THE CENTER FOR CONSTRUCTION
RESEARCH AND TRAINING

SYMPOSIUM REPORT

BEST PRACTICES FOR HEALTH AND SAFETY TECHNOLOGY TRANSFER IN CONSTRUCTION

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CPWR is a 501(c)(3) nonprofit research and training institution created by the Building and Construction Trades Department, AFL-CIO, and serves as the research arm of the BCTD. CPWR is uniquely situated to serve workers, contractors, and the scientific community. A major CPWR activity is to improve safety and health in the construction industry.

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SYMPOSIUM REPORT

EXECUTIVE SUMMARY

Construction work continues to be among the most hazardous occupations in the United States. In 2010, the Bureau of Labor Statistics reported that nearly 800 workers in construction-related fields lost their lives at work. The construction industry also continued to face an injury and illness rate of 4 reported cases per 100 workers.

CPWR – The Center for Construction Research and Training (CPWR) launched an initiative in 2010 to help ensure that research is applied to address the serious hazards in this industry. A first step in this "***research to practice***" initiative was a strategic review and "triage" of completed CPWR research to identify priority follow-up issues. Through this process, the issue of tech transfer challenges was identified.

In some cases new health and safety technologies and practices have been successfully introduced into the marketplace to prevent work-related injuries, illnesses, and fatalities. Still, there are many barriers to the introduction, commercialization, and diffusion of health and safety technologies into construction-related workplaces.

In order to better understand the conditions that support and promote the successful diffusion of health and safety technologies across the construction industry, CPWR organized and hosted a symposium entitled *Best Practices for Health and Safety Technology Transfer in Construction* held on May 30-31, 2012 at the Double Tree Hotel in Silver Spring, Maryland.

The event invited representatives from academia, government, manufacturing, contractor associations, labor, and the insurance industry to engage in a dialogue focused on identifying barriers, challenges, and strategic approaches to promoting the increased introduction, commercialization, and diffusion of health and safety technologies across the construction industry. Participants were provided a ***white paper*** based on a review of the technology transfer literature, as well as case studies in advance of the symposium.

The symposium kicked off with a poster session acquainting participants with a series of case studies describing efforts to introduce new health and safety technologies to the construction industry. This was followed by a panel discussion of these case studies. Subsequent breakout sessions allowed attendees to share their own thoughts, experiences, and recommendations related to health and safety technology transfer in construction. Breakout groups reported back to the larger group of participants on potential strategies to overcome barriers to health and safety technology transfer in construction.

The following seven recommendations came out of the meeting:

1. ***Develop and test a "road map" for technology transfer.***
2. ***Develop and support the testing of a business case model.***
3. ***Develop additional, more in-depth, case studies to capture the lessons from each phase of the program from development, testing, manufacturing, marketing, and diffusion.***
4. ***Develop a guide specifically for occupational safety and health researchers on patenting and licensing.***
5. ***Improve communication between researchers and manufacturers.***
6. ***Look into funding sources that can support the full work that needs to be done to bring a product into use.***
7. ***Review European certification systems for engineering equipment.***

CPWR committed to support programs for improved safety and health technology transfer in the construction industry.

INTRODUCTION

Construction work is still among the most dangerous areas of work in the United States. Technology transfer, or the process of converting scientific and technological advances into marketable goods (or services), is one method that has been identified to address construction workplace hazards. Indeed, the development, introduction, and commercialization of new health and safety technologies have, in some cases, successfully addressed hazards related to construction work sites. Noise reduction devices, proximity alert systems, and strain reducing tools such as the overhead drill are among the examples of technologies that have been successfully introduced to address safety and health concerns related to construction work. However, while these tools and technologies work, they are not in widespread use and most faced difficulties getting into the marketplace at all.

Technology transfer of health and safety innovations has been limited by an array of barriers and challenges. Much of the difficulty that emerges can arguably be attributed to the fact that the environment in which technology transfer takes place involves a complex landscape of various actors with differing motivations and goals. Moreover, the technology transfer environment related to health and safety presents especially unique challenges, since—at least on a large scale— employers and management have not traditionally viewed voluntary investments in health and safety improvements as a primary component to meeting their fiscal goals.

