CASE STUDIES

BEST PRACTICES FOR HEALTH AND SAFETY TECHNOLOGY TRANSFER IN CONSTRUCTION

TABLE OF CONTENTS

Residential Construction Safety Rail System

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Relevance

The event – workers falling to a lower level – has been the primary cause of fatalities in construction since 1992, when the Bureau of Labor Statistics (BLS) began compiling the Census of Fatal Occupational Injury (CFOI) data. This project was initiated as a result of an analysis of the CFOI data. Analyses focused on fatalities and severe injuries caused by workers falling through roof and floor openings, and existing skylights. A pilot study evaluated the strength of guardrails (job-built and two commercial products) that were built around a typical roof opening by residential carpenters who served as test subjects. While evaluating the systems, a unique intervention was developed, which was the initial design of the NIOSH multi-functional guardrail system. The system was further modified through extensive laboratory testing so it could be used in numerous work situations to prevent workers from falling to lower levels.

Impact

The impact of using the NIOSH guardrail system is an adaptable fall-prevention system that is readily available to improve safety conditions for residential and commercial construction workers. The safety intervention can be installed to protect workers in situations where fall protection is not normally used. This guardrail system has the capability to provide protection to personnel who have to work near unguarded (1) roof edges, (2) skylights, (3) roof and floor openings, and (4) on stairs that have not yet had handrails installed. The easy-to-install fall-prevention system has been designed to meet OSHA safety requirements for guardrails. Through extensive testing in NIOSH labs, the final design will support more than twice the OSHA 200-pound top-rail strength requirement for a worker falling against it.

Currently, the system is being evaluated by two WV residential contractors in an on-going one-year field study. The contractors are using the system on a variety of homes to meet the requirements of the OSHA fall-protection standards. Training in the use of the fall-prevention system was provided by the West Virginia University Safety and Health (WVUS&H) Extension Office through a contract with NIOSH, using installation instructions developed by the project team. Interestingly, owners of both contracting firms commented that they normally don't use guardrails during residential construction. However, after the training session, which included a significant portion of hands-on practice installing the system on three typical construction situations (sloped, horizontal, and vertical orientations), all crew members felt very positive about using the system. During the first three months of the field study, both contractors have used the guardrail system, both externally on the roof and internally on stairs and for internal edge protection. Thus far, personal comments indicate high acceptance of this system.

The potential long-term outcome of using the NIOSH guardrail system is a reduction in fatalities and severe injuries (i.e., those involving days-away-from-work). During the 5-year period 2006-2010, a yearly average of 1,001 workers died from all causes in the U.S. construction industry. For the same period, a yearly average of 351 construction workers (35%) died because of falling from elevated work sites. During the same 5-year period, an average of 126 U.S. construction workers were fatally injured each year after falling from roofs and unprotected edges, or through unprotected roof and floor holes and skylights. These are all work situations for which the NIOSH guardrail system would be most effective.

Partnerships

During the 3 1/2-year process to develop and achieve a U.S. Patent for this system (U.S. Patent No. 7,509,702 was issued March 29, 2009), a total of 11 companies were approached about collaborating with NIOSH/CDC to manufacture and market this system. Engineering design drawings, which had been developed by the research team, were individually provided to the companies through a formal Material Transfer Agreement (MTA) process. Three companies were contacted specifically to provide a reliable estimate of costs to manufacture the five configurations developed for the system. The other companies were contacted and paperwork was prepared about collaborating with NIOSH/CDC through a licensing agreement process. During the 2010 American Society of Safety Engineers Meeting and Expo, held in Baltimore, MD, a safety equipment manufacturer talked with the research team at the NIOSH booth, where the guardrail system was installed on a mini-version of a sloped roof and an unfinished staircase. This safety equipment manufacturer became the 12th and final collaborator to work with the research team through an MTA. This company, AES Raptor LLC, North Kansas City, MO signed an exclusive licensing agreement with NIOSH-CDC in June 2011. The NIOSH guardrail system is being marketed under the trade name of Gorilla Rail™.

The role of partners in the research process was quite varied. During the initial development, a former Executive Director of the Construction Safety Council in Chicago and the Vice-President of Engineering for a manufacturer of a roof edge fall-protection system visited NIOSH to observe and comment on the guardrail system. Both individuals were supportive and gave encouraging insight. In fact, the roof edge fall-protection system manufacturer was the first company to sign an MTA to consider the licensing agreement. The company's small size prevented that licensing opportunity from being established. Site visits were arranged by the roof edge fall-protection system manufacturer where the initial design for the roof was modified (in concept) to the second configuration for use on horizontal surfaces. During discussions with the owner of a residential home building company, limitations related to where the horizontal configuration could be used resulted in the third variation for use on vertical surfaces. Another site visit with the roof edge fall-protection system manufacturer resulted in the vertical configuration being modified to the fourth design, the vertical component that has a 2 1/2-inch horizontal offset to clear the overhang of finished stair treads. Internal discussions by the research team resulted in the development of the fifth and final design - the slide guard variation for roofing work. Another research partner was the WVUS&H Extension Office, which assisted with recruiting the two construction contractors who are involved with the current field evaluation study, and developing the training program that was used during the explanation of the system's uses and installation procedures to the two contractors. Finally, individuals from the Center for Construction Research and Training (formerly CPWR), the Laborers' Union, the Roofers' Union, and the National Roofing Contractors Association were all supportive and offered constructive comments at different times during the development process.

Lessons Learned

Advice for others would be to establish working relationships with appropriate trade unions, professional societies, and other organizations related to the specific technology being developed or researched early in the development process. The focus should be on educating the end-users of the safety or health intervention being developed. Emphasis should involve establishing contacts and eliciting their input early in the research process to stay focused on what important features the end-users feel should be included. This would likely encourage them to accept and use the new technology.

This particular project dealt with developing and disseminating new technology. Whether a future project is focused on developing knowledge, intervention, or technology, it is important to realize that future success is heavily dependent on a variety of external factors. For example, is there a perceived need for the intervention? Once an intervention or technology is developed, what is the perception of its importance from the target industry? Can the intervention be easily used, and more important, can the technology be commercialized? Finally, 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? These are questions that have complicated answers. A combination of these factors will actually determine the success of future developments.

Expand on the above text to include the following, where possible:

1. Did you have any intellectual property barriers, or recommendations to make in this area, such as working with the university technology transfer office; patent application processes; and use of exclusive vs. non-exclusive licenses?

This research project dealt with the CDC Technology Transfer Office. After the initial design of the roof bracket system was developed, an Engineering Invention Report was prepared and submitted to the Tech Transfer Office in 2004. We provided them information about the potential effectiveness of and the possible extent of usage in the construction industry for this guardrail system. The Tech Transfer Office prepared an evaluation report as to whether a patent for the guardrail system design should be prepared or not. CDC decided to pursue the patent option and a patent application was prepared. The research team worked with the patent attorney to develop the unique claims that were applicable for this system's design. The patent application was filed with the U.S. Patent and Trademark Office during October 2005. The application was published during April 2007. A U.S. Patent (No. 7,509,702) was issued on March 31, 2009. The research team had discussions with a number of companies regarding possibly manufacturing and marketing the guardrail system as part of a licensing agreement with CDC and NIOSH. Eventually an exclusive licensing agreement was signed between CDC-NIOSH and AES Raptor LLC, North Kansas City, MO. The NIOSH guardrail system is now commercially available under the trade name Gorilla Rail™.

