Prevention through Design (PtD) for Hazards in Construction

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Introduction

Safety, Health, and Environmental (SH&E) practitioners and researchers have suggested that one of the best ways to prevent and control occupational injuries, illnesses, and fatalities in construction is to design out or minimize hazards and risks early in the design process. The most current demonstration of this belief lies in the development and approval of a voluntary national consensus standard—ANSI/ASSE Z590.3-2011, Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes. This standard has incorporated key concepts from prior efforts, such as the National Safety Council’s Institute for Safety by Design, and other existing standards.

Despite the attention to ensuring the safety and health of construction workers through the application of Prevention through Design (PtD) concepts, too many promising control technologies have not been transferred from research into practice. Preventing occupational injuries, illnesses, or fatalities in construction has often driven industry to make changes. Construction companies continually face increased competition, rapidly changing technology, and decreased access to scarce resources. Under these conditions, SH&E efforts to insure a safe and healthful work environment must compete with other organizational needs. Without clear risk communication about the value of SH&E efforts to the organization, the management may view these programs and activities as a lower priority. The challenge for occupational safety and health professionals is to describe the value of SH&E efforts in terms that are understood and accepted within the business community. A significant hurdle to the adoption and implementation of PtD is the availability of common methodology and risk assessment tools. PtD Risk Assessment tool addresses that challenge.

PtD Risk Assessment Tool

The National Institute for Occupational Safety and Health (NIOSH) embarked on a National Initiative in 2007 to promote the use of PtD concepts. One of the goals of the Initiative is to educate designers, engineers, machinery and equipment manufacturers, SH&E professionals, business leaders, and workers to understand and implement PtD methods and apply this knowledge and skills to the design and re-design of new and existing facilities, processes, equipment, tools, and organization of work. Identifying risk factors can be a key benefit associated with PtD initiatives. One way to develop a PtD Risk Assessment tool is to follow the PtD standard methodology depicted in Fig. 1. Any PtD risk assessment tool should include at least the following: task and hazard identification, current controls, initial risk assessment, hierarchy of controls, risk reduction based on the hierarchy of controls, and residual risk with the control measures that should have been in place.
Figure 1 Hazard Analysis & Risk Assessment Process reprinted with permission from ANSI/ASSE Z590.3-2011 (Courtesy of the American Society of Safety Engineers)
Methodology

The PtD Risk Assessment Tool was designed to help SH&E professionals in making decisions, or for presentation to the organizational managers charged with resource allocations. The Tool can be used to select among alternative solutions or demonstrate the benefits of a solution already selected. The information provided by the Tool is expressed in the language understood by all management not just those in occupational safety and health.

The Tool consists of four main steps. For the purposes of this paper, only steps 4, 5, 6, and 7 from PtD Standard Risk assessment process are included. Individual descriptive, analytic tools, or risk assessment methodologies, described in the PtD standard are incorporated in steps one and two. For instance, a modified Preliminary Hazard Analysis (PHA) is used to identify hazards (Addendum G PtD Standard). In order to establish the initial scoring system, utilization of well-established PtD practices may be suggested. Addendum F of the PtD standard offers a number of examples of risk assessment matrices and definitions of terms. The purpose of the risk assessment matrix is to provide “a method to categorize combinations of probability of occurrence and severity of harm, thus establishing risk levels.” (ANSI/ASSE Z590.3-2011)

Figure 2 illustrates the major components of the Tool.

Figure 2: Major components of the PtD Risk Assessment Tool

The first step of the process represents assessment of the current situation. It involves identifying SH&E problem(s), describing control measures that are currently in place to address the problem(s), and determining the business unit where operation the takes place. Understanding the current situation provides critical baseline information needed to identify interventions or solutions that could be implemented, continued, or revised to improve the current state of safety and health.

