EXPANDING PREVENTION THROUGH DESIGN (PtD) IN PRACTICE: INNOVATION, CHANGE, AND A PATH FORWARD

John Gambatese[1], Alistair Gibb[2], Phil Bust[3], and Michael Behm[4]

[1] *School of Civil and Construction Engineering, Oregon State University, Corvallis, Oregon, 97331, USA, Email: john.gambatese@oregonstate.edu*

[2] *School of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK, Email: A.G.Gibb@lboro.ac.uk*

[3] *School of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK, Email: P.D.Bust@lboro.ac.uk*

[4] *Department of Technology Systems, East Carolina University, 231 Slay Hall, Greenville, North Carolina, 27858, USA, Email: behmm@ecu.edu*

ABSTRACT

Prevention through Design (PtD) is an attractive occupational safety and health intervention because it complements the motivation to eliminate hazards on job sites before work commences. Implementation of PtD with respect to construction safety and health, however, is not present or widespread in some countries, and efforts continue to increase its dissemination. This paper presents findings of a research study aimed at determining the impacts of PtD on project team roles and professional practice, with the objective of identifying a path forward for further diffusion of PtD in the United States (US) construction industry. The researchers conducted fourteen structured focus group interviews of six different professional communities in the United Kingdom (UK), where PtD is integrated in practice through regulation. Widespread and sustained implementation of PtD in practice reveals changes in attitudes towards worker safety, especially with regard to who can have a positive impact and should play a role, as well as improved communication, team integration, knowledge transfer, and design innovation. The findings point to a path forward for expanding PtD in the construction community that includes four essential attributes: knowledge, desire (motivation), ability, and execution. Each attribute addresses a fundamental need for effecting positive change and enabling successful PtD diffusion to take place.

Keywords: safety, prevention, design, construction, architecture

1. INTRODUCTION

Implementation of the Prevention through Design (PtD) concept with respect to construction worker occupational safety and health (OSH) is currently limited in some countries, including the United States (US) (Tymvios et al., 2012). While potential benefits of PtD to construction worker OSH have been identified (Lam et al., 2006; Gambatese et al., 2005; Christensen, 2011) and examples of successful and continued PtD implementation exist in practice (Weinstein et al., 2005; Zou et al., 2008), further diffusion of PtD throughout the construction industry is needed. This paper reports on a study designed to explore changes that have occurred as a result of implementing PtD, in an attempt to understand how the PtD concept can be further diffused throughout the construction industry in the US and other countries. Formal application of the PtD concept, while not extensive in the US, is common practice in some other countries and regions around the world (Aires et al., 2010; Toole et al., 2012). In the United Kingdom (UK), the Construction (Design and Management) Regulations were put in place in 1994 to fulfil the Temporary or Mobile Construction Sites Directive of the European Union (EU) (Directive 92/57/EEC) (CDM, 1994). The CDM Regulations place a duty on design professionals and others involved in projects to ensure that foreseeable hazards and risks to construction workers are mitigated (MacKenzie et al., 2000).

The many years of PtD experience among UK architects, engineers, owners, constructors, and health and safety professionals presents a valuable opportunity to learn how an industry adapts to PtD regulations and sustained implementation. While full understanding and implementation of PtD in the UK may still be forthcoming, and educational institutions have yet to fully integrate PtD into design curricula, practical experience gained so far can provide useful insights for those countries that have yet to experience a high rate of implementation. The current research study captures salient perspectives and knowledge from UK companies in the construction sector regarding changes in design and construction practice and project team member roles and attitudes since adoption of the CDM Regulations. For newly adopted interventions, such as PtD, anticipating the potential changes can influence implementation success. Realising and planning for direct and ancillary impacts beforehand can facilitate and accelerate dissemination of the intervention.

