ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

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Paper ID #16012

The Need for Prevention through Design in Civil Engineering Curricula

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The Need for Prevention through Design in Civil Engineering Curricula

Abstract

Prevention through Design (PtD) is an innovative safety management technique in which design professionals explicitly consider the safety of construction and maintenance workers during the design process. PtD (also called Design for Construction Safety) is a direct application of a safety management framework called the Hierarchy of Control and of the principle that the ability to influence the achievement of a project goal diminishes over the design and construction cycle. PtD has been required in Europe for over two decades but adoption in the U.S. has been slow. This paper provides overviews of the PtD concept and process and identifies the challenges to the diffusion of PtD, peer-reviewed educational resources on PtD, and ways that PtD could be added to individual civil engineering courses. It is suggested that PtD provides a compelling context to teach related topics, including engineering ethics, social sustainability, integrated design and construction, life cycle safety, and comparative public policy.

Introduction

The subjects and competencies we choose to include in our civil engineering courses and curricula typically reflect one or more factors. We may choose to teach a subject because it is explicitly required by the ABET accreditation criteria, because our alumni and the employers who hire our graduates tell us they want our graduates to have specific skills, and/or because we feel the topic is part of the historical body of knowledge to which every civil engineering graduate should be exposed. This paper proposes that a new topic and skillset should be added to our civil engineering curricula—Prevention through Design—despite the fact that none of the three typical curricular motivations apply.

Prevention through Design (PtD, also called Design for Construction Safety and Safety by Design) is an innovative safety management technique in which the design of a project explicitly considers the safety of construction workers and maintenance workers[14]. PtD is neither required by the ABET criteria for civil engineering programs, demanded by firms hiring civil engineering graduates, nor considered by anyone to be part of the civil engineering body of knowledge. Nonetheless, this paper suggests that PtD should be included in every civil engineering curricula for three reasons. First, it is likely that employers will eventually seek graduates who have the capability to perform PtD because their clients will demand it. Second, it is anticipated that faculty in civil engineering and other departments on universities campuses will eventually believe that civil engineering graduates should have the ability to perform PtD in order to fulfill their ethical duties, especially related to social sustainability. Third, the author believes that teaching PtD provides instructors with a compelling context to teach underlying issues relating to engineering ethics, social sustainability, collaborative and integrated design, life cycle safety, and public policy.

The author is a proponent of the PtD but not naive to the challenges of adding any to topic or competency to an already full civil engineering curriculum. The paper is intended to help facilitate the adoption of PtD into civil engineering education by summarizing the concept and processes of PtD, discussing candidly the challenges facing PtD in the U.S., and identifying readily available resources that could be used to embed the teaching of PtD into specific civil engineering courses.

The PtD concept

The Prevention through Design concept can be captured by two words: safety constructability. As most faculty whose research and professional experience have included the implementation of engineering and architectural design, constructability traditionally refers to aspects of a design that influence how much it costs to build, how quickly it can be built, and how easily the quality attributes desired by the client can be achieved. PtD adds a fourth criteria to constructability: the safety of the construction worker and of the maintenance worker.

Proponents of the PtD concept point to the research performed in the U.S.[6 14 15 25 37] and around the globe[6 11 17] that show a connection between design and the inherent level of hazards associated with a design, which is manifested in the number of accidents on site. Proponents of PtD are not suggesting that design professionals are responsible for accidents that occur on job sites, but that explicit decisions by designers can reduce or eliminate specific hazards that would otherwise be present on site. An example frequently given involves parapet roofs, a common architectural feature. Rather than choosing the height of a parapet roof simply on aesthetics, a designer could choose the height also on safety considerations. Specifically, by choosing a wall height of at least 42", the wall which would serve as both temporary and permanent fall protection, thereby reducing the fall from height hazard for workers installing the finish roofing system and rooftop HVAC equipment, as well for workers performing roofing and HVAC equipment maintenance over the lifetime of the building.

