provide professional courses for PtD (Gambatese, 2013). Ertas (2010) suggested the PtD education through the integration of six main themes into design and engineering curricula: (1) Classify every education action as developing awareness or capability; (2) Development of educational and instructional material; (3) Tailor approaches according to the industry and sector; (4) Incorporate elements for all size companies; (5) Assessment and continuous improvement; and (6) Identify drivers of education change and work with them.

Data Collection and Analysis

The authors adopted a survey research method for this study. The overall research process of the study involved the following steps: (1) selecting the population of design firms; (2) developing the survey instrument; (3) performing cognitive interviews for instrument validation; (4) administering the survey and collecting data; and (5) analyzing the collected data.

Population Selection

To identify the level of adoption and implementation of PtD among the design firms, all the design firms listed in the American Institute of Architects (AIA) database were included in the population. AIA lists and provides contact information for all of their members according to their state of residence. This provided diversity in terms of geographic location as well as size of firms. Geographic diversity among the survey participants was essential to remove the bias due to different design practices governed by local codes, availability/preference of materials, and contractual practices. In addition, diversity of the firm sizes was also important, as the smaller firms have historically not proved to be early adopters of innovation.

Survey Design

The individual survey questionnaires were composed of two types of questions: (1) questions with ordered choices, and (2) questions with Likert type scale. The questionnaire was divided into three sections. The first section consisted of questions related to identification and differentiation of participants such as location of the firm, type of project(s) the firms deliver, firms' expertise, annual revenue of the firms, number of employees, number of years in business, and similar. The second section of the survey aimed at identifying the level of participant familiarity about PtD. Questions were aimed to identify number of project participants involved with implementing PtD, status of current PtD implementation, champions within the firm for PtD, and resources offered by the firm to employees. This section also asked about the perceived barriers and motivators of PtD. The third section solicited information about the participants' perception about the knowledge of PtD and the receptiveness of PtD among the different stakeholders along with the current state of PtD training and education.

The authors identified the survey items based on the study's key constructs of interest. Once the first draft of the survey instrument was developed, research measurement experts reviewed the instrument to ascertain the content validity of the items and technical quality. Feedback from the research measurement experts was incorporated into the second draft, the pretest version of the survey instruments. Five design firms reviewed the pretest version of the survey for relevance and representativeness. Feedbacks obtained on the pretest version were incorporated into final version of the survey instrument. A few typographical errors were corrected and several words in the questions were revised to increase clarity.

Data Analysis

The survey was emailed to approximately 3,950 architectural firms across the US. 74 architectural firms located across the country responded to the survey, until the compilation of the data. Upon deletion of incomplete responses, data from 69 architectural firms was compiled. Two reminders were emailed to the non-respondents, during this period. Descriptive analysis was conducted with the compiled data. Data was analyzed for demographics, knowledge pertaining to PtD implementation, implementation patterns on projects, and perception about knowledge. Subsequent section discusses results in detail.

Results

During the course of initial descriptive analysis of demographical information (Table 1), it was identified that the majority of the respondents were architectural firms (85.1%). In terms of firm experience, approximately 44.9% of the respondents had a work experience of 21-50 years. Approximately, 57.9% of the respondents indicated that the firm had less than five full time employees. Thereby, indicating that the majority of the responding firms were small. This number is somewhat similar to a national study conducted by The American Institute of Architects (AIA) for architectural firms across the country in 2012. AIA (2012) found that the majority of architectural firms within the country were small. Additionally, approximately 59.4% of the respondents indicated to have an annual revenue of less than one million USD. Furthermore, 75.4% of the respondents reported to have less than 20% Public Projects on an annual basis. Implying that majority of the firms were majorly executing private projects on an annual basis. Lastly, approximately 27.5% of the respondents reported to have commercial sector as the firm's primary business sector followed closely by residential sector with 24.6%. The next section discusses the respondent's familiarity, knowledge, and implementation patterns for PtD.

Table 1: Firm Demographics of Survey Respondents

Item	Groups	Number	Percentage
Firm's Discipline (Expertise)	Architecture	53	76.8%
	Interior Design	8	11.6%
	Engineering	3	4.3%
	Contractor	1	1.4%
	Project Management	1	1.4%
	Asset Management	0	0%
	Other	5	7.2%
	No response	1	1.4%
* 8 Firms have selected more than one			
Firm Experience	1 - 5 years	4	5.8%
	6 - 10 years	8	11.6%
	11 - 20 years	13	18.8%
	21 - 50 years	31	44.9%
	> 50 year	11	15.9%
	< 1 years in business	2	2.9%
Number of Full Time Employees In the Firm	1 employee	19	27.5%
	2 - 4 employees	21	30.4%
	5 - 9 employee	9	13.0%
	10 - 19 employee	7	10.1%
	20 - 49 employee	6	8.7%
	50 - 99 employee	2	2.9%
	100 or more employees	5	7.2%
Annual revenue of the Firm	< 1 million USD	41	59.4%
	1-10 million USD	21	30.4%
	11-25 million USD	1	1.4%
	26-35 million USD	1	1.4%
	36-50 million USD	0	0.0%
	> 50 million USD	3	4.3%
	Not specify	2	2.9%
Annual share of public projects completed	< 20% Public Projects	52	75.4%
	21%-40% Public Projects	4	5.8%