2. CURRENT KNOWLEDGE AND PRACTICE

Whenever the PtD concept has been implemented, the construction industry has had beneficial impacts. In their investigation of a PtD process implemented on a project, Weinstein et al. (2005) found that in 14 (54%) of the 26 changes made to the design of a facility that were studied, trade contractors specifically mentioned that the changes improved safety. Levitt and Samelson (1993) and Hinze (2006) contend that improved OSH also positively influences productivity, quality, time, and activity costs. Öney-Yazıcı and Dulaimi (2015) found that designers in the United Arab Emirates believe that PtD does not limit their creativity. Implementation of PtD has been found to positively impact project aesthetics and ease of structure maintenance (Behm and Poh, 2012), and to lead to a reduction in construction duration (Behm and Culvenor, 2011). A reduction in the time needed from project conception to completion is expected because there is less retrofit required (Christensen, 2011). PtD also increases the constructability of a project (Lam et al., 2006). Better designs, reduced workers' compensation premiums, and reduced environmental damage are some other outcomes associated with PtD that have been observed (ISTD, 2003, as cited in Gambatese et al., 2005). Perhaps one of the greatest impacts comes from the efforts within PtD programmes to provide construction knowledge and expertise early on in the project timeline (Hecker et al., 2005). Lingard et al. (2014) provide evidence of the potential OSH benefits of ensuring that constructors' knowledge about construction methods, materials, OSH risks, and means of risk control are integrated into pre-construction decision-making.

As the PtD concept is diffused throughout the construction industry, it is expected that the industry will react and change. Toole (2001) showed how the characteristics of a task, process, and industry have caused innovative building products to follow one or more trajectories. Similarly, Toole and Gambatese (2007) identified four specific trajectories that PtD is likely to cause: (1) increased prefabrication, (2) increased use of less hazardous materials and systems, (3) increased application of construction engineering, and (4) increased spatial investigation and consideration. Morrow et al. (2015) recommend that designers embed PtD into their work and highlight the importance of dispelling the view that OSH is a lone activity, reserved primarily for the experts to advise upon and direct when required.

Research has identified reasons for the minimal diffusion of PtD in some countries. Barriers to PtD implementation in construction exist (Gambatese et al., 2005; Toole, 2005), yet none are insurmountable. Questions remain, however, about how to overcome the barriers to diffusion. Further research is needed to identify a path forward that will be acceptable to the construction industry and will lead to diffusion of PtD. The current study is different from previous research in that it utilises experiential knowledge from a population where PtD is already practised and has taken hold. The knowledge gained from diffusion within one country provides an example of what to expect when PtD becomes part of standard practice in another country. Furthermore, previous research has mainly focused on direct and quantifiable impacts at the project level (e.g., project cost and quality). For the current study, it is posited that there are additional subtle and latent changes that occur within and among project team members and within the industry that are important and beneficial as well.

3. RESEARCH OBJECTIVES AND METHODS

The strategy chosen for conducting the research study was to gather and analyse experiences and perspectives from within the UK construction industry that have been gained from regulatory mandated application of the CDM Regulations. To do so, the researchers utilised focus group interviews as the mechanism to collect data. While they do not provide a cause-and-effect relationship, focus groups are particularly appropriate when exploring a topic that is difficult to observe and does not lend itself to observational techniques, such as the topic of attitudes and decision-making (Cohen and Crabtree, 2006). Focus groups also provide access to comparisons that participants make between their experiences, which is a benefit that can be very valuable and can provide access to consensus or diversity of experiences on a topic (Cohen and Crabtree, 2006), such as PtD.

The focus group interviews were directed at those in the UK who have been impacted by the CDM Regulations, including architects, design engineers, facility owners and developers, contractors (general contractors and trade contractors), manufacturers and suppliers, and health and safety (H&S) consultants. Selection of the UK as the focus of the study is based on the UK's experience with PtD in the construction industry. Efforts to mandate that designers consider the safety of those who construct or manufacture their designs dates back to the UK's Health and Safety at Work etc. Act of 1974 (Legislation, 2011a). This act obligates designers to ensure that their designs will be safe and without risks to health at all times when the design is being set (installed and/or constructed), used, cleaned, and maintained.

In response to the EU directive of 1992, the UK passed into law the Construction (Design and Management) Regulations (CDM), which became effective in March 1995 (Legislation, 2011b). The objective of the Regulations is to reduce the total amount of risk that is introduced into the construction process, through effective management of OSH upstream of the construction activity. The crux of the Regulations as they affect the design profession is that the Regulations place a duty on the designer to ensure that any design that they create avoids unnecessary risk to construction workers (MacKenzie et al., 2000). The CDM Regulations were revised in 2007, with the aim of reducing the burden of paperwork and streamlining the process. In April 2015, revised CDM Regulations were approved that more closely follow the requirements of the EU directive of 1992 (HSE, 2015). The fundamentals of PtD remain, but the details, such as how the roles are allocated, have changed. The current research was conducted while the 2007 CDM Regulations were in force. The findings from the study do not take into account the changes made to the Regulations in 2015. It is expected that there will be changes in practice as a result of the 2015 revisions, which include the requirement of appointing a principal designer. While design professionals may initially not feel comfortable taking a leadership or co-leadership role in safety, this appointment is likely to further engage the design community in PtD and promote collaboration between design and construction disciplines on a project.