The empirical data that ties design with construction worker safety supports the Hierarchy of Control model, which is one of the theoretical frameworks of occupational safety. As depicted in Figure 1, the Hierarchy of Control suggests that safety management techniques that are higher on the hierarchy are inherently more effective.[20 36] When envisioning construction safety equipment, some civil engineering faculty think of hard hats, safety glasses and steel toed boots.

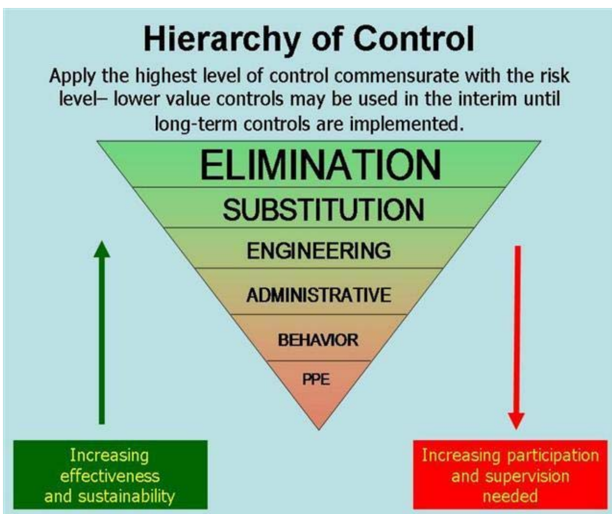

Figure 1: Hierarchy of Control
Source: www.qualitysystems.com/support/pages/hierarchy-of-controls

But such personal protective equipment are lower level measures that are attempts to react to some of the hazards that are inherent in the design and/or the site environment. It is much safer and cost-effective to design out the hazards in the first place when possible.

Figure 2 depicts a second principle that is relevant to the PtD concept: one's ability to influence the outcomes of a project with respect to the goals most critical to the owner—cost, duration, quality, sustainability—are diminished as the project moves along the typical project chronology (concept design, detailed design, procurement, construction and occupancy). It is difficult, for example, to achieve a cost-effective and quickly-constructed building if expensive, labor-intensive materials are chosen during the concept design stage. This same curve applies to the hazards inherent in the design of a building. It is difficult to prevent injuries when the means and methods that are de facto determined by the building's design are associated with high hazard work tasks.

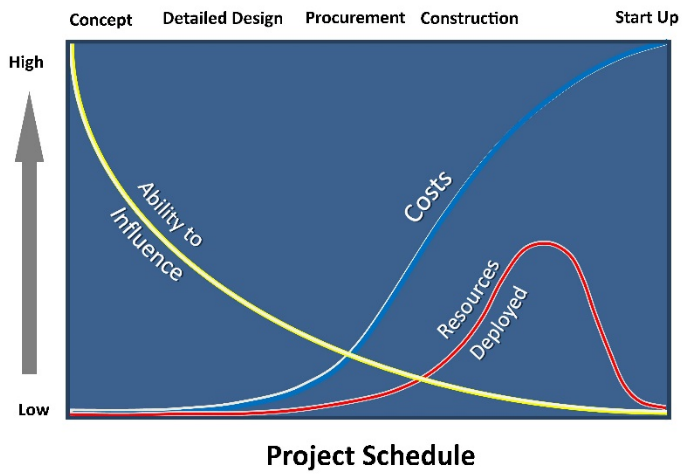

Figure 2: The Project Goal Influence Curve

The idea that design can be leveraged to achieve significant reductions in construction site injuries is certainly not new, not restricted to construction and not recognized only in the U.S. Indeed, building design professionals in the U.K. have been required to explicitly consider the safety of construction workers in their designs since 1994, and PtD is now required throughout the European Union[1], in Singapore, South Africa and Australia.[14] The recognition of the value of PtD and the diffusion of PtD practices has been much slower (due to factors that will discussed shortly), but there are signs the concept is gaining recognition among researchers, project owners,[31 32] and design professionals.[12 16 21] The Occupational Safety and Health Administration's (OSHA) Construction Alliance Roundtable has had a working group that focuses on designing for construction safety since 2005 while the National Institute for Occupational Safety and Health (NIOSH) has had a significant PtD initiative since 2007.

