Prevention Through Design (PtD): Addressing Engineers' Knowledge Gaps

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Prevention through Design (PtD): Addressing Engineers' Knowledge Gaps (Work-in-Progress)

Abstract

Prevention Through Design (PtD) is an approach that systematically identifies and mitigates potential hazards and risks during construction projects' design and planning phases. The goal is to eliminate or minimize safety and health risks of field workers, which is particularly important in the construction industry. However, the implementation of PtD in the construction industry faces several challenges that hinder its widespread adoption. This paper aims to better understand the key factors negatively influencing civil engineers' ability to utilize PtD. The research team, therefore, conducted a survey aimed at gathering insights from engineering practitioners regarding the factors that might impede its utilization and the role of engineers in its implementation. The findings indicate that various factors contribute to the challenge, such as the absence of PtD educational materials in civil engineering programs and the limited awareness of PtD among professionals and faculty members. The limited educational materials and awareness may also contribute to the hesitation and create uncertainty among construction project stakeholders, including civil engineers, about the PtD process and how to utilize it.

Introduction

The construction industry is known for its hazardous working environment. On average, construction workers are 5.5 times more likely to get killed than workers from other sectors [1]. Designing for occupational hazards and dangers is the most efficient technique to protect workers, considering it incorporates preventative measures into all designs that have an influence on workers [2]. The safeguards are arranged from the most effective to least effective and include elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) [2]. A brief description of each safeguard, listed in the hierarchy of controls, is described below:

- **Elimination:** Make sure the hazard no longer exists.
- **Substitution:** Change out a material or process to reduce a hazard.
- **Engineering Controls:** Reduce exposure by preventing hazards from encountering workers.
- **Administrative Controls:** Revise how work is performed or enhance workers' knowledge by providing pertinent procedures, training, or warnings.
- **Personal Protective Equipment (PPE):** Provide clothing and devices to protect workers.

Over the past 20 years, the PtD idea has gradually gained acceptance in the U.S. [3]. However, the traditional curriculum offered by civil engineering programs in the United States does not integrate PtD concepts [4]. It has been suggested that the engineering community will not incorporate PtD into the curriculum until the accrediting body, ABET, includes it in either a General Criteria or the Program Critera. The majority of civil engineering programs in the United States are accredited by ABET. Recently, ASCE’s Civil Engineering Program Criteria Task Committee (CEPCTC) added a requirement for the curriculum to include an explanation of safety, effective for the 2024-2025 accreditation cycle. Specifically, CEPCTC suggests nine

lecture topics that can be used to comply with the new requirement related to safety being a professional responsibility of civil engineers. One of the suggestions is the following:

"***Explain*** how the design has considered the safety of those who construct, use, operate, and maintain the design."

This statement is directly related to the PtD concept. Bloom's Taxonomy classifies learning development outcomes into six levels, from simple recollections of specific facts to integrating complex ideas. In terms of developmental progression, the Explain level resides one step above the Remember level and below the Create, Evaluate, Analyze, and Apply levels. Embracing the new criteria within the civil engineering program is essential for equipping upcoming engineers with the ability to articulate and implement PtD principles confidently.

Research Objectives and Methodology

This paper presents a *Work in Progress* and aims to understand the main challenges preventing construction project stakeholders, specifically civil engineers, from fully utilizing PtD. Accordingly, an online survey was created and administered to achieve the study objective. Screening questions were included in the survey to determine whether respondents possed the required attributes and qualified to proceed with the survey. These questions included a total number of years of industry experience, with respondents requiring a minimum of 5 years of experience. Further screening questions included whether the respondents were aware of the concept of PtD. If the respondent was unaware and/or did not have at least five years of experience in the construction industry, the response was excluded. The survey consisted of five open-ended questions, which respondents answered in an open-text format to allow for answers based on their knowledge and experience. In June 2023, Lawrence Technological University's Human Subject Institutional Review Board (HSIRB) reviewed and approved the research survey. The survey was conducted over three months, and 58 valid responses were collected.

Survey Findings

Respondents were asked to list the three most significant challenges that prevent the construction industry from fully utilizing PtD, resulting in a total of 158 challenges listed by the 58 respondents. The top three challenges are as follows:

- **Increase in Cost** (45 References; 28.48%): One of the most significant challenges was the potential increase in design costs, which highlighted the financial burden that construction project owners might face.
- **Lack of Knowledge** (20 References; 12.66%): Respondents pointed out deficiencies in education, designers' limited awareness of occupational safety and health hazards, and a lack of comprehension regarding integrated safety and prevention in their work.
- **Lack of Training Programs** (16 References; 10.13%): Respondents highlighted the scarcity of available training programs to provide the skills and knowledge regarding PtD. They emphasized that the shortage of a skilled workforce stems from inadequate training and educational programs.