The targeted participants of the focus group interviews were representatives of six different professional “communities” within the UK construction industry: (1) architects, (2) design engineers, (3) facility owners/developers, (4) contractors (general contractors and trade contractors), (5) manufacturers/suppliers, and (6) H&S consultants. The initial aim was to have a total of 12 focus group interviews, two for each professional community, in order to have repeated groups (Krueger, 2002), and to provide multiple data-collection opportunities for each community within the resources allocated for the study.

Recommendations for conducting focus groups suggest that similar types of people be selected to participate in the focus group interviews (Krueger, 2002). The sample of focus group participants was taken from individuals who are members of, or whose employers are members of, one or more of the following construction industry professional organisations in the UK: the Chartered Institute of Building, the Royal Institute of British Architects, the Institution of Civil Engineers, the British Safety Council, and the Association for Project Safety. There may be some overlap in membership across the organisations.

Consistent with the recommendations for conducting focus groups (Krueger, 2002), convenience samples were used to ensure diversity within each professional community. In addition, the targeted size of each focus group, as recommended for focus groups (Krueger, 2002), was 6–9 participants. The researchers developed a series of questions exploring the PtD concept and its application for use as a guide in the focus group interviews. In addition to general demographic information about the participants (position, years and type of experience, education, employer type and size, experience with CDM Regulations, etc.), the focus group questions addressed each of the research questions referred to above. The first focus group session was used as a pilot, so as to ensure that the questions were applicable and clear.

The focus group sessions were scheduled over a period of several weeks, with approximately two hours allocated per focus group, at times that were convenient for the participants. Each individual who showed an interest in participating was contacted via email and/or telephone to confirm their voluntary participation. Interested participants then self-selected a scheduled focus group session in which to participate. As a result, the number of participants in each focus group varied. Due to the fact that some focus group sessions contained only a few participants, additional group sessions were organised to ensure participation by members of all the targeted communities. The researchers ultimately conducted 14 focus groups with a total of 110 participants.

4. RESULTS AND ANALYSIS

At the conclusion of each focus group session, the researchers asked the participants to submit completed demographic forms. In some cases, demographic forms were not completed and submitted by participants. A total of 62 demographic forms were received (56% of the participants). The following is a summary of the participant demographics:

- Type of firm for which the participant works (multiple selections allowed): H&S consultant (25% of responses), engineering (19.3%), architect (18.2%), contractor (9.1%), facility owner (8.0%), subcontractor (6.8%), manufacturer (4.5%), and other (9.1%).
- Services provided by the participant's firm (multiple selections allowed): H&S consultant (25.6% of responses), project management (21.6%), construction (19.9%), engineering (17.0%), and architecture (15.9%).
- Firm size (number of employees): More than 1,000 employees (42.6% of participants), 500–1,000 employees (11.5%), 250–499 employees (6.6%), 100–249 employees (13.1%), 50–99 employees (1.6%), 10–49 employees (8.2%), and 1–9 employees (16.4%).
- Years of experience: Mean of 23.0 years of experience working in the industry, and 11.3 years working with the CDM Regulations.

A large proportion of the focus group participants work for H&S consultancy firms. The roles that these individuals carry out can vary significantly with respect to the type of work actually performed and the project phase in which the work is performed. Nevertheless, the perspectives of the participants are of special interest to the study because of the participants' involvement in PtD and their understanding of safety management practices. With regard to design professionals, 25% of the 62 participants who submitted demographic forms are either an architect or design engineer. Contractors and owners make up even smaller percentages of participants. The number of participants in each role may have impacted the overall nature of the responses. In addition, the participant selection process was not random. The distribution of participants based on expertise, as well as the selection process used, limits generalisability of the results to the population at large. Research using a larger, randomly selected sample size and a different sample distribution will yield more statistically significant results.

