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Research: The Power of Collaboration

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Examples of the prevention through design (PTD) concept exist in practice in all industrial sectors, including the construction, manufacturing, healthcare and service industries. Process and design solutions have been developed and implemented to reduce or eliminate risks to occupational safety and health (OSH). Awareness is building that engaging with designers as part of OSH management is an effective practice for reducing injuries, illnesses and fatalities (Manuele, 1997).

Effective diffusion and implementation of the PTD concept call for detailed understanding of the principles and practices of both design and OSH. PTD also requires that architects, engineers and designers know the processes, jobs and work conditions associated with their designs and that they understand the associated risks. Engaging those who construct, manufacture, use and maintain their designs also is important. PTD is genuinely a collaborative process that encompasses multiple areas of expertise and stakeholders.

While PTD is a recognized and established practice attribute in some industrial sectors, the complexities and barriers associated with its implementation have inhibited its diffusion in other sectors. A lack of OSH knowledge among design professionals, fear of liability for injuries, a lack of available design tools, insufficient funding and time for design, and lack of methods to engage workers and OSH professionals in the design limit PTD implementation (Brown-Williams, Lichterman, Quinn, et al., 2010; Gambatese, Behm & Hinze, 2005; Hecker, Gambatese & Weinstein, 2005; Quinn, Fuller, Bello, et al., 2006; Quinn, Pentecost, Fisher, et al., 2009; Toole, 2002, 2004).

These barriers are not insurmountable (Gambatese, et al., 2005), as is evident from the many instances of PTD in practice. In addition, when PTD design solutions are implemented, it is believed that the benefits are positive, not only for OSH but also for work quality, productivity and cost (Gambatese, Hinze & Haas, 1997). Enhancing the adoption of PTD throughout all industrial sectors requires further research to understand the concept in practice and to develop tools and resources that facilitate its implementation, impact evaluation and diffusion. This article describes PTD research needs, presents examples of current research and identifies areas for future research.

Research in this area necessitates working outside the research lab to engage and understand work practice in design, construction/manufacture, use and maintenance. This need is consistent with NIOSH's Research-to-Practice (R2P) initiative that involves an iterative process in which the OSH community, including researchers, communicators, decision makers and employer/employee groups work collaboratively to (NIOSH, 2012a):

- identify research needs;

- design, plan and conduct studies;
- translate and disseminate NIOSH-generated knowledge, interventions and technologies to relevant users for implementation in the workplace;
- evaluate results to determine the impact on occupational safety and health;
- recycle the results of practical implementation back into the research phase to identify subsequent research needs.

This cycle permits continuous improvement and optimization of any process or product used in practice.

By mapping the R2P process to PTD, specifically with regard to PTD research, it can be seen that research is needed in all phases. That is, research is needed to: 1) determine the connection between design practices and OSH risks, and identify hazardous designs (surveillance); 2) develop PTD solutions to those designs; 3) understand how to effectively translate and implement the solutions in practice; and 4) evaluate the effects of implementation, and monitor and modify the solutions accordingly.

The next sections of this article describe current research in each area and suggest needs and avenues for further research. These examples are taken from presentations at NIOSH's 2011 conference, Prevention Through Design: A New Way of Doing Business: Report on the National Initiative (NIOSH, 2012b). Table 1 lists the conference presentations that relate to research (ASSE, 2012).

Connecting the Design to Hazards (Surveillance)

Understanding how PTD strategies are implemented around the world and the relationship between specific design features and OSH risk reduction is essential to PTD improvement. In a study of the management of quality and working conditions in the European construction industry, Lorent (1987) found that preventive actions taken upstream of the construction work not only eliminate construction defects but also improve construction output (productivity) and worker safety. Gibb, Haslam, Hide, et al. (2003), found a connection between design decisions and safety performance when investigating 100 construction site incidents. The researchers found that in almost half (47%) of the cases, the incident could have been prevented through a design alteration. Similarly, selecting other materials could have reduced the safety risk in 35% of the incidents, and revising the design of construction equipment could have lowered the safety risk in 60% of the injury incidents.

