Making Prevention through Design Work for You

Marjory E. Anderson, CSP
Safety Engineer
Architect of the Capitol
Washington, DC

Craig Galecka, P.E., CSP
Project Manager
LJB Inc.
Okemos, MI

Introduction

Safety professionals find themselves involved in various projects ranging from construction to process development to product development or manufacturing. While all types of projects benefit from having safety professionals involved, it can be frustrating, costly, and time consuming for all parties if safety issues are discovered and addressed too late. When this happens, safety professionals can be viewed as an impediment to project completion. However, if safety professionals, and front line employees that know the work best, are brought in at the beginning of a project, safety concerns can be addressed within the project's original timeline and budget. The Prevention through Design concept ensures that this happens by making safety an integral component of all projects from the beginning.

Safety through Design was introduced in the 1940s, but the design and construction industries did not begin adopting the process until the 1980s. [1] In 1995, the concept was formalized when the National Safety Council published a book entitled *Safety through Design*, authored by Wayne Christensen and Fred Manuele. [2] To date, the process has been primarily used in the petrochemical and automotive industries.

In 2011, a new consensus standard related to this concept, entitled *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes*,[3] was published by the American National Standards Institute (ANSI). This standard became effective January 23, 2012. A national effort has ensued to advance Prevention through Design (PtD) in American industries as a means to ensure that safety is considered and addressed in the earliest possible phases of projects. The goal of this paper is to aid in that effort by

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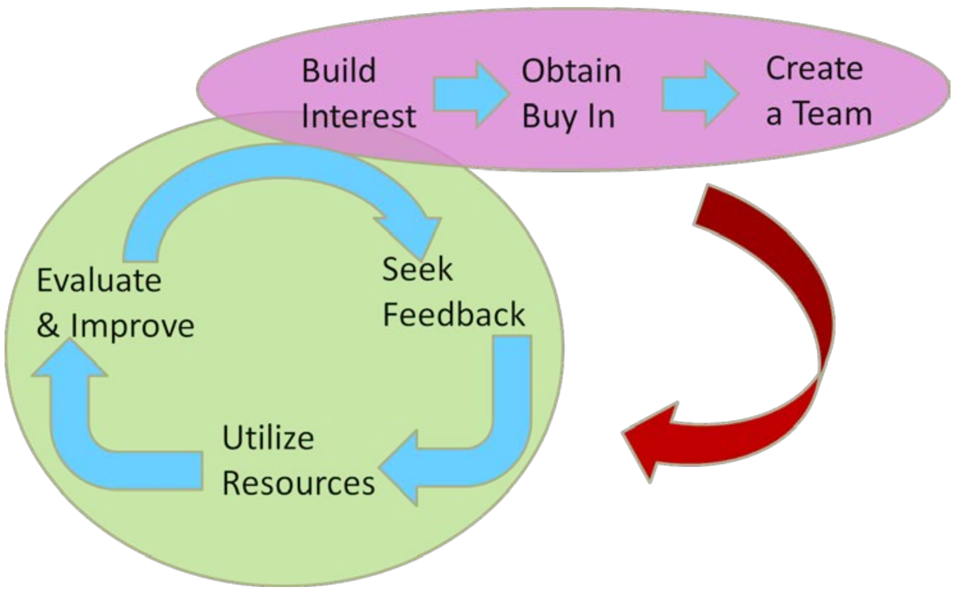
[1] Automotive Industry Action Group (AIAG). *Future Trends in Manufacturing Safety Through Design: Past Efforts and Current Crossroads* (retrieved December 8, 2011) (http://www.aiag.org/StaticContent/files/FutureTrends.pdf)

[2] Christensen, Wayne C. II and Manuele, Fred A. *Safety through Design.* National Safety Council, 1999.

[3] American National Standards Institute (ANSI). 2011. *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes* (ANSI Z590.3-2011). Des Plaines, IL: American Society of Safety Engineers (ASSE).

summarizing how to develop and implement a Prevention through Design program within an organization. The critical steps in program development are outlined, followed by case studies that illustrate the effectiveness of this process.