A more comprehensive understanding of the health and safety technology transfer landscape, the various actors, and their motivations and goals will help to foster increased successful commercialization and diffusion of health and safety innovations.

FEATURED PANELISTS AND HIGHLIGHTED CASE STUDIES DESCRIPTIONS

The *Best Practices for Health and Safety Technology Transfer in Construction* symposium featured 7 panelists who headed research projects to introduce, commercialize, and diffuse new health and safety technologies in construction. The case studies were selected to provide symposium participants with background on key issues in technology transfer. In order to illustrate the full range of issues involved in technology transfer, organizers showcased a mix of projects that have reached transfer success, those still in progress and those facing significant challenges. The case studies consisted of the following:

Residential Construction Safety Rail System

Dr. Thomas Bobick, Research Safety Engineer, NIOSH – Division of Safety Research

Driven by the prevalence of fatalities and severe injuries caused by workers falling through roof and floor openings, and existing skylights, the National Institute of Occupational Safety and Health (NIOSH) worked with residential carpenters to develop a multi-functional guardrail system that could be used in numerous work situations to prevent workers from falling to lower levels. [Transfer in progress]

The Asphalt Partnership

Gary Fore, TRIAD EH&S, The Asphalt Partnership

In the midst of a growing concern over asphalt paving workers' exposure to toxic asphalt fumes, stakeholders came together to form the Asphalt Paving Partnership. The Asphalt Paving Partnership provides a model of how partnerships can play a powerful role in preventing worker injury and illness. The partnership helped to develop and embrace an innovative, collaborative approach to reducing worker exposure to asphalt fumes and achieved the universal voluntary adoption of controls on all new highway class pavers. Building on its initial success, the partnership continued to pursue other health and safety efforts including the warm-mix initiative which continued to address exposure to fumes by reducing emissions at the source. [Transfer success]

Integrating Health and Safety into Project Management Software

Dr. Jim Platner, CPWR – Center for Construction Research and Training

Critical path management (CPM) software is used for project scheduling on virtually all medium-to-large construction projects. Although good scheduling has been shown to correlate with improved safety, no existing CPM software directly incorporated safety interventions or equipment into the schedule. This effort aimed to develop a software technology that would help to identify worker safety risks in construction project scheduling, and assist in making adjustments to promote safer conditions for workers. [Transfer challenge]

Successes in Research to Practice from the NIOSH Office of Mine Safety and Health Research

Robert F. Randolph, NIOSH

The Office of Mine Safety and Health Research (OMSHR) has established world-class research and development capabilities for every major health and safety hazard in mining. Just as important is the Office's research to practice (r2p) initiative that facilitates the transition of technologies from scientific concepts to laboratory prototypes and, finally, to products and solutions miners use every day. The Office's efforts have led to a series of devices that make machines quieter, identify hazardous dust, improve communication throughout the mine during emergencies, and render potentially explosive atmospheres safely inert. [Transfer success]

Inverted Drill Press

Dr. David Rempel, University of California San Francisco

Drilling overhead into a concrete or metal ceiling is punishing work. Construction workers who frequently perform this task with conventional tools often suffer soft tissue injuries in the hands, arms, shoulders, and backs. Data compiled shows that the Inverted Drill Press reduces force to the body by 90 percent, and diminishes fatigue in the neck, shoulders, hands, arms, lower back, and legs. Additional benefits include decreased injuries from falls by allowing workers to perform all tasks from ground level, reduced exposure to silica dust due to the dust collection feature, and potential increases in productivity. [Transfer success]

Business Case for Implementation Battery-powered Tools for Electric Utility Workers

Patricia Seeley, Ergonomics Solutions LLC

Common tasks performed by overhead and underground line workers in the electric power industry often involve the use of manual tools that increase worker injuries and can decrease worker productivity. Research shows that a quantitative business case that supports ergonomic recommendations can be a valuable tool to encourage intervention adoption. [Transfer success]

Autonomous Pro-Active Real-Time Construction Worker and Equipment Operator Proximity Safety Alert System

Dr. Jochen Teizer, School of Civil and Environmental Engineering, Georgia Institute of Technology

Typical construction environments are comprised of multiple resources such as construction personnel, equipment, and materials. A hazardous situation can exist when heavy construction equipment is operating in close proximity to ground workers. Statistics specific to proximity issues in construction demonstrate that current safety practices in construction are insufficient.