Likewise, Behm (2005) reviewed empirical data in NIOSH's Fatality Assessment Control and Evaluation (FACE) program and determined that design was a causal factor in the incident or was indirectly linked to its cause in 94 (42%) of 224 cases reviewed. Such compelling evidence supports the need for surveillance, which involves conducting research that enhances understanding of the specific design elements that contribute to injuries.

As PTD has gained global popularity, knowledge transfer among countries with respect to regulations, best practices and lessons learned has become important. The European Union has issued specific directives (e.g., EU Directive 92/57/EEC) that define designers' responsibility for OSH. Understanding how firms have adapted to these directives is essential for countries such as the U.S. where PTD is still emerging. At the NIOSH conference, John Gambatese (Oregon State University) and Alistair Gibb (Loughborough University) described research that was conducted to investigate the effects of the U.K.'s relatively new Construction Design and Management (CDM) regulations on the PTD practices of designers and contractors.

Gibb described the injury-prevention duties of designers under the Health and Safety at Work Act (HSWA) and the relatively new CDM regulations (ASSE, 2012). He provided a detailed discussion of how hazards were eliminated during the design of the London 2012 Velodrome project as a case study (Photo 1). This project involved a complex roof design with a unique shape. Hazards were removed prior to construction by using a design risk register; by conducting workshops to evaluate the safety implications of design alternatives; and through involvement of construction knowledge during design. The result was a low injury rate, high levels of productivity and lower costs.

Gambatese reviewed research conducted on U.K. designers, contractors, owners/clients and safety professionals who are responding to the recent CDM regulations (ASSE, 2012). Gambatese and Gibb studied the expected organizational and industry impacts related to safety and health perceptions, roles and culture change associated with the response to the CDM regulations.

Gambatese also discussed efforts to identify and disseminate innovative processes and products that evolve from PTD implementation. The findings from 14 focus groups with more than 100 participants and surveys of 258 industry professionals indicate that since the inception of the CDM regulations the U.K. construction industry has:

- increased owner/client safety and health knowledge and involvement;
- increased project team collaboration and communication;
- spread safety and health responsibilities throughout the project team;
- recognized that PTD is important, should be given greater importance and is more than just a legislated mandate;
- included more safety notes and symbols on the drawings, increased modularization, increased prefabrication (Photo 2) and ensured greater transparency of the design rationale;
- increased construction input during design with a focus on safety constructability.

Recent improvements in safety performance in the U.K. suggest that CDM regulations have had a positive effect. In fact, injury rates have declined approximately 75% since the regulations were first enforced in 1995 and updated in 2007. Gibb's and Gambatese's research is vital because it shows the specific strategies used to successfully respond to CDM regulations, which may prove useful as PTD gains popularity in the U.S. although similar regulations have yet to be developed. Gambatese also reviewed recent progress in developing guidance for effective implementation of PTD in the U.S. and for disseminating research findings to the U.S. construction industry.

Another issue in the current PTD knowledge base is that most surveillance studies have examined past incidents to evaluate whether an injury could be attributed to some aspect of the design. Gambatese, et al. (1997), responded to this limitation by conducting interviews to determine specific design suggestions that could be used to improve safety during construction. Similar studies have been conducted in other industries.

The limitation in the current body of knowledge is related to the fact that the data obtained are either retrospective or are defined for existing design elements and work processes. Therefore, PTD knowledge must be collected for each new design feature or new work process that is introduced. An example in the construction industry is the trend of green building, which involves new technologies (e.g., vegetated roofs) and construction processes (e.g., material recycling) that are not included in historical PTD databases. For such innovations, designers must define the potential hazards on an ad hoc basis with limited construction or production knowledge.