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xhibit 1. This graphic illustrates the Program Development Cycle for a PtD program.

Develop and Implement Your Program

Program Development

Developing a program can be a daunting task. However, taken one step at a time, a clear and effective program can be developed, as illustrated in Exhibit 1 above. The first step in making Prevention through Design succeed is to develop an internal program. The key to developing a successful program is to increase interest and gain acceptance, especially from those who will be using and following the program. Although it may be difficult at first, building interest in a PtD program will give it a strong foundation. It is important to approach the right people and provide them with the right information so they develop a thorough understanding of the benefits of PtD for individuals and the overall organization. At this time, a senior manager who will help champion this program is invaluable. Building interest can be achieved by showcasing industry success stories (such as the case studies in this paper) and by highlighting the potential cost savings and safety improvements that can be achieved through PtD.

People, especially senior leaders, tend to be interested in efforts that promote efficiency and save money. Preparing a cost comparison chart as shown in Exhibit 2 can help make your points tangible to various parties. This chart focuses on fall protection efforts and compares the relative cost of abating fall hazards throughout phases of the project from conceptual design to after completion.

Project Phase	Cost Factor
Conceptual Design	$1
Final Drawings	$10
Field Modifications	$100
Start-up and Debugging	$1,000
Post Completion	$10,000

Exhibit 2. This chart compares the costs of implementing fall protection at different project stages.

When safety is implemented during the conceptual design phase, safety is incorporated from the beginning. So, the Hierarchy of Control (Exhibit 3) can be optimized by evaluating each potential solution's effectiveness and defeatability. More effective and safer solutions, such as elimination of the hazard, substitution, and use of engineering controls can be incorporated into the original design. Incorporating safety at this stage saves money because designers do not even need to erase a single line on their drawings – the safety aspects are simply programmed into the design. In the example portrayed in Exhibit 2, implementing safety during conceptual design indicates a base cost ($1) to abate the hazard.

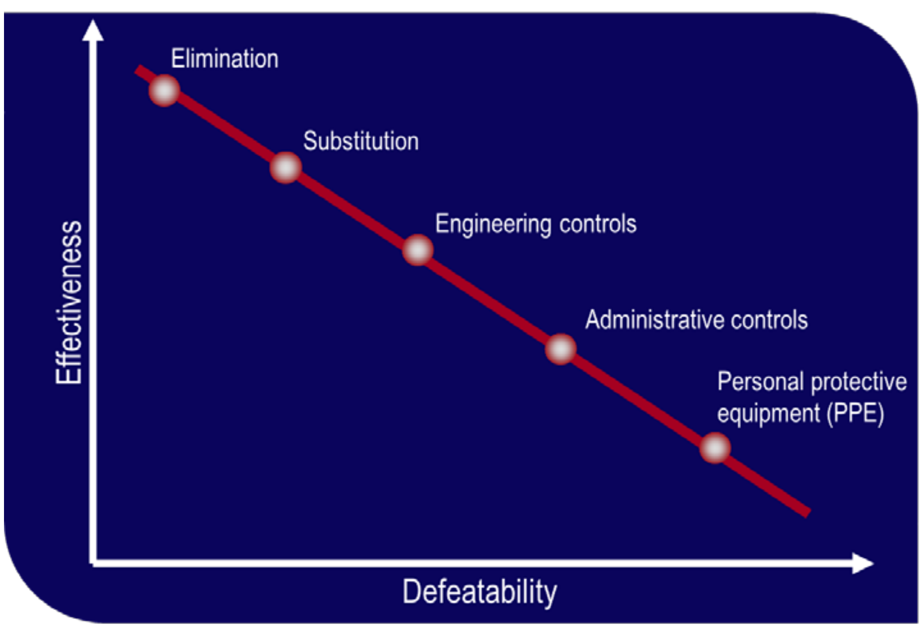

Exhibit 3. This chart shows the Hierarchy of Controls, moving down from most to least acceptable.