The second step of the tool includes an initial scoring system. More specifically, after the hazards are identified in the first step, the risks arising from those hazards can be evaluated using a modified risk assessment matrix from the PtD Standard. It should be noted that the numbers in Table 1 Example Risk Assessment Matrix: Numerical Grading and Scoring were judgmentally determined and are semi-quantitative in nature. Table 2 provides definitions for each of the risk levels for severity and probability.
Table 1 Example Risk Assessment Matrix: Numerical Grading and Scoring

<table>
<thead>
<tr>
<th>Severity Ranking:</th>
<th>Hazard #</th>
<th>1</th>
<th>S</th>
<th>2</th>
<th>HAV</th>
<th>3</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occurrence Probabilities and Values</th>
<th>RAM</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity Level</td>
<td></td>
<td>15</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Conservative P&O Standard Scoring: Very high risk: 15 or greater, High risk: 9 – 14, Moderate risk: 4 – 8, Low risk: Under 4

Table 2 Definitions of the risk levels for severity and probability.

**Incident or Exposure Severity Descriptions**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Catastrophic: One or more fatalities, total system loss, chemical release with lasting environmental or public health impact.</td>
</tr>
<tr>
<td>4</td>
<td>Critical: Disabling injury or illness, major property damage and business downtime, chemical release with temporary environmental or public health impact.</td>
</tr>
<tr>
<td>3</td>
<td>Marginal: Medical treatment or restricted work, minor subsystem loss or damage, chemical release triggering external reporting requirements.</td>
</tr>
<tr>
<td>2</td>
<td>Negligible: First aid or minor medical treatment or minor medical treatment only, non-serious equipment or facility damage, chemical release requiring routine cleanup without reporting.</td>
</tr>
<tr>
<td>1</td>
<td>Insignificant: Inconsequential with respect to injuries or illnesses, system loss or downtime, or environmental chemical release.</td>
</tr>
</tbody>
</table>

**Incident or Exposure Probability Descriptions**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Frequent: Likely to occur repeatedly.</td>
</tr>
<tr>
<td>4</td>
<td>Likely: Probably will occur several times.</td>
</tr>
<tr>
<td>3</td>
<td>Occasional: Could occur intermittently.</td>
</tr>
<tr>
<td>2</td>
<td>Seldom: Could occur, but hardly ever.</td>
</tr>
<tr>
<td>1</td>
<td>Unlikely: Improbable, may assume incident or exposure will not occur.</td>
</tr>
</tbody>
</table>
Next, a Risk Level should be calculated. This typically takes the form of a simple multiplication of Severity (S) x Probability (P). It should be noted that suggested PtD standard rating includes 1-5 low risk rating. However, the author believes that a more conservative approach may be necessary. For instance, a very high severity (5), but low probability (1) hazard will result in “Low Risk” rating. Manuele (2008) issued a call for a new focus on prevention. Manuele (2014) also presented major innovations on how to reduce serious injuries and fatalities. Another excellent resource can be found on ASSE’s Risk Assessment Institute website which provides a series of videos at http://www.oshrisk.org/videos/. The Institute’s video entitled “Fatal and Serious Injury (FSI) Prevention” defines FSI precursors and identifies the role of leadership in FSI prevention. Donald K. Martin and Allison Black, (9/2015) also suggest that our goal is to “reduce and eliminate every type of injury, but consideration should be given to the allocation of safety resources specifically targeted to the reduction of potential for serious and fatal events”. Therefore, a more conservative risk rating is considered in this paper.

Similar risk assessment matrix could be used to evaluate business hazards and risks. To present a 30,000 ft view of the current state, hazards and consequences are presented utilizing a modified Bow-Tie risk assessment methodology. The Bow-Tie risk assessment methodology is well described in ISO 31010/ANSI Z690.3-2011 Risk Management Standard. The Risk Level (RL) numbers are transferred to the modified Bow-Tie risk assessment diagram. Although, the Bow-Tie risk assessment methodology is not specifically mentioned in the PtD standard, the author believes that it is important to include the “big picture” overview of hazards and consequences. (Popov G, Zey JN., 2012)

The next step begins by identifying the solution(s) to hazard(s) recognized in previous steps. Consideration of PtD concepts, including the hierarchy of controls is used to evaluate and select possible solutions for continued analysis. The processes/operations identified in Step 1 are revisited to determine what changes to those processes/operations result from the intervention or solution being considered. These changes again include both the risk of business loss or interruption and the risk of adverse worker health and safety outcomes. A second risk analysis is performed considering the effect of implementing the solution(s) being considered. The relationship of hazard and consequences is evaluated using tools recommended in the PtD and ISO 31010/ANSI/ASSE Z690.3 standards. Another Bow-Tie risk assessment could be included at the end of this step to present possible risk reduction in hazards and consequences.