Challenges to the diffusion of PtD

Despite the theoretical frameworks and empirical data that suggest PtD is an important management technique for improving safety and health on construction sites, diffusion of PtD has been slow within the U.S. One critical factor hindering the diffusion is that civil engineering graduates typically do not learn about construction site hazards, safety management or prevention through design in their degree programs.[13 24 26] Given that most civil engineers have not been educated on how to anticipate site hazards—much less design out site hazards—an effective PtD process requires that designers get safety constructability feedback on designs in progress from professionals who have expertise in site processes and construction safety. Yet on traditional design-bid-build projects, the contractor who will build the project is typically not identified until after the design has been completed. As such, the traditional project delivery method prevents the type of interaction between designer and constructor that is needed for PtD.

An additional factor hindering PtD noted in the literature is concerns about costs. Given that designers lack the needed knowledge of site safety and how to reduce hazards through design, designers appropriately would require more billable hours to perform PtD on a project.[26] A design firm including extra hours for performing PtD in their proposal to the client may lose the project to a firm offering lower billable hours because they will not perform PtD.

A final and more cynical viewpoint is that the growth of PtD in the U.S. has been actively resisted by design professionals, professional societies, insurers, and attorneys attempting to protect engineering firm's business interests, especially the desire to avoid inappropriate lawsuits. Toole[29] includes a narrative about the author's negative experiences with the ASCE Board of Direction and the American Council of Engineering Companies as the civil engineering design community faced an innovation that could put firms on a "slippery slope" regarding involvement with safety. The model contracts between design professionals and their clients explicitly state the designer will have nothing to do with site safety.[26] There is an understandable fear that if a designer makes any attempt to design out a hazard on a project, any injury that occurs on the project will be claimed to have resulted from the designer's failure to act.

PtD as a multi-faceted teaching opportunity

Many civil engineering faculty are good at turning student failures in their classes into effective "teachable moments." In the same way, the challenges to the diffusion to PtD summarized above provide civil engineering educators with an opportunity to teach their students not only about the concept and processes of PtD, but also several related topics that civil engineering students should be taught.

Engineering ethics is a topic that can be taught by discussing the application of ethical frameworks to PtD. It was discussed in the previous section of this paper (and in [29]) that two prominent professional societies had negative reactions to the PtD concept due to the fear that PtD would lead to engineering firms becoming the target of inappropriate lawsuits by injured construction workers. Within the U.S., researchers have explicitly made the connection between PtD and professional ethics. Behm[5] reviewed the existing codes of ethics for the American Society of Civil Engineers and several other design professional societies and concluded that "Little motivation exists to include the design for construction safety concept as a standard practice." On the other hand, Toole[27] argued that the following text in Canon 1 in the ASCE Code of Ethics implies civil engineers have an obligation to reduce hazards that result unnecessarily from design decisions:

> "Engineers shall hold paramount the safety, health and welfare of the public…in the performance of their professional duties."

> "Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions, and practices incorporated into structures, machines, products, processes, and devices."

Whether the two excerpts quoted above are relevant to PtD hinges on whether construction workers and maintenance workers are considered part of the "public." Are codes of ethics applicable to ALL people who are affected by civil engineers actions, or to everyone EXCEPT people who are somehow associated with projects before the projects are completed? It seems that PtD is a fertile topic on which to discuss engineering ethics because PtD clearly involves two valid but potentially conflicting goals within the civil engineering community: the desire to reduce harm associated with the built environment and the desire to prevent the business interests of engineering firms from being harmed by inappropriate lawsuits.