Compare that base cost to a project in which safety is incorporated after project completion, after the contractor leaves the site, and the facility or process is already in place. In this case, the use of the Hierarchy of Control has been compromised due to the lack of pre-planning. Although a solution's effectiveness, defeatability, and long-term cost comparisons can still be evaluated, field conditions will dictate how a hazard is abated, which may affect safety and cost. For fall protection, in certain cases, the only means of protecting employees will be personal protective equipment, due to existing interferences and the inability to access the area with appropriate engineering controls unless significant, costly modifications are made. All interferences, connection details, layout issues and required clearances must be field verified, and details must be developed and designed to match existing conditions. Additional framing may be required to work around existing equipment, so physical modifications will be required. Added to the base cost to abate the hazard are the costs of redesign, additional drawings set for hazard abatement, mobilization of the contractor, potentially significant field modifications, potentially significant rework of interferences, long-term costs of not using the ideal abatement method, and costs associated with using a potentially riskier means of hazard abatement, such as PPE.

When abating a hazard, it is critical to consider the total cost for hazard abatement. Short-term and recurring costs should also be thoroughly considered prior to implementing an abatement solution. As an example for fall protection, short-term costs include installation of systems such as walking/working surfaces and personal fall arrest systems and equipment, as well as employee training. Recurring costs include additional time for equipment inspections or modifications that may become necessary for safety planning, retraining personnel, and productivity gains and losses due to the type of abatement method used. By developing this type of cost comparison, managers, executives, designers, and other stakeholders can better understand the importance of PtD, thereby building interest in the program.

Once interest in a PtD program has been achieved, buy-in must be obtained from those who will be using the program. Providing end-users with real-world examples of success stories will show how useful and cost effective a PtD program can be. It may be necessary to be persuasive in discussions, but questions or concerns that are brought up must also be considered. Listening to and addressing concerns will only strengthen a case for PtD. Upfront buy-in is of utmost importance, so that the program will be used by the right people and in the correct way.

Once buy-in has been obtained from the right people, a PtD team needs to be put together. This team will help write the program based on the ANSI Z590.3 standard so that it is effective and practical for the overall organization and the individual users. These team members should have common goals that will be facilitated by the project manager and/or safety professional leading the effort. By using a team approach, concerns from different departments and different organizational levels will be voiced and can be adequately addressed in the final program document. This team approach decreases the chance that something will be overlooked and allows the program to be finalized more quickly, as the need for revisions and corrections will be reduced. Members of this team should include engineers, architects, safety professionals, facility managers, PtD experts, consultants, and end users. Each team member will provide a unique perspective to help develop an effective PtD program.

Once a program team has been established, the PtD program can be written. In general, a program consists of the following basic elements:

1. Purpose – why is this program being implemented; what is the overall objective?

2. Scope – to which process, facilities, employees, etc., does the program apply?

3. Application/Requirements – what must be done, and how will it be done?

While purpose and scope may vary by facility, ANSI Z590.3-2011 outlines, in detail, the application of a PtD program. The elements are outlined in sections 4 – 7 of the standard and include:

1. Roles & Responsibilities[4] -- this section describes what top management is responsible for, when they carry out these responsibilities, and the methods through which these responsibilities shall be carried out.

2. Relationship with Suppliers[5] -- this section describes discussions companies should have with their suppliers, the requirements that should be placed on suppliers, and how companies can ensure that suppliers meet these requirements.

3. Design Safety Reviews[6] -- this section details the design reviews that should be done for every project, their frequency, and top management's responsibilities in design reviews. The standard also provides, in Appendix E, a design review guide to aid companies in achieving the requirements in this section.

4. Hazard Analysis Process[7] -- this section walks through the steps companies must take to develop and implement a successful hazard analysis process. The steps include:
    a. Selection of a risk assessment matrix
    b. Establishment of analysis parameters
    c. Hazard identification and anticipation
    d. Consideration of failure modes
    e. Assessment of consequence severity
    f. Determination of occurrence probability
    g. Definition of initial risk
    h. Selection of control methods
    i. Assessment of residual risk
    j. Deciding a level of risk acceptance
    k. Results documentation