Step 4 is the last step, but a very important one. It integrates all previous steps and provides risk reduction calculations. This step ends with providing a final risk measure-one that calculates the remaining business and SH&E risk, providing the decision-makers a better understanding of the effect on risk of implementing the solution to mitigate or eliminate the hazard.

The tool is flexible enough and it can be used under a variety of situations or conditions. It can be used in any of the stages of implementing solutions—pre-operational, operational, post-operational, or post-incident—defined in ANSI/ASSE Z590.3-2011.

The following cases examples help illustrate the importance of risk assessments and the benefits they provide when fully utilized.
PtD for Hazards in Construction Tool Applicability

Current research presents opportunities for the SH&E professional to explore alternatives with the goal of reducing occupational injury and illnesses associated with grinding concrete. The following is a description of the steps included in the PtD Risk Assessment tool.

The first step is to identify the main safety and health hazards. SH&E professionals are encouraged to identify and list all the hazards associated with the process/operation. The form provides options to evaluate many different hazards. However, it is a common practice to start with the three top ranked hazards. Three hazards were identified and recorded in Figure 3 below.

With the hazards identified, the next step involved determining the Risk Level (RL) for each of the three potential effects. RL could be defined as a combination of severity and a probability of the potential effects based on the identified hazards. There is a large variety of risk assessment methods, but for this project the risk assessment of the current process was conducted utilizing the simple risk assessment matrix described in the PtD standard (ANSI/ASSE Z 590.3, 2011). The risk to human health and safety is not the only risk associated with workplace hazards. The risk to the continuity of business operations should also be considered. A similar risk assessment matrix was utilized to estimate that risk. Figures 4 and 5 present the risk assessment results for both types of risk.
Figure 4. Determining the risk level for the potential effects of the identified hazards.

<table>
<thead>
<tr>
<th>Severity Ranking:</th>
<th>5</th>
<th>5</th>
<th>4</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability Ranking:</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Risk to the continuity of business operations

To present a big picture overview of the current state, hazards and consequences are presented utilizing a modified Bow-Tie risk assessment methodology. The RL numbers are transferred to the modified Bow-Tie risk assessment diagram presented below.

Figure 6. Current State: Bow-Tie risk assessment diagram

After the evaluation of the hazards associated with the current process/operation, evaluation of PtD concepts, including the hierarchy of controls, should be discussed and documented. A very simple form was developed to present current state hazards and the proposed solutions.
The same risk assessment methodology can be utilized to evaluate hazards and consequences after the new controls are implemented. Hazards and consequences for the new controls are presented utilizing a modified Bow-Tie risk assessment methodology once again.

Notice that below the preventive barriers or controls, layers of protection could be added as needed. A Layers of Protection Analysis (LOPA) and Bow-Tie method integration can be considered a barrier-based approach to risk. It follows James Reason’s ‘Swiss Cheese’ Model of Defenses. (EUROCONTROL 2006)

Calculating the residual risk and risk reduction scores is one of the last steps in the risk assessment process (Liberty Mutual 2010). After the implementation of all the identified control measures, we can potentially achieve a 71.79% risk reduction. The results are presented in Figure 9 below.
Figure 9. Residual Risk and Risk Reduction

The next step in this process is to calculate the financial benefits of the proposed changes. SH&E professionals will have to learn how to determine the changes and impacts on worker health, risk management activities, and the overall business operations (upstream and downstream). Change measurements will serve as the basis to derive the financial and non-financial benefits of modifying the work process by implementing all of the proposed control measures.

Conclusions

SH&E professionals agree that PtD concepts should be employed early in the design stage, or during the planning stages of the process/operation. Demonstrating the value of PtD interventions can be challenging for SH&E professionals who do not have the expertise or experience in such efforts. It was concluded that PtD risk assessment tools could be successfully incorporated in the Risk Management process. Such a logical process, based on the PtD standard, could be used effectively to develop and present the need for SH&E interventions. The PtD Risk Assessment tool was designed for safety students and SH&E professionals to help them support their risk avoidance, mitigation, or elimination decisions, and for presentation to the organizational managers charged with making resource allocation decisions. Eventually, the ‘output’ of the PtD risk assessment is an ‘input’ to the decision-making processes.
Bibliography