The Equipment and Personal Protection Units (EPU and PPU) prototype – a real-time proximity detection and warning system – has proven capable of alerting construction personnel and equipment operators during hazardous proximity situations. It also includes features which allow it to record valuable information about the frequency of proximity issues at individual sites. [Transfer in progress]

(Note: Full case studies are available on the CPWR Technology Transfer Symposium website.)

THEMES

Seven areas emerged as key themes from the *Best Practices for Health and Safety Technology Transfer in Construction* Symposium.

1. Identify and involve stakeholders
2. Make the business case
3. Test for usability
4. Understand the pros and cons of patenting and licensing
5. Be prepared for a long-term commitment
6. Consider construction industry culture
7. Consider external factors

1. Identify and involve stakeholders

Efforts to advance health and safety technology transfer should involve all stakeholders from the beginning. The symposium participants generally agreed that early and consistent involvement of multiple stakeholders from various types of organizations is essential to the successful adoption of new health and safety technologies. Researchers, manufacturers, insurance companies, contractors, workers, labor unions, and relevant government agencies were identified as some of the groups that should be considered for involvement in the process.

The Residential Construction Safety Rail System and Inverted Drill Press case studies demonstrate that early stakeholder engagement helps to create an active feedback mechanism to ensure that the technology design addresses barriers to adoption and usability problems early in the development process. In the case of the Safety Rail System, input from contractors and workers generated design modifications that led to several versions of the tool that address special roof conditions workers face in the field. With regard to the Inverted Drill Press, stakeholder engagement allowed more than 100 workers to test the usability of prototypes and make suggestions for design improvements. The Inverted Drill Press experienced 5 iterations before the current, vastly superior design emerged.

In discussing the Asphalt Partnership, Gary Fore emphasized the importance of including diverse stakeholders expected to be impacted by the introduction of the new technology innovation early in the development processes. Fore acknowledged that competing interests among diverse stakeholders can pose challenges. He noted that the stakeholder partners must be able to agree on, and commit to, a common mission to address the specific health and safety issue at hand. Other lessons of the Asphalt Partnership related to stakeholder involvement include the need to "agree to disagree" about contentious outside issues, emphasizing openness, transparency, and trust and paying attention to relationship building and group dynamics.[1]

1 For more information about the Asphalt Partnership, see CPWR – The Center for Construction Research and Training, ***The Asphalt Case Study Summary Report***, 2012.

Symposium participants noted that the identification of the "right partners" is a critical component of involving stakeholders in the processes of technology development and commercialization. Robert Randolph of the National Institute for Occupational Safety and Health (NIOSH) Office of Mine Safety and Health Research (OMSHR) introduced a model for identifying the right partners.

Randolph noted that the OMSHR begins by identifying all of the stakeholders that could potentially be affected by the introduction of the prospective new technology. OMSHR utilizes face-to-face networking opportunities to gauge an organization's interest and commitment to addressing the health and safety concern. OMSHR assesses candidates to determine if they possess the characteristics and capacities desired in a partner (e.g., problem-solving skills, and ample research and development resources). If the candidate organization is deemed to be a fitting partner, OMSHR develops a proposal for partnership and presents it to the organization. Randolph emphasized that the process of identifying the right partners requires an awareness and understanding of the issues that cause a specific organization concern or grief, and a customer service approach that acknowledges the importance of addressing these issues as a part of resolving the overall health and safety concern. The Asphalt Partnership case study also revealed that successful stakeholder partnerships require the establishment of a clearly defined mission focused on win-win outcomes. Furthermore, it was noted that who the right partners are may vary depending on the technology.