2. What were the usability barriers and how did you assess them and/or address them?: (a) did you identify expenses related to adopting, operating, and/or maintaining new safety and health technologies; (b) degree of worker training needed; (c) impact on job performance (i.e., worker comfort issues, impacts on productivity and/or quality of work); (d) concerns over new safety and health issues; and (e) adaptability to jobsite conditions

(a) There are expenses related to purchasing the guardrail system. The price list is available from the licensing partner. This one-time cost can be pro-rated over a number of job site usages. Costs to use the system are the recurring cost of the fasteners (either 16-penny nails or high-strength screws). If installed correctly, the 2-by-4 cross pieces (the top rail, midrail, and toe board) can be re-used from one job site to the next, thus reducing that repetitive (usage) cost. The system has been designed to be quite durable. Thus maintenance costs should be minimal. None of these costs, however, were part of this initial evaluation.

(b) Basic training is needed to ensure that the guardrail system is used appropriately and installed correctly. Each crew member of the two contractors received both formal classroom training and plenty of hands-on practice with installing all five components of the system. Pre- and post-evaluation tests were part of the training sessions.

(c) Using the guardrail system will improve the safety of the workers who normally work near roof edges that might only be protected with a slide guard system. Being safer (and feeling safer) will improve worker performance. The research team has gotten verbal feedback from workers and management of how much safer they feel when using the guardrail system, especially on 12-in-12 (45°) roofs.

(d) Trying to bring a new safety intervention onto the market during a severe economic downturn was bad timing, and resulted in an extremely difficult situation to deal with.

(e) This guardrail system was designed, tested, and modified specifically to be as adaptable as possible. This multi-functional system can be used on commercial, industrial, and residential flat roofs, as well as being adjustable to 7 different residential roof slopes (from 6-in-12 [27°] to 24-in-12 [63°]). In addition, four other variations were developed for installation on flat and vertical surfaces that are unprotected, including staircases before the handrails are installed.

3. Did you identify any incentives for adoption, such as: impact of existing regulations on adoption; and availability and access to financial incentives for research, manufacturing, and industry adoption (e.g., research funding, subsidized tool evaluation, tax breaks, insurance premium reductions)?

Interestingly, during December 2010, OSHA issued a new directive for the residential construction industry (STD 03-11-002) which rescinded the interim fall protection standards (STD 3.1 and STD 3-0.1A) that had been in effect since 1995 and 1999. OSHA will again be enforcing Subpart M (Fall Protection) of the Code of Federal Regulations (CFR), Title 29 (Labor), Part 1926 (Construction). This change in the fall protection standards will re-emphasize the requirement of using "personal fall arrest systems, covers, or guardrail systems" to protect workers who are required to work at elevations near unprotected holes and edges. The research team thought this might contribute to interest in purchasing the Gorilla Rail™ system.
For this project, internal NIOSH funding through the NORA process was the sole means by which the research was conducted for the years FY 2008 through2011. Unfortunately, there were no financial incentives available for manufacturing and industry adoption.

4. Did you identify any safety equipment marketing issues, such as: challenges in marketing safety features from research, manufacturing, industry consumer and end user perspective; discussion of push and pull factors?

The effects of the severe economic recession, which is still continuing (summer 2012) and is predicted to continue in the residential construction industry until mid-2014, presented an almost insurmountable challenge. Numerous safety-products companies had discussions with the research team and a few with the CDC Tech Transfer Office. Difficult decisions were made based on the depressed state of the residential construction market.
The exclusive licensing partner has been cautious in their marketing of the Gorilla Rail system. The company did display the Gorilla Rail product at the ASSE 2011 Exposition in Chicago in June 2011. This was their only "push" in marketing the product. The lack of OSHA pressure has contributed to a lack of "pull" (or demand) factors.

5. Let us know anything you think you learned about diffusion of innovation, such as: the influence of on-site "trialability" (i.e., the ability to experiment or test technologies in the field) on successful technology transfer; do you think there are types of tools that experience greater rates of early adoption, and did you learn anything about attributes of early adopters

The opportunity to conduct trialability of the system in real-world conditions was indeed a major highlight. A limited field study, which will continue to the fall of 2012, involving two northern West Virginia residential contractors has been extremely valuable for gathering feedback from workers and management who are using the system in a limited capacity.

The research team does not have any experience with early adopters. Thus, it is not possible to comment on what attributes are related to early adopters of innovations. Similarly, the research team could only conjecture as to what types of tools may experience early adoption by an industry.

The Asphalt Partnership

Gary Fore, TRIAD EH&S, The Asphalt Partnership

Background

The remarkable success of the Asphalt Paving Partnership provides a model of how partnerships can play a powerful role in preventing worker injury and illness. In the original Engineering Controls partnership, the partnership pioneered 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.[1] Building on its initial success, the partnership continued to pursue other health and safety efforts. These included the warm-mix initiative which continued to address exposure to fumes by reducing emissions at the source.

To understand the lessons offered by this successful partnership, the Center for Construction Research and Training (CPWR) conducted an in-depth case study of the Asphalt Paving Partnership as part of an overall Research to Practice (r2p) Initiative.

The case study research involved 15 interviews with industry, labor, and government stakeholders who have been involved in the Asphalt Partnership, as well as a review of background documents from the Asphalt Partnership, including award applications, trade articles, and research publications.

What is the Asphalt Partnership?

The Asphalt Partnership is a multi-stakeholder collaboration that aims to improve worker health and safety in the asphalt paving industry. Over its more than 15 year history, it has included partners from industry, labor, and government, as well as academic researchers.

Industry

-National Asphalt Pavement Association (NAPA)
-Association of Equipment Manufacturers (AEM)
- American Road and Transportation Builders Association (ARTBA)

Labor

-International Union of Operating Engineers (IUOE)
-Laborers' International Union of North America (LIUNA)
-Laborer's Health and Safety Fund of North America

Government

-The National Institute for Occupational Safety and Health (NIOSH)
-Occupational Safety and Health Administration (OSHA)
-Federal Highway Administration (FHWA)
- American Association of State Highway and Transportation Officials (AASHTO)
- State departments of transportation (DOTs)

[1] *Highway-Class Pavers:* Large paver equipment over 16,000 pounds

Asphalt Fumes

In the early 1990s, at a time of heightened awareness about toxic hazards in occupational health, concerns about the effects of asphalt fumes, and in particular, their potential to cause cancer among asphalt paving workers, were gaining momentum. NIOSH had been conducting research on asphalt fumes and OSHA was also exploring their inclusion in an update to permissible exposure limits in construction. Labor groups shared these concerns, and the Laborer's Health and Safety Fund issued a report on the health effects of asphalt fumes.[2] Additionally, Congress had recently passed legislation with a requirement to add crumb rubber from scrap tires to asphalt paving mix, and the FHWA was tasked with investigating the potential health effects.