	41%-60% Public Projects	2	2.9%
	61%-80% Public Projects	5	7.2%
	> 80% Public Projects	5	7.2%
	Not specify	1	1.4%
Primary project type executed by the firm	Commercial	19	27.5%
	Residential	17	24.6%
	Healthcare	6	8.7%
	Educational	3	4.3%
	Industrial	7	10.1%
	Heavy Civil	1	1.4%
	Other	16	23.2%
N = 69 (Total number of responding firms).			
Project delivery systems best suited (or encouraging) PtD	Design-Bid-Build	2	20%
	Design Build	1.83	18.33%
	Integrated Project Delivery	1.83	18.33%
	CM at Risk	1.33	13.33%
	CM agency	0	0%
	No response	3	30%

N = 10 (Total number of firms implementing PtD).

Knowledge, familiarity, and implementation patterns for PtD

Any adoption occurrence requires a potential adopter to possess knowledge and understand perceived capabilities of the innovation. Therefore, before the researcher could analyze any aspect of PtD implementation within the firms; the researchers deemed that it was necessary to identify the familiarity of respondents with PtD. 11.6% of the respondents affirmed that their firms were familiar with PtD and 8.7% respondents confirmed that they themselves were familiar with the concept. Thus, about 2.9% of respondents were unfamiliar with the concept, even though the firms were familiar with the concept.

Among the sample of respondents that either possessed the knowledge or had their firms implement PtD, 40% respondents indicated that they had adopted PtD in last five years and 30% respondents indicated that their firms were currently implementing PtD. Figure 1 depicts the implementation trends of PtD for the firms. Though the difference is not major, the depiction indicates neither gain nor loss of momentum in trend. Similarly, when enquired about the requirements for standard guidelines for PtD implementation and practice as in figure 2, 50% of the respondents felt the need for it and 20% did not feel the need. Further 40% of the respondents agreed that there should be regulatory requirement for PtD implementation and practice.

Figure 3 depicts the PtD education needs and the current state within the AEC industry. 60% of the respondents reported that their firms did not require employees to attend (or provide) any PtD training/workshops/seminars. When questioned about the necessity of an organization to provide PtD training/workshops/seminars, 50% of the respondents felt that it was not necessary. However, this finding is contrary to literature where researchers indicate that designers lack the expertise for safety (Toole, 2005; Toole & Carpenter, 2012; Malcolm, 2008; Rajendran & Gambatese, 2012). Respondents identified subcontractors to possess the least amount of knowledge about PtD. However, either of these hypotheses needs to be further tested. Additionally when asked about the most receptive stakeholder for PtD, the respondents identified designers as the most receptive stakeholder followed by owners and engineers as shown in figure 4.