A second topic related to PtD is sustainability, in particular, the concept of social sustainability. More recently in the U.S., researchers have tied PtD to sustainability. Many civil engineering programs are integrating sustainability into their curricula but focusing on environmental sustainability and economic sustainability (such as life cycle costing) and ignoring the third pillar of sustainability, which is social sustainability. Toole and Carpenter[30] drew on Dillard et al's[10] definition of the social aspect of sustainability as "the processes that generate social health and well-being now and in the future" and on Vesilind and Gunn's[35] suggestion that "engineers have ethical obligations to deprived people, distant people, and future people" to argue that attempting to design out unnecessary hazards inherent in designs is a direct application of social sustainability principles. Valdes-Vasquez and Klotz,[33 34] Behm,[7] Albattah et al,[2] and Hinze et al[18] have also discussed the strong connection between PtD and sustainability. This connection led to the US Green Building Council implementing a LEED pilot credit for PtD in 2014.[38]

PtD can serve as an engaging application of social sustainability principles. Many millennials find arguments relating to social equity to be compelling. Indeed, universities that have been successful in attracting and retaining engineering students from diverse populations have done so in part by emphasizing the humanitarian benefits of engineering and what individual engineering graduates can do to make the world a better place. It has been this author's experience that undergraduate civil engineering students find the PtD concept to be quite compelling, especially after they are presented with the high rate of injuries in construction and see images of sites where accidents have occurred.

A third topic that PtD can help teach is the power of integrated, collaborative design and construction that underlies the alternative project delivery methods of design-build and integrated project delivery. This paper previously referred to Figure 2, which illustrated how the ability to influence the outcome of important project goals—including safety—diminished as the design progressed. Figure 3 below applies that principle to the PtD process in a detailed way. Figure 3 depicts the author's understanding of the specific PtD processes needed at each stage of the design process (concept, 30%, 60% and 90%). The text in the upper right corners of each box indicates the specific entities who should participate in the design review at that stage. The text in the lower half of each box indicates the topics they should discuss at that stage. For example, Figure 3 depicts that the building's primary materials (e.g., steel, concrete, masonry or wood) should be discussed during the concept design because some materials have higher risks than others.[9] It is also important that opportunities for prefabrication be discussed during the concept and 30% design phases because prefabrication typically reduces site injuries[28] but is more difficult to achieve if not enabled by the detailed drawings and technical specifications. Figure 3 therefore provides educators with an example of how effective collaboration during design often requires an intentional and planned process that is goal-oriented, methodical, and enabled by one or more design decision making tools.

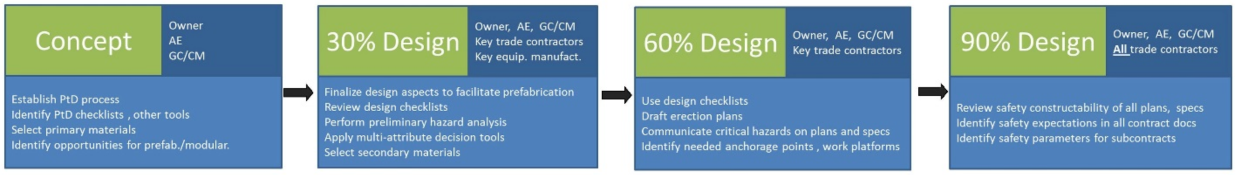

Figure 3: An Effective PtD Process

The owner, architect/engineer (AE) and General Contractor (GC) or Construction Manager (CM) must all actively participate in discussions and review of the concept design because each entity can likely provide critical data and experiences that allow the team to effectively balance cost, duration, quality and safety. Discussing the specific entities who should be involved in each design stage provides educators with an opportunity to increase their students' understanding of the specific expertise, tacit knowledge, and biases that each entity brings to the project table and how the traditional roles undertaken by each entity have been evolving over the past half-century.

A fourth topic that PtD illustrates is the importance of taking a life cycle approach to facility safety. Many civil engineering educators are familiar with the life cycle cost (LCC) approach, in which decision makers are urged to consider all relevant events (such as cash flows) over the entire life cycle of a project. (For example, studies have shown that design and construction costs are typically approximately 20% of the total life cycle costs of a building when all energy, maintenance and renovation costs are included.) The PtD concept urges project design professionals and owners to consider not just the safety, health and welfare of the general public occupying or residing nearby the completed building, but also the safety and health of the construction workers erecting the building and the maintenance workers changing light bulbs, air filters, belts, compressors, etc. over the life of the building. PtD thereby provides a means to make civil engineering students mindful of the "big picture" of the life cycle of the built environment. Students who are learning about one small portion of the design process—in a structural steel design course, for example—need to be reminded that decisions made during the design phase often have significant but invisible consequences over the lifetime of the facility.