Academic studies support the perspective that early and consistent involvement of multiple stakeholders is essential to the successful adoption of new health and safety technologies. Johnson, Gatz, and Hicks (1997) found that early and regular contact with end users can help to overcome the social, political, economic, personal or cultural barriers to technology transfer. Reinke and Smith (2010) adds that close interaction between stakeholders during the "development, testing and refinement of noise controls" helps to address stakeholder needs and helps to provide the industry with "faster access to new controls." Raesfeld (2000) points out that successful technology transfer in construction requires the involvement of "those who develop, those who build, those who regulate, and those who use a technology." Lastly, Debackere, Leuven and Veugelers (2005) notes that technology transfer is "strongly influenced by the character and the intensity of the interactions and learning processes among producers, users, suppliers and public authorities."

2. Make the business case

Symposium participants commented that uncertainty about return on investment makes up a significant portion of manufacturer and contractor concerns about adopting a specific tool. There was a general concurrence that business case studies that demonstrate the organizational viability and financial benefits of adopting specific safety technologies can influence management decisions to adopt specific tools. A business case can focus on labor and materials costs saved, and the time involved to get a return on investment. These cases can be made by using field trials of products with productivity and health benefits measured.

The Business Case for Implementing Battery-Powered Tools case study served as an example of how the business case can be used to promote the adoption of health and safety technologies. The case study notes that the lack of a quantitative business case to support ergonomic recommendations is a frequent reason for non-adoption of interventions. Further, the case study reveals how data collected pertaining to the association between the adoption of battery-powered tools and increases in electric utility worker productivity was compiled and presented to management; ultimately persuading management to make significant investments in the safer tools. Data gathered during usability and field testing can be used to make the business case for the new tool or technology.

Although, the other case studies did not specifically mention using a business case approach, per se, many of the case study panelists noted the value of collecting and using quantitative data to illustrate positive returns on investment associated with adopting specific tools to contractors and other end users.

The case study on the Inverted Drill Press mentions productivity testing along with usability testing. Results of productivity testing can be used to make the business case for adoption. The Proximity Detector case study discussed the necessity of developing a cost-benefit analysis as part of the implementation strategy for the device. In addition, symposium participants noted that the business case should consider including information on the marketability of a product. The group also raised the idea of using students in the universities' business schools to develop the business case and do market research for new products.

Participants noted that industry managers are not likely to adopt a new solution based on injury data and research. They need to see return on investment and a focus on cost, productivity, quality, and safety. The big manufacturers must be able to project sales in the tens of thousands of pieces. Smaller niche manufacturers may be better suited for products that won't serve a large market.

Literature on the topic of health and safety technology transfer substantiates the position that private firms are more inclined to adopt a tool when the organizational viability and financial benefits are clearly illustrated. Entzel, Albers, and Welch (2007) observe that new technologies addressing musculoskeletal disorders among masons are more quickly adopted when they clearly demonstrate "financial savings in the form of increased productivity, decreased labor costs, or reduced workers' compensation costs." The authors note the need for "cost-benefit and return-on-investment analysis to highlight productivity and financial gains that may be achieved by implementing seemingly cost-prohibitive interventions." Similar findings relating to the importance of demonstrating the organizational and financial practicability related to adopting construction-related health and safety technologies are also noted in Stout and Linn (2002), Johnson et al. (1997), Rogers (1995), and Pursell (1993).

Other studies, including DeSimmone and Mitchell (2010) and Hasle and Limborg (2006), point out that small companies operate under different conditions and resource constraints than their larger counterparts. For example, a literature review by Hasle and Limborg found the need to take limited economic and human resources into account when trying to work with small businesses, and the need to disseminate solutions through personal contact. They also found that small businesses may have a better psychosocial work environment but that the environment is likely to be dependent on the owner's behavior. These conditions contribute to a unique culture that impacts decisions made related to health and safety. This research suggests these and other unique circumstances need to be taken into consideration in the development of a business case.

On the topic of marketability, an August 2012 study conducted by Boh, et. al., entitled *University Technology Transfer Through Entrepreneurship: Faculty and Students in Spinoffs* found that “graduate and post-doctoral students are critical participants in university commercialization efforts” (Virtual Strategy Magazine, 2012). The study reveals that mechanisms such as entrepreneur education, class assignments, mentoring programs, and business plan competitions help universities to engage students to help develop “business plans and create roadmaps for the commercialization of university technologies” without high costs for the university or the students (Kauffman Foundation, 2012).