During the focus group interviews, participant responses and discussions were recorded (handwritten and tape-recorded) for later analysis. Analysis consisted of basic descriptive statistics and text analysis in order to understand the participants' shared experiences. The researchers sorted the transcripts of the responses of the participants according to the questions posed during the focus group session. The researchers then conducted content analysis of the responses, so as to identify words, phrases, and comments associated with each research question posed. Those words, phrases, and comments that had a high frequency of use were noted, so as to identify key concepts, themes, and terms, and so as to develop an understanding of the similarities and differences between different parties and projects. The analysis was conducted using multi-level keyword searches of the transcribed focus group discussions, so as to focus on and confirm trends in the response data. The findings of the analysis for each research question posed are presented below.

4.1 How has the CDM legislation affected project design, construction, and safety?

For design, the most-cited changes were increased modularisation and constructability, earlier incorporation of construction knowledge, inclusion of more engineering controls in the design, greater use of less hazardous materials, and slight increases in design cost and design duration. Constructors have experienced increased prefabrication, reduced material handling and less use of scaffolding, and more use of specialised equipment to remove the worker from hazardous conditions and eliminate hazardous operations. There was no clear trend in the responses with regard to impacts on construction cost and duration. In addition, the participants cited improved construction quality, worker productivity, and end-user H&S.

4.2 How has involvement in PtD affected perceptions of safety, roles on the project, and organisational and professional culture?

Generally, perceived effects of involvement in PtD related to greater collaboration and communication within project teams, and specifically between designers and constructors. Perspectives on safety, and the role that each individual can and should play in regard to safety, were also positively affected. OSH is now viewed as important to the overall success of a project, and designers now generally view construction OSH as an imperative. Perspectives on the designer’s responsibility for OSH, and their ability to affect it, have changed. Construction OSH now immediately features in conversations in the planning and design stages. In terms of roles on projects, there is greater recognition that, as part of the project team, designers have a role in and responsibility for OSH. Project management efforts now include active assessments and management of OSH risks. OSH is included in project feasibility assessments. Other parties besides the architect/engineer, such as the quantity surveyor and the owner/client, are playing a greater role in project safety leadership. Impacts on organisational and professional culture have been closer relationships between disciplines (working more as collaborators), greater consideration of the needs and priorities of the other disciplines, a more thorough design approach (better professional design practice), and a more even spread of OSH across the disciplines.

4.3 To what extent have innovative processes and products been developed in response to the directive to address safety in design?

The focus group participants cited instances of changes having been observed in regard to the physical features of designs, the design process and tools, communication of safety hazards, and safety organisations. Most of the changes have been project-specific; the intent and application was to solve a problem on a project. Diffusion beyond the project to other projects or to other companies has been limited. In regard to the physical features of designs, most of the changes have been revised designs to eliminate hazards and facilitate safe construction operations. That is, rather than creating some new design or product, it is more common for existing designs to be slightly revised. Examples of this type of change are the following: including anchorage points for fall protection in the design; modifying the size, location, shape, or materials of a design; and designing such that the systems can be prefabricated. In addition, much of the change has occurred in the structural, mechanical, and electrical systems within a facility. When new designs have been created, the examples cited by the focus group participants were mostly related to modularisation of designs and the design of features used in the maintenance of structures (e.g., window-washing systems).

4.4 What is done differently now compared to practice prior to the CDM Regulations?

Much of the difference since implementation of the CDM Regulations is related to how information is developed and shared, and how communication occurs. The differences noted ranged from general project team interactions to specific details on project documents. The project development process now includes more off-site construction and modularisation, greater collaboration between design and construction personnel, and a greater focus on safety throughout the project life cycle. With regard to differences in project documents, some designers are now placing symbols on drawings, so as to alert constructors to potential hazards (e.g., where a tripping hazard exists, placing a picture of a person tripping). Notes describing potential safety hazards and needed personal protection are also being added to design documents. Within design firms, online networks and databases have been developed to collect and share OSH knowledge. These systems are often tied to a firm’s lessons-learnt resources. Lastly, many different risk-assessment tools have been created to help identify, evaluate, and mitigate the risks present in a design, as well as to provide a formal record of having conducted a risk assessment.

4.5 How has management of projects changed under the CDM Regulations?

Overall, the greatest change has been additional efforts to formally manage OSH risk. These efforts include ensuring that the appropriate parties and roles are in place, that the required documentation is created, and that OSH risks are recorded and addressed. Whereas construction worker OSH was previously confined to the management within the constructor’s organisation, it has now been expanded to include the entire project team.