From the industry perspective, a possible classification of asphalt fumes as an occupational carcinogen was a serious threat. In addition to adverse health consequences for workers, the carcinogen label carried potential implications for regulation, legal liability, and public perception. However, NAPA disagreed with conclusions drawn from existing research linking asphalt fumes to cancer and initially responded to government and labor's concerns by contesting the science.

Even as industry was investing substantial sums in research to counter government evidence, a breakthrough occurred within NAPA. A prominent paving contractor and chairperson of the association emerged as a champion for a new approach: he recalled thinking, "we're crazy to fight this. Why don't we just get away from exposing our people to these fumes, and then the issue goes away whether they're bad or good." The contractor leveraged his relationships to convince a core group of contractors and manufacturers to investigate the possibility of reducing worker exposures. Manufacturers developed prototype control packages, and initial tests suggested that fairly simple ventilation systems could significantly reduce the level of fumes near workers.

With promising preliminary tests of engineering controls, NAPA began reaching out to other stakeholder groups. They knew that they needed the collaboration of key government agencies and labor unions in order to move forward with developing, testing, and implementing the controls. Challenges to collaboration were substantial, with stakeholders from all sides – labor, government, and industry – all wary of participation. Leadership at NAPA embarked on efforts to establish trust and facilitate relationships within the fledgling partnership, a strategy which helped to overcome partners' concerns, and pave the way for future success.

What has the Asphalt Partnership accomplished?

In 1997, all six manufacturers signed a Voluntary Agreement with OSHA, FHWA, NAPA, and labor groups, agreeing to equip all new highway class pavers with engineering controls that capture at least 80% of the asphalt fumes generated during paving. By the mid-2000s, all such pavers in the United States included the controls. This timeline stands in contrast to the traditional OSHA rulemaking procedure in which it can take many years to even initiate the process for establishing a new health standard, and then typically up to ten years more to complete the process, if at all.[3,4,5]

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[2] Kojola, B. (1994). *Construction; An Emerging Issue, Asphalt Fumes*. Applied Occupational and Environmental Hygiene, 9(5), 323-329.

[3] Public Citizen. (October 2011). *OSHA Inaction: Onerous Requirements Imposed on OSHA Prevent the Agency from Issuing Lifesaving Rules*. Available at: http://www.citizen.org/documents/osha-inaction.pdf (Accessed 2/22/2012).

Follow-up field testing conducted by the partnership indicated that the engineering controls were effective at keeping worker exposure to asphalt fumes below the levels recommended by the American Conference of Governmental Industrial Hygienists (ACGIH).[6]

The partnership took protection from fumes a step further through a follow-up effort to develop, test and disseminate warm-mix asphalt, an achievement which collaborators describe as "the ultimate success story of the partnership." Warm-mix asphalt (as compared to traditional "hot mix" asphalt) can be laid at lower temperatures, so it emits fewer fumes, decreasing worker exposure by at least 30-50%.[7] The partnership's investment in innovations to decrease worker exposure also paid off in other ways: it was soon discovered that warm-mix also has considerable economic and environmental benefits, and it is now expected to largely replace traditional hot-mix pavements in the coming years.

In addition to the warm mix initiative, the partnership spun off additional collaborations and projects such as the testing and development of controls to suppress silica dust on asphalt milling machines; work-zone safety; and research to assess workers' dermal exposures to asphalt in the paving industry.

Lessons Learned

The partnership was able to sustain their health and safety efforts by developing lasting infrastructure for future collaboration. A variety of elements contributed to the partnership's success, and lessons learned from this case study include: 1) having a common vision with clear goals and concrete deliverables, 2) "agreeing to disagree" about contentious outside issues, 3) actively involving all stakeholders, 4) paying a high level of attention to relationship-building and group dynamics, 5) emphasizing openness, transparency, and trust, 6) having facilitators, champions, and leaders within the partnership. At the core of all activities was a commitment to rigorous science to support health and safety solutions and to fully integrate the strengths, resources, expertise, and concerns of all partners through development, testing, and adoption.

Conclusion

The collaboration attained universal adoption of engineering controls to reduce worker exposure to asphalt fumes faster, with less acrimony, and possibly more effectively, than attempting to advance a regulatory standard. Furthermore, they did not stop with this initial success but continued the work on other efforts to protect worker health.

Partners unequivocally believed that their model was transferrable to other areas of construction. By bringing together the right partners from labor, government, and industry, making the case for

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[4] National Advisory Committee on Occupational safety and Health (NACOSH). (June 2000). *Report and Recommendations Related to OSHA's Standards Development Process*. Available at: http://www.osha.gov/dop/nacosh/nreport.html (Accessed 2/22/2012).

[5] Skryzcki, Cindy. *OSHA Withdraws More Rules than it Makes, Reviews Find*. The Washington Post: Oct. 5, 2004; Page E01.

[6] Mickelsen, R.L., Shulman, S.A., Kriech, A.J., Osborne, L.V., & Redman, A.P. (2006). *Status of Worker Exposure to Asphalt Paving Fumes with the Use of Engineering Controls*. Environment, Science and Technology, 40, 5661-5667

[7] Federal Highway Administration, Office of International Programs. (February 2008). *Warm-Mix Asphalt: European Practice*. Available at: http://international.fhwa.dot.gov/pubs/pl08007/pl08007.pdf (Accessed 5/9/2012)

how a precautionary approach can create win-win situations, enlisting the help of skilled facilitators and champions, and building strong relationships through trust, transparency, and openness, real and significant change through "practical research and best practices implementation" is possible.

Focus Four Personal Digital Assistant (PDA) Audit Tool

Dr. Mark Fullen, West Virginia University

West Virginia University (WVU) has developed a dynamic audit program to assess risk for falls in construction, and adapted that audit for use on a Personal Digital Assistant that was originally used to measure fall hazard reduction as part of an intensive Fall Hazard Management intervention research project called "Fall-Safe." Based on industry interest "wanting the audit tool for their own use" WVU Technology Transfer supported the development of a for-profit spinoff "BackPocket" which was formed in 2003 and in 2004 secured a National Institute for Occupational Safety and Health (NIOSH) Small Business Innovation Research (SBIR) grant to develop the PDA application as a commercial product. Since the SBIR, the BackPocket software development partner dissolved, so WVU sought out a new partner in the industrial quality control PDA software development business. This partnership has not resulted in increased dissemination of the product and did not result in increased usability for the customer.