3. Test for usability

Usability testing helps to identify and address prototype concerns, and ensure that tools work as desired. Several of the case studies highlighted the importance of usability testing via laboratory and/or field-testing as an essential component to increase the success of tool adoption, and group discussion supported the idea that usability testing is an essential element of technology transfer. The discussion also revealed that there are many bad tools being marketed and a history of tools that don’t work. This history has made some contractors wary of new tools that are promoted as ergonomic or safer.

Tom Bobick (NIOSH) noted that having access to a testing facility where rail system prototypes could be tested in real-life scenarios by contractors and workers played a substantial role in identifying safety rail design concerns early on in his Residential Construction Safety Rail System. This ultimately resulted in the development of several design offshoots to meet worker needs related to various specific roofing conditions.

David Rempel noted a similar experience in the development of the Inverted Drill Press. Rempel shared that approximately 100 workers (at 80 sites and by 30 contractors) field-tested prototype models of the tool and provided valuable feedback that resulted in 5 design adjustments, greatly improving the usability and productivity of the tool. The process allowed construction workers, who will ultimately end up using the tool, to recommend design features.

The case study focusing on battery-powered tools for electric utility workers unveiled that adopting new tools can involve unsettling changes in the way tasks are performed. These changes can impact work organization and workplace culture, and can sometimes conflict with competing demands (e.g., productivity). Trisha Seeley and other participants noted that the tools that experience the greatest rates of adoption are those that do not depart radically from current ways of performing tasks, and/or do not negatively impact worker productivity. Seeley echoed the sentiments of Bobick and Rempel that field-testing prior to commercialization helps to ensure that a tool works as desired; thus supporting the likelihood of widespread adoption. In response to this, the group noted the importance of demonstrating that the tool will hold up over time and does the task as intended.

It is particularly important to ensure that the right people are identified to test the tool/technology and to be able to demonstrate through testing that worker productivity does not suffer as a result of the tool's use. Furthermore, the products must not be promoted until they have been tested and proven to perform as desired. During both the group discussion and the breakout sessions, the importance of using union training centers as labs to evaluate usability and productivity was raised. Union training centers provide hands-on and classroom training to apprentices and journeymen. One breakout group participant noted that it is crucial to have the tool representatives go to the training facilities and show the workers how the tools are supposed to be used. Then the workers can use them and provide feedback. Another participant encouraged field testing, noting that it is essentially a "free sample" and gets new products into the hands of workers.

Testing may also be done in simulated circumstances, as in the example provided by Jochen Teizer in the Proximity Safety Alert System case study. His experiments simulated a typical construction environment to test the proximity detection devices prior to testing the device in the field with equipment operators. These experiments led the researcher to conclude that other parameters and potential influences on the system should be evaluated. These include the effects of temperature, humidity, and precipitation; mounting positions of the devices on workers and equipment; and workers' reaction to using the devices, including the extent to which the weight of the device impacts their ability to perform tasks.

Other participants pointed to the European Union's approach to certification of tools as a model for usability testing. The European Standard specifies a test bench method for the measurement of the emission rate of a given airborne hazardous substance from machines using a test bench under specified operating conditions of the machine. The measurement of the emission rates of any air contaminant, such as silica, can serve to: a) evaluate the performance of a machine; b) evaluate the reduction of pollutant emissions of the machine; c) compare machines within groups of machines with the same intended use (groups are defined by the function and materials processed); d) rank machines from the same group according to their emission rates; e) determine the state of the art of machines with respect to their emission rates.

Bob Randolph gave an example of a magnetic mining tool that had worked during computer simulations. The simulations led to the development of a prototype, yet once the prototype was tested by users it failed. The users were able to provide feedback for improvement. He warned of talking about a "great idea" before it is tested and noted that word of failure can go viral.