Matthew Hallowell (University of Colorado, Boulder) described recent efforts to conduct risk analyses of design at the attribute level (ASSE, 2012). Content analyses of more than 10,000 NIOSH and OSHA injury reports were conducted to identify fundamental design attributes that contribute to injury. Examples include exposed edges, low clearance, low-visibility regions and uneven working surfaces. Once the attributes were defined, a risk analysis was conducted to reduce the dataset to essential causal attributes using principal components analysis. Finally, the spatial and temporal interactions that occur among design attributes to cause injury were modeled using social network analysis. These combined analyses yielded a robust database that can define the risk of any design layout provided that the designer can simply identify a site's expected attributes. These data are currently being integrated with advanced design systems such as building information models.

Developing Design Solutions

Knowledge of the hazards associated with specific designs leads to the next step in the R2P process—development of design solutions that enhance OSH. Beginning with an idea, research studies enable development and testing of solutions to prove their utility and impact. Solutions may come in many forms including such innovations as new or modified equipment that prevents traumatic and repetitive stress injuries, nontoxic materials, and processes that enable efficient and effective design reviews.

This step in the R2P process is critical. Without appropriate examination and validation, design solutions may require extensive effort to implement with little gain and, therefore, dampen motivation to implement PTD in favor of OSH techniques that are lower on the hierarchy of controls. Several examples of research on the development of design solutions are summarized here.

Frank Renshaw (Bayberry EHS Consulting LLC) presented a foundational PTD process that helps organizations assess and address safety and health effects of new and modified facilities, equipment, processes, work methods and products during the design and redesign stage (ASSE, 2012). The program includes: 1) a model SH&E policy statement and management system language that defines PTD and commits an organization to PTD methods; 2) strategic guidance in the form of model work processes and procedures to integrate PTD with the design and redesign process; and 3) tactical guidance in the form of tools and best practices to assist business leaders, designers, engineers, and safety and health professionals in applying PTD methods.

Renshaw described a three-step approach of the model program that starts with setting policy and standards, followed by establishing work processes and procedures, then applying tools and best practices. He also discussed a specific application of PTD methods for the elimination and control of open system chemical operations. Application of the hierarchy of controls, a PTD fundamental, was highly successful in addressing hazards of exposure, fire, explosion and environmental releases across numerous plants in a chemical manufacturing organization. The model process provides an excellent example of what can be accomplished with advance planning and controls.

Researching and developing design solutions can be hampered by imperfect information or an overabundance of critical impacts. Approaches to developing design solutions must recognize the complexity of design. This can be especially important with regard to selecting chemicals. Joel Tickner (University of Massachusetts Lowell) described alternatives assessment as a process to solve this problem (ASSE, 2012). He cited multiple reasons for using alternatives assessment, including the slow chemical-by-chemical risk assessment and risk management processes with high burdens on government, and the limited amount of available data on toxicity use and exposure.

Tickner pointed to CDC's recommendations to include ranking chemicals according to their toxicity, use and exposure; establish an initial list of toxicological properties, uses, and exposures of concern and identifying chemicals with those known characteristics; establish scientific principles for identifying safer substitutes, including methods to address the lack of chemical toxicity data; and establish a comprehensive database of chemicals, basic toxicities that are known or suspected, and safer substitutes or alternative processes.

As an example assessment process, he presented the Lowell Center for Sustainable Production alternative assessment framework that defines two types of assessment:

1. comparative assessment of existing technologies;

2. design assessment to guide the development of new technologies.

Multiple benefits accrue from implementation of the alternative assessment process, including a shift from problem-sphere to solutions and opportunities to promote innovation, cost-savings and job creation. This shift is an important part of promoting PTD as a focus on possibilities rather than problems.

EPA's Cal Baier-Anderson supported the need for alternatives assessment and introduced the agency's unique Design for the Environment (DFE) initiative (ASSE, 2012). The initiative was developed to promote the design of safer products and develop tools to identify safer chemicals. Four programs exist within the DFE initiative: 1) safer product labeling; 2) life cycle assessment; 3) chemical alternatives assessment; and 4) best practices. Given that chemical hazards exist on a continuum, Baier-Anderson noted that DFE considers chemical hazards within the context of chemical function; incorporates criteria that closely mirror GHS criteria; and facilitates the identification of safer alternatives and informed substitution to minimize unintended consequences.