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[4] American National Standards Institute (ANSI). 2011. *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes* (ANSI Z590.3-2011). Section 4.0. Des Plaines, IL: American Society of Safety Engineers (ASSE).
[5] American National Standards Institute (ANSI). 2011. *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes* (ANSI Z590.3-2011). Section 5.0. Des Plaines, IL: American Society of Safety Engineers (ASSE).
[6] American National Standards Institute (ANSI). 2011. *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes* (ANSI Z590...3-2011). Section 6.0. Des Plaines, IL: American Society of Safety Engineers (ASSE).
[7] American National Standards Institute (ANSI). 2011. *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes* (ANSI Z590.3-2011). Section 7.0. Des Plaines, IL: American Society of Safety Engineers (ASSE).

l. Follow-up of actions taken

Each of the elements defined above combine to create an effective PtD program and need to be addressed in a facility's written PtD program. ANSI Z590.3-2011 details each element so that companies can readily develop their own program and ensure that safety is designed into all projects. Writing a clear and effective program is critical to implementing PtD in any organization.

Use all the resources available to develop the program. These resources provide a wealth of information and examples with which a program can be built. Some available resources include:

1. "Safety Through Design" text by Christensen and Manuele

2. ANSI Z590.3-2011, Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes

3. Checklists such as the Building Design Safety Checklist (Christensen, Manuele 227)

4. The National Institute for Occupational Safety and Health (NIOSH)
5. Consultants

The next step is to seek input and feedback from those that will be affected by the PtD program. Ask personnel for their opinions on what has been developed by the team and ask for suggestions to enhance the program. Seek this input from the development team, organizational management, and fellow employees. Remember that throughout the development process all ideas should be given due consideration. Nothing is off limits. The more input and creativity allowed, the better the program will be in the end.

Finally, embrace continuous improvement to regularly evaluate and improve the program. This is done by auditing random projects in which PtD has been used compared to similar projects completed prior to program introduction. Evaluate the cost differences and employee feedback on the solutions. Also, use the audits to track decreases in the number of redesigns and retrofits that have been initiated since program introduction. While conducting these audits, engage customers and obtain feedback on the projects that have been completed for them. Get their opinions and seek out suggestions for improvement. Do the same thing by interviewing the program end-users. How has this new program changed their jobs? Are projects completed more efficiently and within budget compared to projects completed before the program? Take all the information gathered, review this information with the PtD team, and improve wherever needed. This may include process alteration, program editing, training adjustments, or other improvements within and outside the PtD program.

The results of using the process discussed above to develop a PtD program can be dramatic and will result in improved overall safety as the program serves to:

1. Define acceptable risk
2. Control costs
3. Ensure safety is "built in"
4. Assist in compliance with OSHA and other standards

Program Implementation

Once the program is developed, it must be implemented so it does not become idle or forgotten. While gaining interest and obtaining buy-in can be difficult, implementation of a new program is often the most challenging and frustrating aspect. It is likely that people will resist the program because they generally avoid change or because they believe that safety should be the safety professional's job. Don't let these challenges distract you from the ultimate goal. Program implementation includes the following elements and may include others depending on facility requirements.

1. Publish and distribute program
2. Conduct management reviews
3. Deliver employee training
4. Conduct progress audits
5. Perform program evaluation

Consider the ideas below to ease the burden of implementing a new PtD program. First, don't simply work with team members – develop relationships with them and become allies. This effort will result in gaining their backing for the implementation process. Having others' involvement will reinforce that safety is not the job of any one person or department. Asking team members to aid in implementation will demonstrate that safety is everyone's job.

Next, the end users should be engaged in the implementation process. These are the people that will use the program, and they are the most likely to identify needed adjustments. Involving end users again demonstrates that safety is not just the job of one person or department. Working together on implementation also helps develop good working relationships with the end users and provides a forum to exhibit knowledge throughout the design process. By doing so, end users will be more likely to become engaged earlier in the design of a new structure or process. This will help illustrate that the safety personnel's goal is to help the organization and the employees, not just to demand unquestioning compliance. All this effort will help sell the program to the rest of the organization and will increase the overall effectiveness of the program.