The importance of usability testing is also supported by research. Studies such as Farooqui, Ahmed, Panthi, and Azhar (2009) demonstrate that end users tend to abandon tools that cause discomfort, impede productivity, and/or negatively affect work quality. Other studies including Raesfeld (2002) and Johnson et al. (1997) show the early and continuous involvement of "end users" in the development of new technologies is essential to ensuring that the new tools adequately consider the concerns of the workers and to promoting greater rates of adoption.

4. Understand the pros and cons of patenting and licensing

The symposium produced a rich discussion on intellectual property (IP) issues relating to new health and safety technologies. Participants noted that university and government technology transfer offices often prioritize securing intellectual property over goals of spurring safety innovation. This strong emphasis on securing intellectual property can delay commercialization.

The Residential Safety Rail System case study illustrates the rigorous and lengthy nature of the patenting and licensing process. Moreover, it reveals that licensing agreements with manufacturers to commercialize the tool can raise other challenges to getting the safer product into use. The design for the Safety Rail System had to undergo a thorough evaluation to determine whether or not a patent would be pursued by NIOSH. Once the decision was made to pursue a patent, it took four years before the patent was finally issued. An exclusive licensing agreement was established with a manufacturer, but challenging economic times caused the manufacturer to delay production. Recently, the licensing agreement was amended to a nonexclusive status. Other manufacturers have now started to explore the opportunity to produce the tool. Bobick commented that, while he is proud of the patent, the process contributed to complications that have delayed the introduction of the Safety Rail System into the marketplace. He suggested, in some cases, it may be better to consider giving the design information away for free to promote quicker introduction of safety technologies into the marketplace.

David Rempel added that health and safety tools already face a challenge with the common perception that tools of this nature do not necessarily translate into large profits for investors. Rempel agreed that patents can create an additional barrier to commercialization.

Other symposium participants expressed disagreement with Bobick and Rempel. A participant noted that companies prefer patents because they provide protection from competition for a limited time. Without exclusive rights to produce the product, the cost and risk associated with making the tool are higher. Another participant commented that patents offer acknowledgement to inventors for their contributions to society. However, other participants noted that acknowledgement can be achieved through publication instead of a patent.

Symposium participants generally agreed that researchers would benefit from a more thorough understanding of intellectual property, and the pros and cons of patenting and licensing. They should use this understanding to work more effectively with manufacturers to increase health and safety technology transfer.

Studies also reveal the need for researchers to gain a greater understanding of intellectual property, and patenting and licensing issues. Speser (2011) notes, "deals between research institutions and companies or venture capitalists involve transactions between people who live within different cultural frameworks." Universities, Speser states, "have a culture primarily focused on the creation and transfer of knowledge through research, teaching, and publication. Corporate culture is primarily focused on generating profits." Thus, understanding how intellectual property is looked at from the different cultural perspectives will be useful to developing strategies to support quicker commercialization of tools.

In addition, other research points out alternative approaches to patenting and licensing. These include non-exclusive licenses for startups (DeSimmone and Mitchell, 2010); express licensing (Casola, 2011); and easy access IP and licensing (Speser, 2011). Awareness of these alternatives and education about the conditions in which they yield the best results would also be useful to researchers.

Lastly, researchers would likely benefit from instruction on the recent *America Invents Act* – signed by President Obama on September 16, 2011 – that aims to "help American entrepreneurs and businesses bring their inventions to market sooner" (White House Press Release, 2011).

5. Be prepared for a long-term commitment

Technology transfer takes time and funding. Bobick's Safety Rail System has been in the works for at least eight years. Rempel spent four years on productivity and usability testing for the Inverted Drill Press. The Asphalt Partnership took about 12 years to achieve reduced exposure to asphalt fumes on all new highway class pavers. The lesson is that those seeking to develop and introduce new tools and technologies into the construction market should not expect to do so quickly. It takes dedication and perseverance.

Many of the elements that were mentioned as those necessary for technology transfer to work – building successful partnerships, performing usability testing and field tests, then making the changes based on the feedback received during testing, building the business case for the tool, and getting patents – all require significant investments of time.

Presenters noted the amount of time it takes to bring a technology or tool from inception to market. In his presentation, Jochen Teizer stated that organizations often take too long to provide funding for projects. He noted that timeframes are important with regards to funding researchers and meeting industry demands.