In research related to PTD in the healthcare sector, Margaret Quinn (University of Massachusetts Lowell) also demonstrated the benefits of alternatives assessment and implementation (ASSE, 2012). Quinn's research aimed to develop methods to engage occupational and environmental health professionals and hospital staff to identify safer, more sustainable technologies, and to implement and evaluate them. At a minimum, the solutions were aimed at preventing risk shifting between the environment, worker and patient.

Several case studies were conducted: substituting digital thermometers for mercury thermometers in pediatrics; substituting other materials for mercury in dental amalgam; replacing a conventional floor mopping system with one that includes alternative microfiber design; and eliminating the toxic antibacterial ingredient Triclosan from clinical soap and lotions.

Quinn drew the following conclusions from the case studies:

- An alternative cannot be introduced successfully without understanding its function, associated job requirements and work practices, and its final product or service.
- Information about safer alternative materials, products and devices seldom exist in a form that is readily accessible to healthcare workers.
- Few alternative designs are perfect. The focus of alternatives assessment should be on the process by which an alternative is evaluated and implemented rather than on a particular alternative.
- Whenever a new alternative becomes available, the process to evaluate it should be repeated.
- Long-term success depends on the participation of those affected because they understand the functions and work practices best and ultimately maintain the change.
- Once engaged in a PTD process, hospital staff identified previously unrecognized design problems and possible solutions.

Creating success in this area goes beyond the technical aspects of a design. Achieving successful design and implementation is a social process as well. Ultimately, PTD represents change. As a result, PTD practice with its OSH criteria can be drivers for innovation.

Amy Wolfe (AgSafe) provided an excellent example of research and development of a design solution in the agricultural industry (ASSE, 2012). The study focused on wine grape growers and aimed to provide employers with tools they need to keep employees safe and healthy while running profitable businesses. Study participants included three wineries, one wine grape vineyard management organization and 200 permanent employees. The research effort entailed employee health record reviews, ergonomic analysis of work performed and identification of viable solutions.

The health record review revealed that 69% of injuries were back injuries from lifting during the harvest that included multiple actions (stooping; reaching; hand cutting; and lifting, carrying and sliding the load). As a result, a new wine grape harvesting bin was designed; it is smaller, lighter and contains handles making it easier to hold (Photo 3). The new design is 2 in. narrower in length, 1 in. narrower in width, and has a 46-lb capacity compared to the original design's 57-lb capacity. The new design decreases the risk to back injuries without negatively affecting worker productivity.

Implementing PTD in Practice

With any new technology or process, its inception and initial implementation are important steps. However, they are not the only steps required for innovation. Innovation within an industry requires diffusion past the initial problem-solving phase. Diffusing a new technology or process beyond the initial application and testing validates its utility and value, and brings overarching change in an industry. Research is needed on this step. The research typically includes validation of a PTD design solution that has been implemented and confirmation that the solution has been disseminated to expanded populations.

Wolfe illustrated such research well when describing the second phase of the wine grape harvesting study (ASSE, 2012). This phase involved the research team returning to the winegrowing region 10 years after the initial implementation of the new harvesting bins. What they found was promising. Wolfe and colleagues surveyed employers/managers, conducted focus groups, and performed interviews with employers and farm workers.

The survey revealed that the smaller, lighter tubs were being used by 45% of workers compared to 30% using the larger tubs. The success of the smaller tubs was almost immediate, as 85% of those using them started using them the next harvest season. The primary reason cited for using the smaller tubs was employee safety (81% of respondents). In addition to improving safety, researchers found that other motivators for using the smaller tubs included less prep work, easy to find/use, less tired after work and happier workers.