Discussion

Occupational safety and health management plays a vital role in all construction projects; consequently, civil engineering programs should utilize the recent change in ABET's Civil Engineering Program Criteria to integrate PtD concepts into their curriculum. A potential increase in project cost was identified most frequently as a significant challenge preventing the implementation of PtD principles. Owners will ultimately bear the potential increase in cost, encompassing both direct expenses associated with engineers' time and efforts, as well as the escalation in professional liability insurance. The cost increase will be offset by the benefits of improving site safety, similar to what has been observed with Leadership in Energy and Environmental Design (LEED) certification. For example, it has been suggested that obtaining a gold LEED certification might result in a 7.43% increase in construction costs. Still, project owners can save 31% on energy and water expenses throughout the project's life [5]. Investing in safety yields numerous benefits, such as enhancing the well-being of workers and their families, minimizing disruptions to work production, reducing worker's compensation costs, upholding a positive business reputation, and decreasing workers' absenteeism [6]. Thus, further research is necessary to compare the life cycle costs of projects implementing PtD with those that do not. These studies will assist civil engineers in advocating for PtD to project owners as a valuable enhancement to their services.

"The Lack of knowledge" and "Lack of Training Programs" are challenges related to the engineering community. These challenges result in a significant PtD knowledge gap among civil engineers, who are well-positioned to lead the PtD implementation efforts due to their interaction with construction project stakeholders (i.e., project owners, architects, and general contractors). With the recent changes in the ABET's Civil Engineering Program Criteria, PtD is one of the potential topics that could be integrated by the civil engineering programs to satisfy the new program criteria. Accordingly, there is an opportunity to overcome these challenges. However, there are currently no available resources or educational materials to facilitate the integration of PtD into the engineering curriculum.

A recent study surveyed civil engineering department chairs to maximize the potential employment of PtD educational materials to satisfy the new civil engineering criteria to better understand the feasibility of introducing PtD in civil engineering curricula. It concluded that it is recommended to introduce the PtD in small modules in engineering design courses [7]. This is because the department chairs highlighted insufficient space within the engineering curriculum to introduce PtD as one course. Civil engineering programs should incorporate the PtD concept through compact modules integrated into civil engineering design courses.

In addition, obtaining faculty acceptance and departmental encouragement is crucial for successfully integrating PtD into design courses [7]. The faculty members of civil engineering programs specialize in various sub-disciplines such as transportation, structural, water resources, geotechnical, and construction. Thus, the PtD concept should be strategically integrated into their respective courses. When faculty members comprehend the advantages of PtD and its potential to save lives, their willingness to support and engage with it is anticipated

to increase. Faculty members who teach engineering design courses often have limited knowledge of construction means and methods, making it unreasonable to expect them to introduce the PtD into their courses without first providing them with the necessary resources and incentives [7]. Therefore, designing, developing, and refining course-based modules is essential. The development of these modules will form the cornerstone of PtD education, fostering the growth of knowledge, skills, and awareness among future civil engineers. To develop these educational modules, input should be sought from civil engineering program advisory boards, alumni, and faculty members. Establishing PtD educational and training programs is paramount to enhancing PtD utilization nationwide.

Closing Remarks

PtD is a vital skill that civil engineers should possess. Within the civil engineering community, two primary obstacles slow the wide utilization of PtD. The two obstacles are the lack of knowledge among practitioners and the absence of training materials. Thus, it is recommended that these obstacles be overcome strategically. Following the survey recommendations, the next step in enhancing PtD utilization involves developing educational modules in collaboration with civil engineering design faculty and other stakeholders. Hence, these modules will meet the requirements of diverse civil engineering disciplines and address potential concerns. Additionally, they will fulfill industry requirements by incorporating the perspectives and input of practitioners who are potential implementers of PtD in their planning, design, or construction processes. Thus, the modules should address the target audience's skill levels (students or practitioners). The successful development of these educational modules will also address other potential obstacles, such as potential up front cost increases and lack of awareness among construction project owners.

References

[1] A. J. Al-Bayati, A. T. Rener, M. Listello and . M. Mohamed, "PPE non-compliance among construction workers: An assessment of contributing factors utilizing fuzzy theory," Journal of Safety Research, vol. 85, pp. 242-253, 2023.

[2] "“Hierarchy of Controls | NIOSH | CDC.” https://www.cdc.gov/niosh/topics/hierarchy/default.html," [Online].

[3] T. M. Toole, J. Gambatese and D. A. Abowitz, "Owners’ Role in Facilitating Prevention through Design," Journal of Professional Issues in Engineering Education and Practice, vol. 143, 2007.

[4] T. M. Toole, "Adding Prevention Through Design to Civil Engineering Educational Programs," Journal of Professional Issues in Engineering Education and Practice, vol. 143, no. 4, 2017.

[5] L. O. Uğura and N. Leblebicib, "An examination of the LEED green building certification system in terms of construction costs," Renewable and Sustainable Energy Reviews, vol. 81, no. 1, pp. 1476-1483, 2018.

[6] A. J. Al-Bayati, A. Alghamdi and O. Abudayyeh, "Improving the Safety Culture and Climate of Smaller Construction Firms: A Necessary Addition to the OSH Intervention Model," Journal of Civil Engineering and Construction, vol. 12, no. 4, pp. 187-196, 2023.

[7] A. J. Al-Bayati, E. Jensen, R. Eiris and O. Abudayyeh, "Integrating Prevention Through Design (PtD) into Engineering Curricula in the United States," in Proceedings of International Structural Engineering and Construction, Quito, Ecuador, 2024.