4.6 What can the US and other countries learn from the UK’s experience, and what should be included in a path forward to enhance diffusion of PtD?

The focus group responses provide an indication of the needs and best practices for expanding PtD in the US and other countries in the absence of legislation similar to the CDM Regulations. The needed practices and resources are summarised as follows:

- The owner/client must be involved;
- Designers must be knowledgeable about how their designs influence construction means and methods, and about OSH hazards commonly present on construction sites, and designs which mitigate these hazards;
- The contractor must be involved, so as to ensure inclusion of construction knowledge;
- Design tools and resources must be supported, including a design risk-assessment process;

- There must be a means to motivate implementation of PtD;
- Designers must be engaged, so that they can be convinced and shown that they play a key role;
- There must be responsibility for implementing PtD; and
- Involvement in PtD must be expanded beyond the main project team members.

In addition to the open-ended discussion related to the research questions referred to above, the focus group participants brought up, or the conversations led to, other issues that are important to PtD. Below are some additional issues and experiences that arose from the focus group interviews and which are of interest to PtD implementation and diffusion:

- Much of the focus remains on end-user safety, not construction-worker OSH;
- The true benefit comes from working together and communicating; the CDM Regulations are simply the catalyst to enhance project team member communication and integration, which ultimately leads to improved safety;
- Changing the design culture in a way that respectfully engages designers recognises that the burden should not be placed solely on the designer and the design culture; apportioning blame in this way is not beneficial to the industry or to worker OSH;
- The extent of responsibility for mitigating OSH risks in the design remains unclear (i.e., how far should a designer go to design out hazards?);
- There is an unclear understanding of, and lack of confidence in, the ability of designers to positively impact construction safety as part of their design role;
- It is common to have a focus that is misdirected at meeting the CDM Regulations, rather than implementing PtD; and
- The PtD message needs to be expanded beyond the main project team members.

5. CONCLUSIONS

As an OSH intervention, PtD is an attractive concept. PtD provides an opportunity to eliminate and reduce OSH hazards in the workplace, and therefore greatly reduce OSH risk. Fewer job-site hazards means a safer place to work; there is less chance of getting injured. When employees feel safer on the job and are not distracted by unsafe conditions, improved worker morale, work quality, productivity, and organisational culture follow. Consequently, PtD is also an appealing proposition for employers, particularly construction employers. PtD helps to fulfil moral and regulatory obligations in regard to employee safety, health, and welfare, and can also lead to enhanced financial gains and recognition for a firm. The potential benefits from implementing PtD processes and practices in a workplace are clearly recognised.

When PtD is implemented, the design impacts are typically expressed in increased modularisation of the design, and in modified designs to accommodate and promote safer construction methods. When a safety hazard is identified, and alternative construction methods are desired to more safely conduct the work, the design is changed to accommodate the alternative methods. The alternative methods may be implemented on the job site, although much emphasis is put on prefabrication. PtD promotes and leads to prefabrication away from the job site, so as to eliminate safety hazards on the job site.

To implement PtD, design-for-safety checklists are now commonly used, together with risk assessment pro forma. These tools are applied as part of PtD processes, which commonly consist of multiple design and constructability reviews throughout the planning and design stages. Utilising constructor, H&S consultant, and end-user input, "safety constructability" reviews are conducted to identify hazards and manage the risk. The result is modified designs, together with additional hazard-communication information placed on the design drawings, so as to alert constructors to hazards and communicate safety measures to be taken or regulations to follow. However, caution is advised not to create complicated, crowded, or overly extensive drawings by adding too many notes, especially notes that indicate an obvious hazard and are likely to be superfluous. Competency in understanding drawings and fulfilling project team roles should be addressed. A suitable contractor should be able to address the OSH hazards associated with typical designs. Designers do not have to inform constructors of "obvious" hazards, only hazards that are unusual or derive from some unique aspect of the design.

Perhaps the most important impact of implementing PtD is the change in the project team. There has been a transformation in how project team members interact, communicate, regard construction worker OSH, and conduct their work. These changes include more and improved communication, greater project team integration, increased interest in safety, and better overall professional practice. These changes are the success of PtD, which have ultimately led to safer construction sites and improved worker OSH.