Since the original Fall-Safe audit tool development WVU has successfully utilized the existing auditing technology to measure changes in fall hazards pre- and post-intervention in a NIOSH study focused on Roof Brackets, in a study supported by the Occupational Safety and Health Administration (OSHA) Susan Harwood Residential Fall protection grant and to develop and test an electrical audit tool for worker use to measure electrical hazards over time supported by CPWR funding.

With lack of funding to support further development and the less than successful with an industry partner the plan to evolve the product into a full-fledged commercial product has stagnated. The rapid growth of iOS and Android applications has reinvigorated the project team and they are currently exploring ways to redevelop the audit tool for iOS and Android devices.

Health and Safety Integration into Project Management Software

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

Introduction

Critical path management (CPM) software is used for project scheduling on virtually all medium-to-large construction projects. The schedule provides a basis for coordination, planning, and adjusting time frames as the work progresses. Although good scheduling has been shown to correlate with improved safety, no CPM software incorporates safety interventions or equipment into the schedule.

Most activities that promote safety and health on the jobsite are tied, in some manner, to the schedule. For example, if there is an activity in the schedule for "Install Sewer Line", the safety manager should verify delivery and availability of trench boxes or shoring materials prior to the start of this activity. By monitoring progress on the schedule, safety personnel could ensure the well-being of the on-site workers and the neighboring community. Short term look-ahead schedules (usually one or two weeks) can also be generated from the master schedule, and are used by foremen and superintendents to manage the job, and to report back on progress or task completion to update the schedule.

Typically, ES&H managers do not have access or training to directly modify the schedule electronic file. Scheduling software has been a tool of the operations personnel, sometimes through a subcontracted scheduler, or the CM and there is great reluctance to "share" access to modify the schedule with ES&H personnel

Timeline/History

1996-1997 CPWR and colleagues at the University of Maryland College Park, and in collaboration with several members of the ASSE Construction group, proposed development of this software as part of a CPWR Intervention grant. Initial software described as "Safety CPM/Net Works". This consisted of two parts: "Safetybase" and a mock-up of "Safety/Net Integrator". SafetyBase was a database of construction hazards and check lists associated with specific Construction Specification Institute (CSI) MasterFormat cost codes. The focus was on technical safety/hazard control information. Safety/Net Integrator was intended to flag schedule items associated with certain CSI cost codes associated with high risk tasks. The software developer returned to India, and left no documented source code. However, the safety professionals involved were enthusiastic supporters, and encouraged CPWR to continue the project.

1999 CPWR approached Conceptual Arts and University of Florida. It was recognized by the new team that this approach required CSI codes be manually inserted into the schedule, which was not done on many projects at the time. They proposed a process to directly flag schedule activities that need safety management attention.

2000-2004 Jeff Nelson from Conceptual Arts, and a team assembled by Jimmie Hinzie from the M.E. Rinker School of Building Construction at the University of Florida proposed a redefined project which was named "Salus/JSA" and later "SALUS CPM". Through a co-developer agreement with Primavera they developed a very effective software program which would insert and track safety activities into a Primavera Suretrak schedule. This developer agreement was critical to assure access to changing Primavera schedule file formats and software changes. Although the safety professionals were enthusiastic about this innovative product, in field trials it was immediately apparent that most safety managers did not have access or authority to modify the project schedule on the large projects where this was most useful.. It appeared that because of the hours invested in creating and updating the schedule, schedulers were very protective.

2002-2004 A new approach was devised, named “Salus Link”. This worked in parallel with both Primavera P3 and Suretrak schedules, with read-only access, and regular updates from the master schedule file. It allowed safety managers their own version of the project schedule, in which they could link any electronic document or hyperlink to each schedule activity. These could be check-lists, policies, JSAs, tool box talks, slides, etc. It also provided a "project wrap-up" function that could be used at the end of the project to archive all of the linked documents with schedule information.

2006 Conceptual Arts applied for and was awarded a one year NIOSH Small Business Innovation Research (NIOSH) grant to commercialize this software product. Agreements were reached to pilot the software on projects with Bechtel, Bovis Lend Lease, and Willis Construction.

2008 Oracle Corporation purchased Primavera and terminated all third-party or external developer agreements. SBIR funds were returned and project terminated.

Software Development and Maintenance Challenges

Technology transfer related to new software products, or in this case add-ons to existing commercial software, presents multiple challenges:

1. Multiple platforms, multiple operating systems, complex network access issues. As these platforms change, software must be continuously updated in order to remain functional, and users now expect automated checks for updates over the internet. Even on construction sites, access to internet, WIFI, and cell phones have become an expectation. In a rapidly changing environment, software products must also be continuously updated to remain functional across multiple employers and multiple projects. Given that most grant funding is short term, at least the cost of updates and upgrades must be covered by income from a commercial product.
2. Rapid changes in applications, in this case Primavera P3 and Suretrak, can require unexpected changes and rapid development of the product. If you take too long to develop the product, a new version may be needed to respond to a changing environment.
3. Usability testing is critical, and is the norm. An additional challenge faced with SalusLink was verifying needs and usability from the perspectives of various positions within an organization. The product was enthusiastically received by safety managers, who immediately recognized the value of this tool, and how it would allow them to do their work faster and better. Until late in the process, the schedulers were not considered as part of the usability testing, only to find they could delay or block use of the software.
4. The perceived value of the software relied in part on the work that would be saved on future projects, since many components could be used on other projects with minor modifications. This initial barrier, of entering information and collecting documents on the first use, may discourage adoption.
5. Multiple interface formats, can now require redesign of user interface for several screen sizes (cell phone, tablet, desktop), and several versions of each. This can further increase the effort and cost of usability testing and updates.
6. Recruiting actual users is a challenge in construction. Scheduling is usually contractually required on a site by the owner or construction manager, which makes adoption of change easier. To be most effective schedules must span multiple employers on a project, so individual subcontractors may have little ability to influence site-wide use. There is limited research on organizational structures on multi-employer sites.

Outcomes/Conclusions

CPM scheduling software, of which Primavera remains the market leader for larger projects, still offer an opportunity for future improvements in planning and coordination of safety activities. On large multi-employer projects, which can consist of hundreds of overlapping contracts, paper-based schedules are often inadequate. Inadequate integration of safety managers into the construction design and operations teams continues to be an issue on many sites. As Building Information Management (BIM) software databases grow in popularity, these are a related opportunity for safety and health managers.

This project failure illustrates several challenges related to software development and updates, and organizational structures that can allow hoarding or restricting access to critical information (knowledge is power), and inadequate software security which is needed to increase confidence that data destroyed or changed by other employees or other employers can be readily recovered. Sharing requires trust, which can be difficult to develop on a rapidly changing multi-employer work site.

This project also illustrates the importance of understanding organizational structures and work processes, as well as technical knowledge. Safety managers and schedulers, for example, may not agree on the value of change.

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

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Mining has long been one of the most hazardous occupations, but technologies from NIOSH research have led to marked improvements. Miners now have devices to make their machines quieter, identify and avoid hazardous dust, communicate throughout the mine to survive emergencies, and render potentially explosive atmospheres safely inert. These technologies are the most recent examples of a series of innovations that are being generated by NIOSH's Office of Mine Safety and Health Research (OMSHR). The Office 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.