It is important to remember that simply publishing the program will not ensure that everyone reads and follows it. It is common for people to put aside large documents or only read portions that directly apply to them. To address this reality, it is helpful to administer a test project with the new program. This can be done by approaching a project team leader to test the new program throughout a project. The PtD team can help ensure the right people are pulled together and the project team is led through identification and evaluation of potential hazards. Once hazards are identified, ask the individuals on the team to develop controls and abatement methods. As this is done, the PtD team should keep track of challenges, as well as the aspects that work well. When the test project is complete, findings should be reported back to the development and implementation teams, and any needed adjustments should be made to improve the process. The results of this test project can be used to help promote the program throughout the organization by providing a real, organization-specific success story.

Finally, continue to develop a knowledge base. Take note of changes in standards, upgrades in technology, introduction of new control methods, and any other information that can affect the program and projects. This will provide readily available references when it comes time to evaluate and update the PtD program. In addition, it is important to keep others in the organization informed of new, relevant information so that it can be put to immediate use on new projects and designs.

Through projects and research, PtD programs have been implemented in organizations, individuals have been trained in the process, and designs have been improved. Below are three examples of successful use of the PtD process.

Case Studies

U.S. Botanic Garden Production Facility

The U.S. Botanic Gardens (USBG) is a facility of the Legislative Branch of the U.S. government and is managed and maintained by the Architect of the Capitol (AOC). This facility houses innumerable plant species from all over the world and displays them in the U.S. Botanic Gardens Conservatory on Capitol Hill. To supply the Conservatory and its surrounding gardens, the USBG maintains a production facility where plants are nurtured, grown, and hybridized. The U.S. Botanic Gardens Production Facility is 117,000 square feet, including 85,000 square feet of greenhouse space, as shown in Exhibit 4.

Exhibit 4: The PtD process was used on changes to the U.S. Botanic Garden Production Facility.

This production facility is essentially a huge greenhouse. The roof of this greenhouse was frequently accessed by employees to replace broken glass panels and to clear snow. Access was gained using a chicken ladder (Exhibit 5)[8], which resulted in decreased protection for employees. The AOC decided to implement new fall protection measures for this facility. The initial

[8] Specialty and Other Scaffolds, OSHA, Accessed March 1, 2012, http://www.osha.gov/SLTC/etools/scaffolding/supported/specialty.html

proposed solution included fixed ladders and guardrails. A consultant developed drawings, and the project team came together with the consultant to discuss the design.

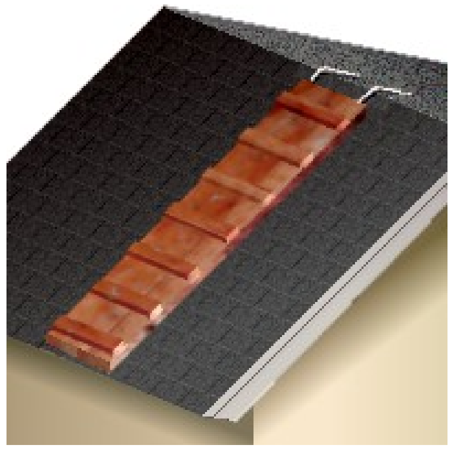

Exhibit 5: Chicken Ladder (OSHA, 2012)

During these project meetings, several concerns were raised by members of the project team. They noted that ladders would need cages (since several would exceed 20 ft. in height), flat walking surfaces were not available, and guardrails might compromise the integrity of the glass panels. In addition, a modified chicken ladder was still needed to allow employees to move across the thin glass panels.

Fortunately, the team included a representative from the original design team of the greenhouse. After listening to discussions regarding these concerns, the representative proposed a potential solution: replacing the glass panels on the roof with acrylic panels. By doing so, the need for continual panel replacement would be eliminated and employees would no longer need to access the roof. It was also decided that aerial lifts would be used for clearing snow when necessary. When this option was researched, it was discovered that the cost to replace the panels would be less than the cost of adding fall protection—$6.3 million as opposed to $7.5 million—a savings of 16%. In addition, this option also increases employee safety, since the risk of falls would be completely eliminated. This option was chosen and the fall hazards were eliminated.