The changes to the project team, professional practice, and the industry culture are important results and one of the successes that is attributable in part to the CDM Regulations. The traditional model for construction worker OSH risk management in the US has been to rely solely on the constructor to implement primarily downstream, lower-level safety controls. PtD is an effective intervention that can be part of a new model to address and improve construction worker OSH. Much like the current trend towards integrated project delivery and building information modelling, PtD is a model which involves integration of design and construction, collaboration between all project team members, and all parties playing a role. It is also a model in which a choice is made to design out the hazards before construction begins, rather than protecting against them during construction.

Changing an industry such that it adopts a new model for managing worker OSH risk is a difficult prospect. Making the change requires recognition that the current model, which is identified and clung to as standard practice, is not the best model.

PtD as a construction safety intervention is currently being employed, not only in the UK and countries possessing similar legislation, but also by some companies in the US and other countries. An environment of acceptance is needed for PtD to diffuse throughout the industry. Those in architecture, engineering, and construction who are involved in its implementation must accept that current practice is insufficient and should be augmented with inclusion of PtD. Causing this change, a change that requires internal reflection by the design community on its own practices, has so far been slow to occur and has been spurned by many in the US. Continued reflection on and consideration of PtD promotion by the design community, and diligence by industry organisations in this regard, are needed.

6. RECOMMENDATIONS

Actions undertaken to expand PtD must be selected and implemented with due consideration of the structure and the nature of both the construction industry and the PtD concept. Doing so will increase the likelihood of PtD acceptance and diffusion, and ultimately its effectiveness and impact. Previous research suggests that diffusion and implementation of a construction worker OSH intervention such as PtD requires attention to four key attributes: knowledge, desire (motivation), ability, and execution (Behm and Culvenor, 2011; Gambatese et al., 2005; Hecker et al., 2005; MacKenzie et al., 2000; Toole, 2005; Toole et al., 2012). Each attribute addresses a fundamental need for effecting positive change and enabling desired outcomes. The research findings reveal that each of the attributes needs to be fulfilled in some way to realise PtD success. Evaluation of the focus group findings shows that, for each attribute, a variety of components can be identified that exist to address and accentuate the attribute within the context of PtD in construction. Selection and pursuit of each component depends on the resources available and the industry environment. Accordingly, both previous research findings and the findings of the current study highlight the key attributes and related components shown in Figure 1 (Gambatese, 2013).

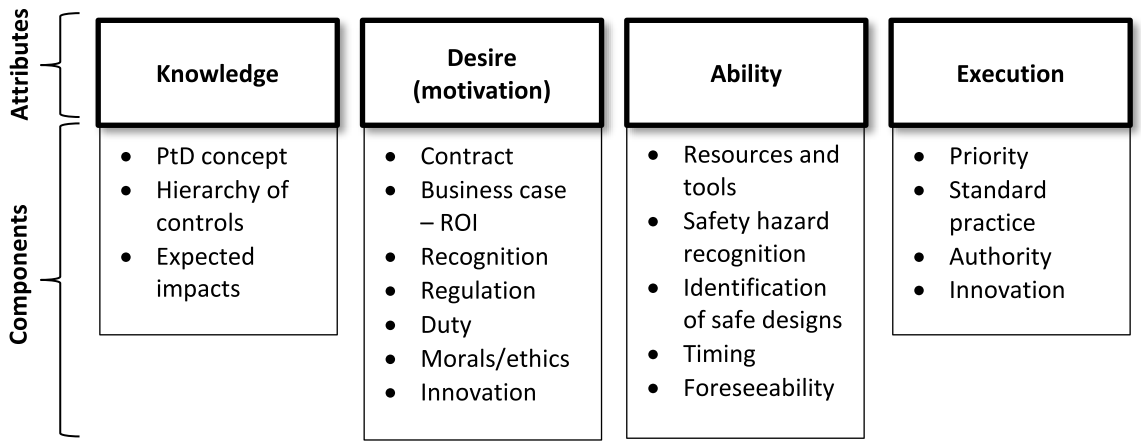

Figure 1: Attributes and components for PtD diffusion and implementation (used with the permission of Gambatese, 2013)

Careful consideration should be given to the selection, pursuit, and timing of components included in a PtD action plan. The availability of resources, the industry culture, the political environment, and the timing of the implementation (i.e., having the right information at the right time) must be considered. While a component may support a given attribute, implementation of the component may not be desired, or it may be delayed, based on the current nature of the industry and expected impacts.

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