The case study highlighting the effort to integrate health and safety considerations into project management software for project scheduling revealed that delays in tool development resulting from lengthy funding processes can also cause new software-based technologies to become outdated before they are ready to be introduced into the marketplace. The case study points out that rapid change in software applications can require unexpected changes and rapid development of the product. If it takes too long to develop the product, a new version may be needed to respond to a changing environment.

In an article on putting academic ideas into practice in construction, David Gann (2001) notes that "technological progress across the [construction] sector is …likely to be slow" since companies working in science and technology based sectors typically invest more in research and development than most construction organizations. In addition, the Electrical Power Research Institute's web site notes that the Technology Innovation organization within EPRI plans on a 5-10 year period for technology adoption.

6. Consider construction industry culture

Much of the discussion of the case studies underscored that the values, norms, and organization of the construction industry can significantly impact dissemination and adoption of safety innovations. Participants noted in a variety of ways that these cultural factors can help or hinder the diffusion process. For example, construction tends to be a traditional field, with crafts handed down from generation to generation (either within families or between journeymen and apprentices). There can be a resistance to change in the construction industry, as younger generations of workers often prefer to stick to the proven work practices handed down to them by their predecessors. Construction is also perceived as a somewhat closed culture. There is a common opinion expressed that those who don't "swing a hammer" (or climb a scaffold, or dig a trench) don't understand the nature of the work. Outsiders are not considered experts. Respected champions from within the industry play an important role.

Participants also emphasized that construction is generally a highly competitive industry, with many small businesses seeking to maintain a foothold. In this environment, productivity is paramount, making it difficult for contractors to consider a long-term return on investment, focusing instead on short term costs of any new equipment or methods. This can make it difficult for any one contractor to invest in improvements, unless all of his/her competitors are required to do the same. When a company does adopt a new method that is advantageous, there may be a tendency to keep the innovation as a competitive advantage, rather than spread the word.

The role of the construction culture as both a barrier and a driver for adoption of health and safety interventions is also described in the literature. The fragmented nature of the industry can inhibit diffusion. The lack of interaction between different trades, subcontractors, and individuals working as "independent contractors" is often noted, as well as the relative isolation of small contracting businesses. While larger companies are often kept up to date on safety innovation through safety professionals they employ, there is no such mechanism for the vast majority of contractors. On the other hand, the tremendous mobility of the industry, with workers and subcontractors moving from job to job, contractor to contractor, provides opportunities to observe and spread innovative practices. A particularly innovative contractor may have a broad influence in this way (Shepherd et al. 2010).

7. Consider external factors

Economic Climate

Symposium participants noted that the arduous economic climate in recent years has created an environment where businesses are more reluctant to make investments where quick investment returns are uncertain. Tom Bobick (NIOSH) shared that the company that initially obtained the exclusive license to manufacture the Residential Safety Rail System decided to delay its production of the tool due to the unfavorable market conditions for introducing the new product. Specifically, in his case study, Bobick advises that one of many questions to ask regarding external factors is "How is the economy? How dramatically will budget reductions affect development opportunities – both internally for continuing research activities, and externally for companies to accept the challenge and sign a licensing agreement for future collaboration or to agree to a partnership during an economic downturn?" Another participant commented that lots of great investment ideas are not pursued by companies for a variety of reasons, including limited resources, and the current economic situation only exacerbates the limited availability of investment capital.

Regulations and Standards

Traditional regulations and standards or the possibility thereof are still a driving force for workplace safety and health improvements, but should not be viewed as the only means to achieve safety and health improvements. Participants agreed that, historically, government regulations and standards have played a significant role in addressing workplace health and safety issues, and are an important part of making a business case. The Inverted Drill Press case study helps to illustrate this point; the California silica standard helped to increase employer interest in trying new technology that includes a feature that captures dust emissions and reduces worker exposure to silica as well as to musculoskeletal disorders and fall hazards. Gary Fore added that concerns about the potential designation of asphalt fumes as a carcinogen and of OSHA including it in an update to permissible exposure limits in construction was also a driver for the formation of the Asphalt Partnership.