Transferring technologies to benefit miners is an integral part of the OMSHR mission to eliminate mining fatalities, injuries, and illnesses through research and prevention. The prevention aspect of this mission depends on ensuring that the research solutions are implemented in practice. At OMSHR, this is being done systematically by identifying the most important health and safety hazards, performing research and development of solutions, partnering with manufacturers to commercialize the solutions, and verifying that the solutions are effective.

OMSHR's recent successes addressing hazardous noise illustrate how this process works. The prevalence of hazardous noise from mining machines has resulted in over 80% of miners becoming hearing impaired by the time they retire. NIOSH has long advocated engineering controls that eliminate noise sources or isolate workers from noise as the most effective solution. Although earplugs and other hearing protection devices had been the dominant solution for mining noise, in 1999 NIOSH initiated a concentrated research effort to develop engineering controls for mining machines. Also, engineering noise controls are now required wherever feasible under a Mine Safety and Health Administration (MSHA) regulation that was put into effect in 2000.

NIOSH is systematically addressing noise in each sector of the mining industry, and underground coal miners benefit directly from NIOSH noise controls. When first beginning to develop engineering noise controls, NIOSH convened a stakeholder committee consisting of representatives from mining companies, labor unions, machinery manufacturers, and regulatory agencies. This Noise Committee and NIOSH reviewed the noise surveillance data and identified continuous mining machines and roof bolting machines as the primary sources of noise overexposures to underground coal miners.

Continuous Mining Machine Noise Controls

Implementing solutions for continuous mining machine noise involved several R&D studies and manufacturing partnerships. Initial studies showed that most of the noise was generated by the conveying system that moves coal from the machine's cutting head to the rear of the machine, where it is captured and hauled away by shuttle cars. NIOSH developed two solutions: Changing the conveyor chain design to use two drive sprockets instead of one and coating the horizontal metal flight bars on the chain with a tough urethane material. Both solutions reduced noise caused by metal-to-metal contact between the moving chain and the stationary conveyor assembly.

NIOSH involved manufacturers in the development process early on in the research process. One manufacturer, Cincinnati Mine Machinery, worked with NIOSH to develop a single-sprocket urethane-coated chain that is now in production. Joy Mining Machinery (the largest manufacturer of continuous mining machines) worked with NIOSH to develop the dual-sprocket chain and created a new production facility to accommodate the new chain configuration. NIOSH evaluation studies showed that the dual-sprocket chain results in a 3 dB(A) noise reduction, which is a 50% decrease in sound intensity. Since putting the dual-sprocket chain on the market in 2008, Joy has received 380 orders worldwide, with 311 of the chains installed on 30% of the continuous mining machines in the U.S. Joy has also worked with NIOSH to create a combination of a dual-sprocket chain with a urethane coating. NIOSH testing verified a 4 dB(A) noise reduction for this version and Joy has recently begun receiving orders for a commercially available model.

Roof Bolting Machine Noise Controls

Developing and implementing noise controls for the roof bolting machine followed a process similar to that for the continuous mining machine, with some variations. NIOSH found that over 50% of the operator's noise exposure occurred while drilling holes into the mine roof in preparation for installing bolts that hold the mine roof safely in place. Furthermore, most of the sound was radiated from a steel shaft used to drive the spinning drill bit through the rock and coal layers of the mine roof. NIOSH devised an isolator device that installs between the drill bit and the shaft to reduce transmitted vibrations that produce radiated sound. Because operators can drill over 100 holes every workday, it was important to develop a solution that would be durable and would not interfere with the worker's drilling procedure. NIOSH partnered with Kennametal Inc. (a major drilling component manufacturer) and Corry Rubber Corporation (a rubber isolation system manufacturer) to develop a device that would meet these noise reduction, durability, and usability goals. After development, a series of field tests under a range of conditions at participating mines confirmed that the design objectives had been met along with a 3-5 dB(A) noise reduction. The device is now commercially available and is already being used in mines.

Personal Dust Monitor

To reduce the risk of coal worker's pneumoconiosis (black lung), NIOSH developed the Personal Dust Monitor (PDM). The PDM is a mass-based, dust sampling instrument that provides real-time measurement of respirable dust exposure for mine workers. Under current dust regulations, a mine worker wears a gravimetric sampling pump to collect a respirable dust sample on a filter that is then mailed to the MSHA laboratory for processing. MSHA determines the average exposure concentration and sends the result to the mining company. This process takes one to two weeks, during which time the mine worker may continue to be overexposed. In a major advancement, the PDM provides the wearer a measure of his or her respirable dust exposure during the shift so that corrective actions can be taken to prevent an overexposure from occurring. NIOSH organized a partnership with industry, labor, and MSHA to help guide decision-making during the development of the PDM. Results from extensive laboratory testing and in-mine testing at 20% of underground coal mining sections determined that the PDM performance was equivalent to or better than that of the current gravimetric sampler. The PDM is commercialized by Thermo Fisher Scientific and has been certified by MSHA and NIOSH as an approved coal mine dust sampling device under requirements stipulated in 30 CFR Part 74. The PDM is specified as the compliance dust sampler in new dust regulations proposed by MSHA, which are expected to be finalized this year. In addition, approximately 200 PDMs have been purchased by mining companies and are being used to assess dust exposures and the effectiveness of dust control technologies.

Coal Dust Explosibility Meter

An ever-present danger in underground coal mining is the accumulation of combustible coal dust generated by the mining process. Federal regulations require that an incombustible material, such as pulverized limestone or dolomite, be applied in all underground areas of a coal mine to mitigate the propagation of a coal dust explosion by maintaining a total incombustible content (TIC) of at least 80%. The typical process of collecting samples, shipping them to a remote laboratory, analyzing them for TIC, and delivering the results to the mine is quite lengthy and leads to long delays in receiving notice of potentially explosible conditions. The Coal Dust Explosibility Meter (CDEM) allows immediate determination of the explosibility of a coal and rock dust mixture. In partnership with H&P Prototyping, Geneva College Center for Technology Development, and Sensidyne Inc., a handheld device has been successfully developed and commercialized for the industry. An extensive study in cooperation with the Mine Safety and Health Administration (MSHA) showed that 97% of the samples identified by the CDEM as being explosible or nonexplosible agreed with the results of parallel MSHA analyses.

This study strongly supports the use of the CDEM in the underground coal mining industry. To date, over 200 of these devices have already been purchased by U.S. coal operators to produce real-time assessments of explosibility of coal and rock dust mixtures, a significant improvement over the lengthy procedure currently employed. These mine operators use the CDEM to ensure that minimal inertization requirements are achieved to reduce the hazard of explosion propagation.