A fifth and final topic related to PtD is comparisons of public policy around the globe. Why is PtD required across the European Union, in Singapore, South Africa and Australia, but not in the U.S. or any nation in North or South America? Does the explanation include differing perceptions about the importance of occupational safety, the appropriate role of the government, and/or the balance of power of business versus labor in different nations? Does the lack of PtD regulation in the U.S. reflect a pragmatic understanding that even well-intentioned laws can be abused in our excessively litigious society? Such questions clearly require a stronger background in public policy and political science than most civil engineering educators possess. An effective discussion of these issues in a course therefore likely requires inviting a faculty colleague from the appropriate department to lead the discussion. Such cross-campus collaboration may be rare in many programs now but is needed if civil engineering faculty are to expose their students to emerging interdisciplinary topics such as social sustainability.

Educational resources on PtD

The growing awareness of the PtD concept has fortunately been accompanied by the growing set of online resources on PtD that civil engineering and other educators can access and embed in their courses. NIOSH has a website[23] that explains the PtD concept and provides links to peer-reviewed journal articles, newsletters, and textbooks that include PtD examples. This site also allows access to four educational modules on PtD intended for engineering instructors to use in their courses. The four modules focus on PtD concepts in structural steel, reinforced concrete, architecture, and mechanical, electrical and plumbing systems. An OSHA website[22] makes available a set of "Construction Workplace Design Solutions" documents that provide guidance on how to prevent fall hazards through design and site management techniques. Educators may wish to obtain the ANSI standard on Prevention through Design[2], although this standard provides generic principles and processes applicable to all industries and does not focus on civil engineering or construction.

Various websites outside of the U.S. provide PtD resources such as documents that provide designers with practical guidance on how to comply with a specific nation's requirements to perform PtD. These international websites also provide content that educate designers about specific hazards associated with each major trade (such as steel erection, concrete, roofing) and provide brief suggestions for specific design decisions that may improve site safety during construction of the design. The reader can find links to these international webpages and documents at www.designforconstructionsafety.org/links.shtml, which is a non-profit website run by the author that also provides a bibliography of PtD publications and links to various PtD presentation files.

Adding PtD to civil engineering curricula

Civil engineering educators considering adding PtD to their curriculum likely face the same decision they faced when adding other new topics: Is it better to create a new required or elective course that focuses on the topic, or to embed an application of the topic in several classes? The author is aware of one university (Virginia Tech) that has a course that focuses on PtD, but much of the course covers application of PtD principles to general industry safety, not to civil engineering and construction. Popov et al[24] identifies 13 universities thought to include PtD in the curricula but does not identify whether the curricula are associated with civil engineering, construction management or occupational safety and health. Popov et al[24] also lists textbooks with PtD examples and discusses how PtD relates to five of the (outgoing) ABET a-k criteria. Lopez-Archillos et al[19] discuss the challenges of teaching PtD in concrete courses at a university in Spain.

The previous section of this article mentioned several online resources that civil educators can use to insert one or more modules on PtD in their specific classes. The NIOSH PtD Education modules on steel design and construction is intended for an undergraduate course in structural steel design. Similarly, the NIOSH PtD Education modules on concrete design and construction is intended for an undergraduate course in reinforced concrete design. The NIOSH PtD

Education module on mechanicals is probably best suited for a civil engineering elective in construction.

The five emerging topics related to PtD identified in the "teaching opportunity" section of this paper—ethics, social sustainability, integrated design and construction, life cycle safety, and public policy comparisons—are all topics that would be best embedded in upper level civil engineering courses. Using PtD to explore these topics seems to be highly relevant to many of the ABET a-k criteria and in particular to the following criteria:

- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (f) an understanding of professional and ethical responsibility
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Conclusions

Adding any new topic to an already full civil engineering curriculum is always challenging, especially when the topic requires an investment of faculty time to implement. The default path, whether intentional or not, seems to be to NOT add the topic until it is required by ABET or another external force. Yet, this paper has boldly suggested that Prevention through Design should be added to one or more civil engineering courses before it is required by ABET or explicitly demanded by employers at our universities' job fairs. It was discussed that PtD is an intuitive concept that can be used to expose students to principles of social sustainability and engineering ethics. It was also noted that owner's increasing desire to have zero accidents on their project sites may lead to owners to demand that PtD be performed on their projects in the not too distant future. As some schools have found when adding sustainability and BIM to their curricula, implementation of a new topic may take much longer than desired, so the sooner long-term change is started, the better.