Taft Memorial

The Taft Memorial and Carillion (Exhibit 6), dedicated in 1959, is comprised of a 100-foot tall Tennessee marble tower and a 10-foot bronze statue of Senator Taft sculpted by Wheeler Williams. As part of a comprehensive refurbishment of the Memorial, a new fall protection system was to be installed. . Employees needed to access the roof of this memorial to remove snow and to clean leaves from roof drains.

During discussions with the design consultant, it was determined that using existing ladders were very awkward since access was gained through the Carillon that houses the bells. It was also discovered that design changes regarding ladders, stairs, and fall protection could affect the harmonics of the bells. These concerns may not have been discovered without the involvement of members of the original design team. Also, the refurbishment design team took several photos and inquired as to the reasons for employee access to the roof.

Once the reasons for access and the past difficulties were understood, the consultant suggested potential methods to eliminate the need for employee access. First, the drain could be moved closer to the access hatch. Second, ladder access systems could be included on the replacement ladders to be installed during refurbishment. These two design changes would allow employees to complete necessary tasks while remaining within the structure. In addition, the modifications would protect employees against falls from ladders, while eliminating the risk of falls to the ground. The changes also reduced the design costs, allowing the project to remain within budget. These options were chosen and again, fall hazards were eliminated.

Exhibit 6: Using the PtD process eliminated fall hazards related to roof maintenance on the Taft Memorial.

Confined Space at Manufacturing Facility

During the final design stages of a new testing facility for a manufacturing organization, the project team realized that a confined space was being created. Two of the test chambers had a lower level, and the 90% design drawings included a single ladder for access to this lower level. This lower level became a confined space, since it met the following criteria:

- A person could physically enter
- It was not designed for continuous human occupancy
- Entry and egress was limited

Due to the chemicals being used in the area, the space also had the potential for a hazardous atmosphere, making it a permit-required confined space. To illustrate how the team evaluated the confined space based on the Hierarchy of Controls; the options are presented below from the most effective to the least effective:

1. *Could the space be eliminated?*
   This option was evaluated initially, but was considered infeasible due to the requirements for access below the test chamber and the inability to raise the test chamber.

2. *Could the confined space become just a "space"?*
   This option evaluated the possibility of eliminating at least one of the three characteristics of a confined space. Because access to the space was needed, the space was only evaluated for entry and egress limitations and not designed for continuous occupancy. It was determined that the simplest and most cost-effective option was to change the access from a ladder to a stair. The final design also included lower level door access from a separate stairwell.

In this case, options 3-5 were not considered, since an acceptable solution was created in Option 2. The additional options are presented here as an example of how the other options may be evaluated to arrive at a solution.

3. *Could the space become a non-permit required confined space?*
   If this option was considered, the team would have evaluated whether modifications could be made to eliminate the potential for a hazardous atmosphere. More generally for other spaces, the characteristics listed below that would make a space become permit required per OSHA 1910.146(b) would be evaluated:

   (a) Contains or has a potential to contain a hazardous atmosphere
   (b) Contains a material that has the potential for engulfing an entrant
   (c) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section
   (d) Contains any other recognized serious safety or health hazards

4. *Could the space be temporarily reclassified?*
   If considered, modifications that would allow for all hazards to be eliminated without entering the space would have been evaluated.

5. *Could modifications be made to make entry into the space "safer?"*
   While remaining a permit-required confined space, modifications that would make the entry safer would have been considered. An example would be designing the space to allow for rescue (e.g. providing a davit arm in lieu of a tri-pod).

Conclusion

The case studies show effective use of Prevention through Design and application of the Hierarchy of Controls. While these short case studies may indicate that the outcomes were reached quickly, please note that proper, effective, practical, and safe designs are only achieved through meetings and reviews that can be time consuming. It can be shown however, that the time put into the design of a project is extremely valuable when hazards can be effectively controlled, safety improved, and cost reduced.

Prevention through Design offers a method for improving safety that also enables projects to be completed on time and within budget. It is a win-win method of design that benefits not only safety professionals, but also design team members, end users, and organizational management.