In-mine Gas Nitrogen Generating System

Mine seals are used in underground coal mines throughout the United States to isolate abandoned mining areas from the active mine workings. When a coal mine area is sealed, the atmosphere can become hazardous due to oxidation of coal and other materials in the sealed area. Methane gas may also accumulate in the sealed area and create an explosive mixture with the ambient oxygen. Adding inert gas to a sealed mine area is designed to quickly reduce the oxygen concentration in the sealed area to a level that will not support combustion. Under a program created by the Mine Improvement and New Emergency Response Act of 2006, also known as the MINER Act, NIOSH awarded a contract to On Site Gas Systems to design and construct a reliable in-mine mobile plant that would extract nitrogen gas from the mine atmosphere and use the gas to create and maintain a safe sealed mine area. Under this contract, On Site Gas Systems developed an altogether new pressure swing adsorption sieve bed design that achieves a breakthrough in reducing the size of the plant while maintaining an effectively high nitrogen output. The nitrogen gas output of the plant produces 95% purity at 300 standard cubic feet/minute. This unique gas-generating system can be placed within the mine in close proximity to a sealed area and provides mine operators with the capability to inert any sealed area for as long as needed. The system is currently available for sale to the mining industry.

Communication Systems

To improve the chances of surviving a mine emergency, the MINER Act mandates wireless communications and electronic tracking systems for all underground coal mines. These systems must be capable of surviving a mine disaster so that miners can use them to coordinate their escape and emergency response. The systems must also pass MSHA permissibility requirements for safe operation in a potentially explosive methane environment.

The Act required mine operators to include these systems in their Emergency Response Plans by June 2009, and required NIOSH to conduct the R&D and commercialization of these systems within that time frame. With only three years to develop and commercialize systems that did not exist prior to the Act, NIOSH collaborated with labor, industry, and regulatory stakeholders to identify candidate technologies that had the best chance of meeting the intent of the Act. NIOSH issued a series of competitive contracts that led to the commercialization of several permissible systems including the wireless mesh communications and tracking system manufactured by L3 Communications, and an enhanced leaky feeder communications system manufactured by Becker Mining Systems. All of these systems operate in a conventional radio band and provide the miner with a wireless communication device that is compact and portable. Nearly all underground coal mines now use this type of technology to establish a primary communications system.
More recently, NIOSH has developed secondary systems to serve as back-up systems or alternate communication paths for the primary systems. Unlike primary systems, these secondary systems operate in non-traditional parts of the electromagnetic spectrum, which reduces the need for vulnerable infrastructure in the mine and improves their survivability in a mine disaster. The secondary systems that are now commercially available and were developed in collaboration with NIOSH include a through-the-earth (TTE) communications system manufactured by Lockheed Martin and a medium frequency system manufactured by Kutta Technologies.

Summary

NIOSH has actively pursued a systematic r2p process for implementation of its research-based technologies in the workplace where they can protect miners from health and safety hazards. Although the processes have differed to some extent because of the technology, hazard addressed, and participants needed to complete the solution, there are several key commonalities across these development efforts. In every case, the need for the technology was established through hazard analysis and stakeholder input at the inception of the development process. Multiple stakeholders were involved along the way, especially mine operators, organized labor, regulators, and manufacturers. Actual development was performed by various combinations of NIOSH researchers, contract organizations, and potential manufacturers, depending on technical complexity and available resources. Regardless of the specific development path, each technology remained focused on reducing the targeted hazard, and its performance was evaluated repeatedly in laboratory simulations and in real-world trials. The successful development of these technologies is now being used as a model for more efficient development of new technologies that address other significant hazards in the mining industry.

Inverted Drill Press

Dr. David Rempel, University of California San Francisco

Drilling overhead into 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. To address the issue, David Rempel set out to design a tool that could keep workers off ladders when drilling overhead.

The Inverted Drill Press keeps workers safer by allowing them to perform all tasks from ground-level. Workers rated the Inverted Drill Press superior in many areas. It 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, and potential increases in productivity.

The Inverted Drill Press met and has overcome a series of challenges. Regarding intellectual property and patents, the University of California, San Francisco Office of Technology Management determined that the design of the Inverted Drill Press was not patentable because it incorporated several design features that had already been patented. The patent office does not grant patents for combined concepts. To overcome this hurdle, the company that ended up building the inverted drill press (TelPro) added several design features. TelPro has since applied for patents.

During the development process, a partnership including more than 20 contractors and labor unions provided invaluable input through focus group meetings, prototype development, and field testing opportunities with more than 100 workers in three states.

Over the course of 4 years, usability and productivity testing helped to identify and resolve many new safety, cord management, silica dust collection, rapid vertical alignment, transportation and storage, wheel type, drill stop, bit changing, and other issues. Also considered was worker training required (very little needed), maintenance (field testing identified failure points), and to some extent cost. Construction workers were able to recommend design features.

Through research and collaboration, the Inverted Drill Press evolved to have a tripod base on locking wheels, a telescoping vertical column with a drill-mounting saddle on top, alignment devices, and gears and a handwheel that extends and retracts the column. It can be assembled on-site in 30-seconds, weighs 90 pounds with a drill, and is compatible with scissor and other lifts. Some barriers still exist, such as transportation, storage, seating anchor bolts, and marketing.

To market the technology to tool manufacturers, presentations were given by the primary researcher at several construction safety meetings, union meetings, and contractor trade associations. This generated some interest, but manufacturers would be more befitted to develop more thorough and strategic marketing approaches.

With limited existing incentives to support the development and commercialization of construction health and safety technologies, the project funding provided by CPWR/NIOSH was essential. Secondly, the California Silica Dust Standard helped to motivate contractors to try the device. Construction insurance companies have also been supportive, but they have not offered premium reductions to date.

Business Case for Implementing 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 a manual tool. A biomechanical analysis revealed that less than 1 % of the general population has sufficient strength to manually perform this common task, resulting in decreased productivity and worker injury.

Ergonomics work task studies of four distinct line worker populations sponsored by EPRI (Electric Power Research Institute) revealed that the ergonomic interventions with the greatest improvement in worker occupational health as well as productivity were battery-powered cutters and crimpers. However, battery-powered tools of this nature can cost over $3500 each, compared to less than $300 for their manual counterparts. Often three or more such tools were required per line crew; unlike manual tools, replacement tools and batteries would be needed at regular intervals.

These studies were initiated by a request to EPRI for funding from the lead safety consultant and the occupational health nurse at Wisconsin Electric (now known as We Energies). This request followed a pilot study of preassembly warehouse operations conducted by Marquette University and funded internally. Since the first study, EPRI has spent several million dollars each for 3-4 year studies of overhead, direct bury cable, and cable/conduit line workers; power plant operators, mechanics, electricians and plant design; utility fleet process, fleet mechanics, vehicle specifications and design. Each study has included a unique business case. We Energies provided over two million dollars of in-kind contributions for worker bimonthly meeting time and travel, and time for pilot field studies in between meetings. By combining funds from up to 32 utilities, these studies have had a large impact on the occupational health and productivity of several hundred thousand workers in the industry.