Perhaps the most compelling reason to teach PtD is that it aligns with the values espoused by the civil engineering community. Adding PtD into civil engineering curricula will convey to students, the design professionals and contractors we partner with, and our owner clients that we are sincere about ASCE policy statement 350 on Construction Site Safety, which states. "The American Society of Civil Engineers (ASCE) believes improving construction site safety requires attention and commitment from all parties involved."[4] Adopting PtD will also convey that when Canon 1 of our Code of Ethics states, "Engineers shall hold paramount the safety, health and welfare…." we mean that it applies to every person, all of the time, not just to a subset of humanity and not just when it is convenient for us.

References

[1] Aires, D. M., Gomez, C. R., and Gibbs, A. (2010). "Prevention through design: the effect of European directives on construction workplace accidents." *Safety Science* 48:248-258.

[2] Albattah, M.. Roucheray, M. and Hallowell, M. (2013). "Sustainable buildings applying prevention through design." *Professional Safety*. June. P. 76-80.

[3] ANSI/ASSE Z590.3 (2011). "Prevention through design guidelines for addressing occupational hazards and risks in design and redesign processes." American National Standards Institute/American Society of Safety Engineers. Des Plaines. Illinois, American Society of Safety Engineers.

[4] ASCE policy statement 350. Downloaded from www.asce.org/issues-and-advocacy/public-policy/policy-statement-350---construction-site-safety.

[5] Behm, M. (2004). "Legal and ethical issues in designing for construction worker safety." *Designing for Safety and Health in Construction, A Research and Practice Symposium*. University of Oregon Press, Eugene, OR.

[6] Behm, M. (2005). "Linking construction fatalities to the design for construction safety concept." *Safety Science* 43(8): 589-611.

[7] Behm, M. (2012). "Safe design suggestions for vegetated roofs." *J. Constr. Eng. and Mgt* 138(8):999–1003.

[8] Bennett, L. (2004). "Peer review of analysis of specialist group reports on causes of construction accidents." Research Report 218 prepared by Habilis Ltd for the Health and Safety Executive. ISBN 0 7176 2836 1.

[9] Dharmapalan, V., Gambatese, J.A, Fradella, J., and Vahed, A.M. (2014). "Quantification and assessment of safety risk in the design of multistory buildings." *J. Constr. Eng. and Mgt* Nov. 2014: 04014090-1.

[10] Dillard, J., Dujon, V., and King, M. C., eds. (2009). *Understanding the social dimensions of sustainability.* Routledge/Taylor & Francis, New York.

[11] Driscoll, T. R., J. E. Harrison, et al. (2008). "The role of design issues in work-related fatal injury in Australia." *J. of Safety Research* 39(2): 209-214.

[12] Gambatese, J. (2000). "Safety in a designer's hands." *Civil Engineering*. June. P. 56-59.

[13] Gambatese, J. (2003). "Safety emphasis in university engineering and construction programs." *International e-Journal of Construction*. ISBN 1-886431-09-4. May 14, 2003.

[14] Gambatese, J. A., Behm, M., and Hinze, J. (2005). "Viability of designing for construction worker safety." *J. Constr. Eng. Manage*., 131(9), 1029–1036.

[15] Gambatese, J., Behm, M., and Rajendran, S. (2009). "Designer's role in construction accident causality and prevention: Perspectives from an expert panel." *Science Safety* 46(4), 675–691.

[16] Goh, Y. M. and Chuaba, S. (2015). "Knowledge, attitude and practices for design for safety: A study on civil & structural engineers." *Accident Analysis and Prevention.* Doi.org/10.1016/j.aap.2015.09.023.