Still, multiple participants pointed out weaknesses in an approach that relies on the establishment of regulations and standards as the sole driving force for change. The process to establish new regulations in the U.S. is a lengthy one, and therefore fails to address the immediate safety and health needs of workers. In her case study, Patricia Seeley stated that without the regulatory driver of an OSHA ergonomics standard, safety and health professionals need to learn to develop the business case for ergonomic interventions.

Publications confirm that the rulemaking process is too slow to protect workers who need immediate protection from hazards. *Cranes & Derricks: The Prolonged Creation of a Key Public Safety Rule*, by Public Citizen (2011), shows that even when a negotiated rulemaking process (a process designed to speed up rulemaking) was used it took 12 years for OSHA to issue the Cranes and Derricks standard. A 2012 U.S. Government Accountability Office (GAO) report, *Workplace Safety and Health: Multiple Challenges Lengthen OSHA's Standard Setting Process* (GAO-12-602T) shows that it has taken OSHA an average of 7 years and 9 months to develop and issue a standard, and that it has taken as long as 19 years.

RECOMMENDATIONS

Several recommendations for CPWR and other organizations to pursue came out of the symposium.

1. ***Develop and test a "road map" for tech transfer.*** Consider developing a web-based, interactive tool where one could access more detailed information, references, resources, and guidance relating to each of the phases of technology transfer. Seek an opportunity to test the model – including facilitation of the partnership process and building the business case.
2. ***Develop and support the testing of a business case model.*** A business case model based on the lessons learned presented at the symposium should be developed. CPWR should encourage dialogue between CPWR-funded researchers and business schools at those universities. At a minimum, researchers could benefit from relationships whereby business school students do market research, help develop a business case, and develop marketing plans for the researchers' technologies as part of their programs. CPWR should also promote the use of diffusion theory to inform commercialization plans.
3. ***Develop additional, and more in-depth, case studies to capture lessons from each phase of the program from development, testing, manufacturing, marketing, and diffusion.*** Participants commented that the case studies compiled for the symposium contained valuable lessons about health and safety technology transfer. Additional case studies could highlight lessons from each phase of a specific tool's development, testing, manufacturing, marketing, and diffusion. This would make it easier to compare and contrast approaches across the various case studies and better understand successful and less successful practices.
4. ***Develop a guide specifically for occupational safety and health researchers on patenting and licensing.*** Participants noted a need for researchers to gain a greater understanding of the patenting and licensing process. A recommendation was made to develop an educational resource that includes information on patenting and licensing processes, alternative routes to advance widespread adoption of a tool or technology, and guidance for researchers to assist in deciding when a specific approach may be most appropriate.
5. ***Improve communication between researchers and manufacturers.*** Perform in-depth interviews with manufacturers to understand the factors that influence their decision-making process. In addition, look for opportunities to learn from one another by exploring possible venues for bringing researchers together with manufacturers.
6. ***Look into funding sources that can support the full work that needs to be done to bring a product into use.*** Participants raised concerns about funding structures that result in delays for tool development that can potentially prolong the introduction of new technologies into the marketplace that are designed to decrease construction worker injuries and fatalities. It was suggested that there is a need for funding to support not just the research, but also the development stage of "research and development."
7. ***Review European certification systems for engineering equipment.*** A suggestion was made to review international certification systems to explore opportunities for establishment and implementation of similar systems in the United States. Specifically mentioned in one of the breakout sessions was the work done by the European Union to set standards for a test bench method for the measurement of the emission rate of any given airborne substance from tools under specified operating conditions.

CONCLUSION

Investments of knowledge, time, and funding have been made to develop and bring new safer tools and technologies into the construction marketplace. To date, however, the investment has not resulted in the market diffusion health and safety specialists have wanted to see. CPWR brought together those parties having a role in technology transfer in construction to explore the lessons learned from case examples of both successful and challenging tech transfer experiences. While significant challenges were noted, the conference identified several key elements to making the process work. CPWR will contribute to the development of an improved and sustainable technology transfer function in construction by focusing on these elements.

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