A business case was developed by the corporate ergonomist for the purchase of the first set of battery-powered tools for overhead line workers. Implementation problems were identified and subsequently addressed for the succeeding three business cases for direct bury cable, cable/conduit, and troubleshooter line mechanics. These included: holding workers and managers accountable for intentional misuse and breakage of tools, purchase of the wrong, insufficient or excessive number of tools for some work groups, continuation of manual tool usage by workers who did not want to change. The effects on injuries among the 300 overhead line workers far exceeded predictions.

The following business cases focused far more on productivity benefits for cost savings and justification of their purchase. Each business case was tailored to the unique characteristics of the work group, based on interviews and available data on workers, illnesses, their work tasks. The business cases resulted in payback periods varying from six to 14 months. As a result of these business cases, the electric utility spent over $2,000,000 to purchase battery-powered tools for all of its line mechanic crews.

In addition, some simpler business cases for “no-brainer” interventions were very easy to adopt due to the labor and material costs saved. These were developed by a team organized by the outside materials vendor engineer to promote field trials of new products with productivity and health benefits. Ultimately, the manufacturers just sent them to We Energies before launching new products.

Lessons Learned

Partnerships may include various actors such as trade and research organizations, vendors, manufacturers, distributors as well as the companies who are the potential customers of new tools, materials, and equipment. These partnerships offer a mechanism for communication with external organizations that may have an influence on the successful commercialization of the technology. Early and consistent communication among these organizations during the development process can help to identify potential problems before attempting to introduce a technology into the market.

Partnerships that will get the tools in the workers' hands may also be pursued by vendors and manufacturers with the companies who employ these workers and would be their target customers. For example, We Energies worked successfully with Milwaukee Electric Tools, Huskie Tools, and Snap on Tools on several projects. We Energies ergonomics worker teams identified several safety, ergonomic and productivity issues with existing tools. They trialed the tools of several manufacturers and then went to the companies for modifications. One example was for Milwaukee Electric to give them a new prototype of their cordless impact tool which was sorely needed to replace gas powered drills with numerous operational and safety concerns. It was found to be the best performer among several tested, but line workers needed it to have a ring for hanging on a lanyard as well as a keyless chuck quick connect. Milwaukee Electric engineers provided a prototype within one week. It met with instant acceptance. The overhead line workers ergonomics team presented it to upper management and they requested several hundred be manufactured by Milwaukee Electric. At this point, the vice president of Milwaukee Electric called the corporate ergonomist and asked her "just how many utility workers are there in the US?" The company had always marketed to the construction and residential purchaser, and had never considered that utilities also perform construction tasks. This led to new marketing, research, and production opportunities.

Another case study involved Border States Electric, who had the distribution line of business tools and materials contract with We Energies. An engineer at Border States formed a health and safety team to review new trends in utility goods. By providing lunch and a convenient meeting place, he convinced We Energies employees to meet with him on a monthly basis. Two teams were formed: one for overhead, one for underground operations. They consisted of two engineers, a representative of supply chain, a health and safety onsite expert, a member of the appropriate ergonomics team. He presented new and potential applications. In many cases, the engineers were the naysayers and had to be convinced that the item would meet electrical codes and safety requirements. The workers would test them in the field and report back. Once the engineers signed off, the team would prepare a business case of how much time would be saved per application with the new product or method. A good example was gel wrapped underground cable slices. While the new—not even on the market—product was quite expensive it saved many minutes over the traditional heat shrink method and provided substantial health and safety benefits as well. It was decided by We Energies to purchase them for large storm emergency outage use only when time to restore service was of the essence. After several months of field usage, the time savings were proven to make them cost effective for all direct buried cable faults. In one year's time, the team saved the company over one million dollars with several recommendations, an amount expanded substantially in future years.

Lack of a quantitative business case to support ergonomic recommendations is a frequent reason for non-adoption of interventions. Proper documentation and sound methodology can lead to relatively short payback periods, which can greatly increase the probability of the implementation of the interventions. The business case process for the battery-powered tools presented in this manuscript could assist health and safety professionals in their efforts to implement ergonomic interventions.

Lacking the regulatory impact of an OSHA ergonomics standard--apart from the general duty clause--occupational health and safety professionals need training in the necessity of and methods for developing business cases for ergonomics interventions. In addition, they need to learn how to best present them to the intended audience: supervisors and crew leaders, mid-managers, as well as top management. All involved need to be receptive to consideration of additional cost savings apart from workers compensation. Once an ergonomic intervention is approved and purchased, workers and management need to be champions for addressing implementation difficulties. Finally, success needs to be marketed, so that cost-effective and readily accepted ergonomic solutions continue to be communicated across the company and the whole industry, making the case that ergonomic investment can have a short payback period.

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Business case summaries from selected EPRI studies—applications at We Energies			
	Data	The REAL driver	Outcomes
Battery operated tools: overhead	Training apprentices, replacement workers	Capital funds that were running out FPL—same thing—they had Fed $ from Hurricane disaster relief	$2 million spent on these tools at We Energies Several "knucklehead" workers who had not been on the ergonomics team decided to intentionally break the cutters—it took the VP to come down on them, retrain everyone, to hold them accountable. Next time—get buyin from all over the company
Battery operated tools: underground	Sick days used for MSDs Productivity: current vs. proposed labor	Worker buyin to no brainer solutions CAIDI—reliability measure (time to restore service was cut to 1/3 or less)	One worker quit the team when we didn't recommend what he liked (1 second faster, 1 lb lighter) , badmouthed efforts. But tools selected were same brand as overhead with same ergonomic and productivity benefits as his preference, much longer warranty, and huge benefit of using the same battery
Knee pads—power plants	Strict cause-effect relationship between occupational hard surface kneeling and expensive knee MSDs	No OSHA mandate—yet Workers don't like restrictive knee pads We make them available—they should use them Belief that knee injuries are age related	Found knee pads in pants—always available, comfortable Workers love them Now—gel pads permanently in the pants
Pneumatic "ergonomic" cart wheels	Not perceived by Mgt as a problem	New wheels last a lot longer , are easier to push/turn, saves money (higher initial cost—much less effort (time saved) and longer replacement window WIN WIN	6 wheeled cart even better The carts with pneumatic wheels continually "walked off"—couldn't find them—even painted bright red—(hidden by "thieves")
Platforms for power plant access	Many done as retrofits after months/years	Regulation Design company won't operate the plant (except for Southern Company) States allow only so much in capital plant design/construction—has to come out of operating funds	 Retrofit costs 10-40* upfront cost—this is stupid but the norm A few get done—not 1/4 of what is needed
Engineers need training in how to design for the workers	We have engineer design courses for ergonomics now (EPRI—Tailored collaboration)	4 engineers had getting this course designed after it was added to their annual performance goals. They were strongly motivated because their pay increase was hanging on getting this done.	For implementation, need capital funds to complete a few projects/year Engineers are using the guidelines and pushing to get their designs approved Other utilities are requiring this training