[17] Haslama, R.A., Hidea, S.A., Gibb, A.G.F., Gyia, D.E., Pavitt, T., Atkinson, S., and Duffc, A.R. (2005). "Contributing factors in construction accidents." *Applied Ergonomics* 36 (2005) 401–415.

[18] Hinze, J., Godfrey, R, and Sullivan, J. (2013). "Integration of Construction Worker Safety and Health in Assessment of Sustainable Construction." *J. Constr. Eng. and Mgt* DOI: 10.1061/(ASCE)CO.1943-7862.0000651

[19] López-Arquillos, A., J. C. Rubio-Romero, et al. (2015). "Prevention through design (PtD)--the importance of the concept in engineering and architecture university courses." *Safety Science* 73: 8-14.

[20] Manuele, F. A. (2008). "Prevention through design: addressing occupational risks in the design and redesign processes. *Professional Safety*. October:28-40.

[21] McLaughlin, M. (2015). "Safety in design." *Professional Engineer*. May. P. 24-27.

[22] OSHA. Downloaded from www.osha.gov/dcsp/alliances/roundtables/roundtables_construction.html#!2B.

[23] NIOSH. Downloaded from www.cdc.gov/niosh/topics/ptd.

[24] Popov, G., Blunt, L. A. et al. (2013). “Education: integrating PTD into undergraduate curricula.” *Professional Safety* 2013(3): 45-49.

[25] Rajendran, S. and Gambatese, J. (2013). “Risk and financial impacts of prevention through design solutions.” *Pract. Period. Struct. Des. Constr.*, 10.1061/(ASCE)SC.1943-5576.0000129, 67-72.

[26] Toole, T. M. (2005). “Increasing engineers’ role in construction safety: opportunities and barriers.” *J. of Professional Issues in Engineering Education and Practice* 131(3): 199-207.

[27] Toole, T. M. (2007). “Design engineers’ responses to safety situations.” *J. of Professional Issues in Engineering Education and Practice* 133(2): 126-131.

[28] Toole, T. M. and Gambatese, J. (2008). “The trajectories of prevention through design in construction.” *J. of Safety Research* 39(2): 225-230.

[29] Toole, T. M. (2011). “Internal impediments to ASCE's vision 2025.” *Leadership and Management in Engineering* 11(2): 197-207.

[30] Toole, T. and Carpenter, G. (2012). “Prevention through design as a path toward social sustainability.” *J. Architectural Engineering* 19(3): 168-173.

[31] Toole, T. M. and Gambatese, J. (2014). “Prevention through design: a path to social sustainability.” *Owners’ Perspective* (COAA). Fall. P. 22-25.

[32] Tymvios, N. and Gambatese, J. (2014). “Perceptions about design for construction worker safety: viewpoints from contractors, designers, and university facility owners.” *J. Constr. Eng. and Mgt*. DOI: 10.1061/(ASCE)CO.1943-7862.0001067.

[33] Valdes-Vasquez, R., and Klotz, L. (2011). “Incorporating the social dimension of sustainability during construction project planning and design.” *Int. J. Environ. Cultur. Econ. Soc. Sustain*., 6(6), 167–180.

[34] Valdes-Vasquez, R. and Klotz, L. (2013). “Social sustainability considerations during planning and design: framework of processes for construction projects.” *J. Constr. Eng. and Mgt*. DOI: 10.1061/(ASCE)CO.1943-7862.0000566.

[35] Vesilind, P. A., and Gunn, A. S. (1998). *Engineering, ethics, and the environment*. Cambridge University Press, Cambridge, U.K.

[36] Walline, D. L. (2014). “Prevention through design: proven solutions from the field.” *Professional Safety* 2014(11): 43-49.

[37] Weinstein, M., J. Gambatese, et al. (2005). “Can design improve construction safety?: Assessing the Impact of a Collaborative Safety-in-Design Process.” *J. Constr. Eng. and Mgt* 131(10): 1125-1134.

[38] USGBC. Downloaded from www.usgbc.org/credits/preventionthroughdesign.