Based on the study, the researchers observed that PTD diffusion occurred among employers/managers and farm workers, and continues via word of mouth, safety training sessions and organizational outreach efforts. Importantly, the researchers found that continued use of PTD was driven by demand from labor, with modifications developed by labor. The design solution made sense from a safety perspective and was desired by employees. The value to employee satisfaction and morale became integral in management decision making.

Stephen Newell (Mercer ORC HSE Networks) spoke about a benchmarking evaluation of management practices that support PTD (ASSE, 2012). Focusing on *Fortune* 500 companies, the researchers aimed to determine the level of adoption of PTD concepts among companies that pride themselves on superior safety and health performance. Using a survey process, the research scope included identifying the level of leadership commitment to PTD among safety-conscious corporations, and identifying PTD practices in manufacturing and work processes, and corporate procurement policies and procedures.

A total of 35 companies were represented in the survey responses. Results revealed that most companies believed they understood PTD principles, although some confusion remains about the term. More than 75% of respondents require some form of PTD in their own operations, and two-thirds of those responding indicated they require PTD practices of contractors and/or suppliers. The findings also show that PTD is most often implemented through standard operating procedures, written requirements or rules, or corporate-wide policy statements, and is most often applied in design or redesign processes. The researchers found that many corporate leaders still mistakenly believe design solutions and/or other strategies that use higher-level controls are cost prohibitive. Research and dissemination efforts must be conducted to connect the dots for them (i.e., demonstrate a connection between higher-level preventions and downstream production benefits).

Identifying & Measuring PTD Effects

Understanding and confirming the effects of implemented PTD solutions is an important step. The value of PTD is demonstrated when safety and health performance improve. Effects on work quality and productivity are believed to occur as well. These secondary outcomes support PTD implementation and can help drive the needed change. Research studies of PTD effects provide evidence of the benefits.

Elyce Biddle presented a study aimed at demonstrating the process of conducting an economic analysis and making a business case for PTD solutions (ASSE, 2012). She began by identifying six key business objectives: create sustainable business, excel in SH&E, retain employees, increase profits, support product stewardship and increase market share. Financial value can be measured in different ways, such as return on investment (ROI), net present value (NPV) and internal rate of return. Nonfinancial value is commonly assessed by reviewing risk reduction/elimination, reduced injuries and fatalities, percentage of objectives accomplished and specific achievements.

Biddle's research focused on a mechanical lifting program for hospital patients (Photo 4), the wine grape harvesting tubs studied by Wolfe and wet garment cleaning. For the mechanical lifting program, the research revealed a positive NPV and ROI greater than 1.0. In the wine grape tub case, the company experienced lower worker turnover and improved morale, and workers experienced fewer aches, pains and injuries. Wine grape production levels were maintained or improved with similar results related to grape quality. In the wet garment cleaning case study, wet cleaning proved to have a higher and positive NPV compared to all other cleaning methods. In all three cases, the business case results also demonstrate the value of doing the right thing.

The research demonstrates the availability of tools and their value in making a business case for PTD. Further research is needed to evaluate and disseminate the financial implications of additional solutions to other companies. Research also is needed to explore the development of PTD-specific models for conducting financial analyses of PTD solutions.

Conclusions & Recommendations

Within OSH management, PTD is recognized as a top priority. The ability to remove or reduce job-site hazards and, therefore, eliminate or decrease risk to worker safety and health is an attractive and welcome proposition. Moving from concept to implementation, however, has proven difficult in some industrial sectors and for various reasons. PTD requires expertise in multiple disciplines, is enabled by tools and resources to expose and address hazards when a design exists only on paper, and depends on an individual's and company's desire to move OSH management up the hierarchy of controls. Further research is needed that supports the interest in PTD and goals to expand its implementation in practice.