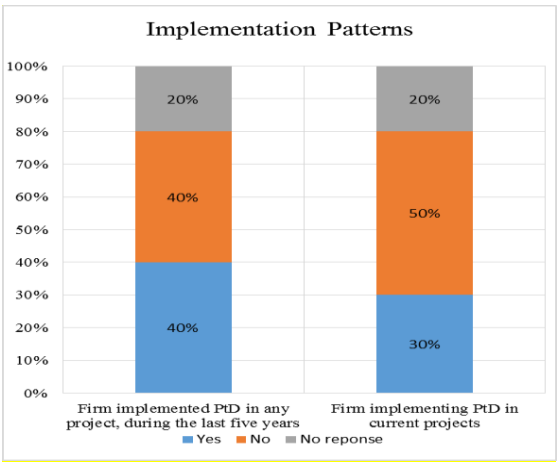

Figure 1: Responses for PtD implementation

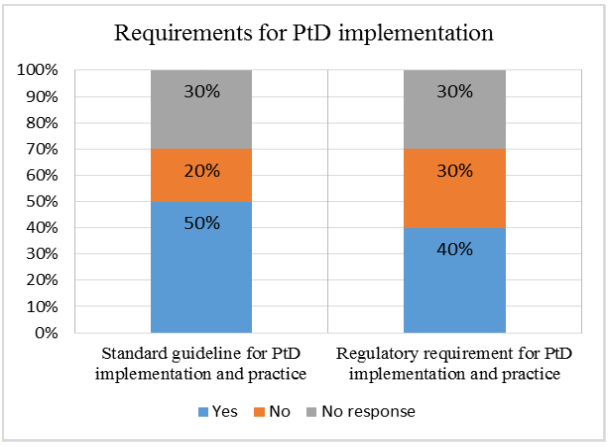

Figure 2: Requirement for PtD implementation

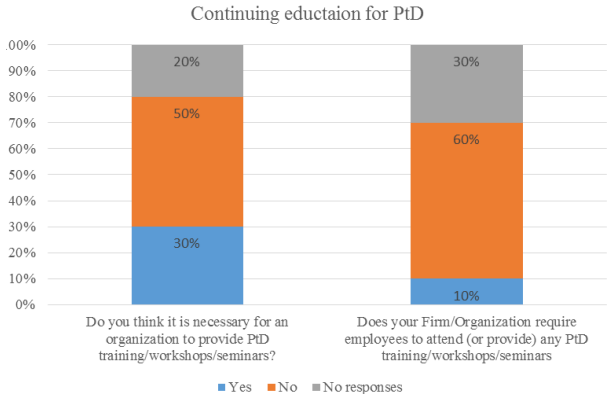

Figure 3: Requirement of continuing education for PtD implementation

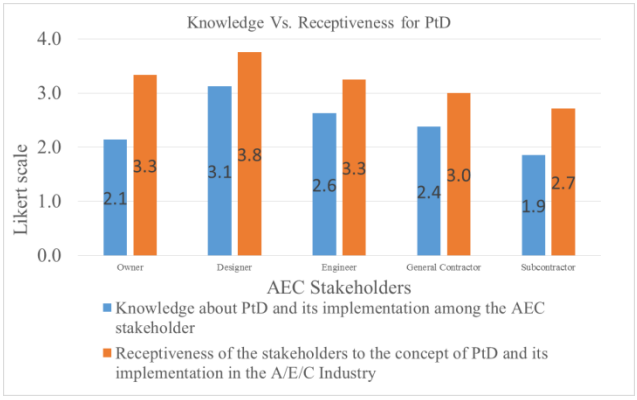

Figure 4: Perception of respondents for knowledge and receptiveness of the stakeholders

Conclusion

As per the surveyed literature, designers possess ability to influence the safety of construction workers. Addressing safety in the design phase is not only convenient but also economical. However, the adoption and implementation of PtD exposes designers to social and economic risks. Additionally, the resistance to change by the AEC industry, continuously updating owner requirements, and budgetary considerations add additional layers of complexity for designers. Thus, this study aimed to identify Knowledge and Implementation of PtD among Designers. This exploratory study found a very small percentage of responding firms (11.6%) familiar with PtD which is an overwhelming indication that PtD is still in its infant stages and needs more training and educational initiatives. The low familiarity percentage indicated in the results can definitely explain the ensuing lack of implementation that is also reported in this study. The study also showed that even though adopters of PtD felt the need for standard practices, they were not in favor of regulatory requirements introduced for the same. These results ties to what researchers have pointed earlier regarding the designers' fear of liability and extra cost incurred to incorporate safety measures into the design (Toole, 2005; Toole & Carpenter, 2012; Malcolm, 2008; Rajendran & Gambatese, 2012). Even though the researchers cannot ascertain from this sample size, the results (figure 3) showed that there is a lack of cognizance for the need of PtD education within the Design industry.

Preliminary results indicated that designers perceived A/E to be top receptive stakeholder in PtD implementation. Although, results being preliminary, it is important to highlight the contradiction where 11.6% of the designers surveyed were familiar with the PtD concept. The perception of responding designers to be most receptive towards PtD implementation also contradicts most of the literature, where scholars indicated that designers lack expertise for safety (Toole, 2005; Toole & Carpenter, 2012; Malcolm, 2008; Rajendran & Gambatese, 2012).

Furthermore, based on the analysis of data at a generalized level, for the section dealing with continuing education and the section of knowledge Vs. Receptiveness, as depicted in Figure 3 & 4 respectively, the following trends emerge: (1) Even though owners are perceived to be one of the most receptive for PtD, they are perceived to lack the

knowledge. This gap between perceived receptiveness and knowledge has to be addressed by educating the owners about the PtD concept and implementation. (2) None of the stakeholders are identified as experts in PtD, and there is a need for needs to be improvement in PtD knowledge; and (3) Even though the knowledge is required, the respondents do not feel the need of continuous education of the employees. Multiple hypotheses have been associated for the trend, but they need to be assessed in detail.

Further research is currently in progress to address some of the limitations in this study and widen its horizons within the AEC industry. The research is expanding to address a larger and more diverse sample to represent the whole AEC industry including Contractors, Architects, Engineers, and Owners. It will also include the educators in AEC higher education so the research can address the gaps between the PtD industry needs and the upcoming AEC graduates and their education curricula.

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