Presentations at the NIOSH conference reveal that research is being conducted throughout the R2P life cycle. This includes surveillance research to determine the connection between specific design features and OSH hazards. New PTD solutions are being developed, implemented and evaluated in practice. All of these steps are critical parts of the drive to expand and improve PTD implementation. As more safe design solutions are developed and implemented, research needs to continue to improve and optimize the solutions.

The conference presentations also reveal some important aspects of the concept and related research. PTD is a collaborative process; it requires input from designers, constructors/ manufacturers, facility users and maintainers, as well as from OSH professionals. All parties must be involved in the PTD process on the research and practice sides.

While PTD aims to improve OSH, other benefits also accrue. Quality, cost, productivity, morale and environmental stewardship improve due to PTD implementation as well. These additional benefits can be presented as motivating factors in PTD dissemination efforts.

In addition, implementation forces designers to think differently, change and innovate. Rather than selecting an OSH intervention that simply warns about or controls a hazard, PTD prompts designers to remove the hazard. This effort often contradicts standard practice in an industry, and challenges designers to create unique solutions that lead to innovation.

Research will continue as its use is expanded and optimized across all industrial sectors. The NIOSH presentations indicate that much research has been performed, yet more is needed. Further research is needed to evaluate risk factors associated with designs. With such factors, a design rating system should be developed that allows designers to proactively assess designs based on OSH. Investigations are needed to determine the connection between the design and those who build the product, and who use, maintain and work near it. Additionally, to increase diffusion of the concept, research is needed to explore opportunities to promote PTD and motivate stakeholders. Without acceptance of the concept by industry, and a desire to implement it, PTD diffusion will be impeded.

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Biographies

John Gambatese, Ph.D., P.E., is a professor in the School of Civil and Construction Engineering at Oregon State University. He holds a B.S. and an M.S. in Civil Engineering from University of California Berkeley, and a Ph.D. in Civil Engineering from University of Washington. Gambatese is a member of the American Society of Civil Engineers (ASCE) and ASSE, and actively participates on ASCE's Construction Site Safety Committee, Constructability Committee and Construction Research Council.

Matthew Hallowell, Ph.D., is an assistant professor at the University of Colorado, Boulder. He holds a Ph.D. with a dual focus in Construction Engineering and Management, and Occupational Safety and Health from Oregon State University. Hallowell conducts research in construction safety specializing in injury prevention strategies, risk management and cost modeling. Before moving to academia, Hallowell worked as a laborer for Fenderson-Howe Builders, project engineer for Pine Tree Engineering, engineering and construction manager for Penn Lyon Homes and president of Modular Design Solutions.

Frank M. Renshaw, Ph.D., CSP, CIH, is managing member of Bayberry EHS Consulting LLC, after 35 years with Dow Advanced Materials (formerly Rohm and Haas Co.), for which he held various safety-related positions. He is a past president of AIHA, AIHA

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Margaret M. Quinn, Sc.D., CIH, is a professor in the Department of Work Environment, University of Massachusetts Lowell. She has more than 25 years' experience in occupational and environmental safety and health professional practice, research and education. Quinn is the founding director of the Sustainable Hospitals Program in the Lowell Center for Sustainable Production, and she is a member of NIOSH's NORA Healthcare and Social Assistance Sector Council and the NIOSH Prevention Through Design Committee.

Pamela Heckel, Ph.D., P.E., is a senior service fellow at NIOSH, where she develops educational outreach materials for the Prevention Through Design initiative. Heckel holds a B.S. in Engineering from Vanderbilt University, a B.S. in Civil Engineering from Purdue University, and an M.S. in Architecture and a Ph.D. in Environmental Engineering from the University of Cincinnati. Her work experience includes design and manufacturing of nuclear reactors and construction of nuclear containment facilities.

Research Case Study

Integrated Environmental Sustainability & OSH for the Preventive Maintenance of Green Buildings

Advances in the design and construction of green buildings are making important contributions toward improving environmental quality, and the safety and health of building occupants. Recent case reports, however, provide evidence that green building features can present safety hazards for preventive maintenance workers who maintain the buildings.

A research study was conducted at the University of Massachusetts Lowell to develop, apply and evaluate practical methods to guide the design and operation of common green building features so as to protect and promote the occupational safety and health (OSH) of these workers.

In the first phase of the research, OSH impacts related to preventive maintenance of five common green building features were evaluated using job hazard analyses and structured interviews with maintenance workers. The green building features were identified by reviewing written applications for the buildings to be certified as green by U.S. Green Building Council (USGBC) using the Leadership in Energy and Environmental Design (LEED) rating system. Results show that the selected green building features posed an increased risk of OSH hazards to preventive maintenance workers. Many hazards were related to design aspects that could be redesigned to eliminate the hazard.

The second phase of the research explored practical means to incorporate OSH considerations into the design, commissioning and operation of green buildings. Six SH&E specialists were interviewed in the study and a rating system was developed: Occupational Safety and Health Assessment and Rating System for Green Buildings (OSHARS-GB). OSHARS-GB is compatible with the approach used by USGBC LEED rating system and is intended to be a practical tool for architects, builders, engineers, building owners and managers involved in the design and operation of green buildings. It promotes the design of green building features that prevent or minimize occupational hazards as compared to strategies that control, rather than eliminate, the hazard.

In the third phase of the research, six occupational and environmental safety and health specialists used the OSHARS-GB tool to evaluate five green building features in new buildings. Results show that all of the specialists could use OSHARS-GB as intended, that all were able to score the building features, and that there was consistency in the overall ratings of the OSH hazards of the green building features.

It was concluded that the OSHARS-GB could be used in practice to evaluate OSH hazards. When used together with the LEED rating system it is a practical tool to evaluate OSH along with environmental sustainability criteria. Future studies will be able to add new green building features to the OSHARS-GB tool.

Photo 1.
The Velodrome for the 2012 Olympics in London (Photo 1) involved a complex roof design with a unique shape. Hazards were removed prior to construction by using a design risk register; by conducting workshops to evaluate the safety implications of design alternatives; and through involvement of construction knowledge during design.

Photo 2. Use of a prefabricated formwork system (Photo 2) can lead to improve safety on construction sites

Photo 3. The redesigned bin (on the left in Photo 3, above) decreased injuries related to the original design (right)

Photo 4. Research involving hospital patient mechanical lifting devices (Photo 4) revealed a positive return on investment

Table 1

NIOSH PTD Conference Presentations Related to Research

Presentation title	Presenter
Construction (Design and Management) Regulations: PTD Survey of U.K. and U.K. Experience	Alistair Gibb, Ph.D., CEng, Loughborough University
Improving the Work Life of Workers in the Wine Grape Harvesting Industry Through PTD	Amy Wolfe, AgSafe
Design for the Environment Approaches to Safer Chemicals	Cal Baier-Anderson, Ph.D., U.S. EPA
Variability in Business Cases Associated With Adopting PTD Design Solutions	Elyce Anne Biddle, Ph.D., CDC, NIOSH
Incorporating Prevention Through Design Methods Into the Design and Redesign Process	Frank M. Renshaw, Ph.D., CSP, CIH, Bayberry EHS Consulting LLC
Alternatives Assessment in Context	Joel A. Tickner, Sc.D., University of Massachusetts Lowell
Findings from the Overall PTD in U.K. Study and Their Application to the U.S.	John A. Gambatese, Ph.D., P.E., Oregon State University
Implementing Prevention Through Design in Hospitals: Alternatives Assessment	Margaret M. Quinn, Ph.D., University of Massachusetts Lowell
Design Risk Analysis: An Attribute-Based Method	Matthew Hallowell, Ph.D., University of Colorado, Boulder
Structural Collapses During Construction: Lessons Learned 1990-2008	Mohammad Ayub, P.E., S.E., OSHA
Benchmarking Management Practices That Support PTD: ORC Worldwide Survey Results	Stephen Newell, Mercer ORC HSE Networks