Costs from Manual Pressing of Connectors and Manual Cutting of Cable at the Host Utility and Costs that can be Saved by Purchase of Battery-operate Tools (Based on 123 Cumulative Injuries to Direct Buried Cable Workers at Host Utility from 1999-2003)

Type of Data	Description of Data	Total Cost from MSDs 1999-2003	Annual Cost During 1999-2003 period	Annual Cost Savings projected
WC costs from 123 injuries	Medical and indemnity	$104,788	$20,958	**$6986** (1/3)
Replacement workers for LWD	Avg. pay rate for URD installers +31% benefits=$50/hour 8 hours/day for LWD, 4 hours for RWD	$74,400	$14,880	**$4960** (1/3)
Replacement workers for RWD	Avg. pay rate for URD installers +31% benefits=$50/hour, 4 hours/day for RWD	$138,600	$27,720	**$9240** (1/3)
Elimination of future purchase and repair of manual tools	Manual and remote hydraulic tools for pressing connectors and cutting cable	$12,498 (19 mos)	$7893	**$2,836** (from replacement/repair of tools turned in)
Productivity—labor cost—savings from reduced setup time and excavation size	1 hour per week setup, ½ hour/day excavation for dedicated URD crews only		$57,200 setup $143,000 excavation	**$200,200**
			Total annual savings	**$224,222**

Cost/Benefit Analysis Summary and Payback Data

Category	Annual savings projected	Totals	Annual Costs
WC	$6986		
LWD	$4960		
RWD	$9240		
Productivity	**$200,200**		
Manual tool repair and replacement	$2836		
Purchase of Battery Tools		$254,937	$50,987
Repair of battery tools (broken blades)		$20230	$4046
Total	$224,222 annual savings	$275,167	$55,033 costs
	Payback Period **3 months/year if tools are capitalized over 5 years;** **($55,033/$224,222=0.25 years or 3 months)** **Payback Period** **15 months if paid in lump sum** **($275,179/$224,222 = 1.23 years or 15 months**		

Data for 2nd Business case for Battery powered tools

In order to determine whether the battery-powered tools would be cost-effective replacements for the manual press and cutter, the corporate ergonomist for the host utility compiled medical and other cost data from WC for the OSHA recordable injuries. In addition, the corporate ergonomist and a specially-appointed implementation team reviewed the following cost data outside the WC system that were attributed to the 123 cumulative injuries. All of this data is summarized in the tables

- Replacement workers for LWD and a percentage of RWD (light duty days)
- Productivity gains from the URD workers and supervisors' estimates—after nearly two years' trial use in the field—on the frequency of use of the .battery-operated tools where there were reduced times documented. There were two categories of time savings
    - reduced setup times as compared to the hydraulic tools This was calculated as 1 hour per week for the dedicated URD crews.
    - reduced excavation size. A smaller trench means less hand digging. This not only reduces time but also can be expected over a period of years to lower the rate of MSDs due to digging and shoveling. Crews stated that they used the battery-operated tools at least 10% of the time or 4 hours per week, though overtime is sometimes required, it was not involved in the calculations. Troubleshooting crews would have similar savings. In the end, a more conservative figure of 2.5 hours per week for a dedicated URD crew was used. No productivity forecasts were included for the cross-trained overhead/underground crews were included because the implementation team did not include supervisors and workers from this portion of the host utility in order to capture the time savings. This can certainly be done in the near future, but was not necessary to make the business case.

- Repair or replacement of the existing manual cutters and crimpers. This data was supplied from the Supply Chain and distributor. Elimination of certain manual tools could be expected to save these costs as long as they would be turned in when the new tools were distributed. This was a very controversial issue with the overhead line crews. In the intervening two years, however, underground crews were well aware of the benefits of use of battery-operated tools and there were few objections to giving up tools. The only difficulty was accounting for their location and numbers. Also, since cable sizes and work practices differ greatly across the utility, which tools were needed before and after the rollout of battery operated replacements varied widely for trouble or customer restoration work.
- In addition to the cost of the tools, it was learned that there may be additional costs associated with damaged tools. Investigation of these incidents showed patterns in selected locations with repeated breakage, particularly with the cutters by workers who chose to cut items which the tools were not designed to handle. As a result the blades were typically broken. After one year's experience, the breakage trickled to a minimum with familiarity. Hence, a smaller allocation was calculated as a tool cost.
- There are categories of data which do not appear in this analysis. Clerical costs and training costs are not included. New hires acquisition and training required due to replacement of injured workers were not included. This is because when the host utility was making its business case, the less intractable data—WC costs, productivity-were more readily available and made a highly compelling case without the full data set. In addition, the host utility had already developed an articulated process for ergonomics analysis, recommendations, the business case and implementation which was predisposed to accept its findings since the demonstrated benefits of the previously chosen battery-operated tools were so great.

Business Case Presentation Lessons Learned

The initial business case was presented to the Ergonomics Steering Committee. While the committee approved the concept, it was mandated that the implementation team meet with supervisors in each of the areas in order to review work practices, cable sizes, numbers and types of tools required. This had not been done in the overhead battery tools rollout and probably resulted in some of the tool breakage and cultural concerns raised.

Following this presentation, at least one member of the implementation team and a URD ergonomics team member working on a crew in the area met with area supervisors within a three week period. This was an extremely tight time schedule mandated by the need to capitalize the tools during the current calendar year, receiving them from the manufacturer before mid-December. Experience from the overhead rollout was referenced to get Supply Chain to put out requests for bids and issue the resulting requisitions in a short time window.

These meetings revealed considerably varying needs. The dedicated URD crews would be getting one 6.6 ton, 2 ½" jaw opening scissor type battery-operated cutter, one battery-operated scissor type 6 ton crimper (with a closed jaw to reduce excavation time, otherwise the same as the overhead crimper) and also an additional, somewhat slower gear driven cutter for use in repairing service outages with two workers in a trench.

The other crews in the northern portion of the utility's customer area would receive no additional 6 ton crimpers since they already had them from the overhead rollout. They requested additional 12 ton crimpers (one per service center was previously approved last year and more were needed up north), and two 6.6 ton cutters. They were unable to use the gear driven cutters due to their typical cable sizes.

It was vital to ask the supervisors and their workers for their input and to have someone from the team who had used the various tools over a period of time to explain the relative merits for their specific work requirements.

Ultimately, the initial request of $217,500 was increased to $254,937 with this input. The tools were put out for competitive bids and the utility realized some quantity cost savings. The tools were capitalized over a five year period.

It also needs to be noted that business cases for the host utility are works in progress. Typically when the presentation is made, there are numerous requests for additional and modified data. Often the final decision involves a different number and/or type of tools from the initial recommendation. Furthermore, the utility may find additional cost savings through quantity purchases. It is highly recommended that utilities review their cost/benefit results in the next several succeeding years.

Descriptions and costs of battery-powered tools for direct-buried cable work

Tool Description	OVH[1] or URD[2] Use	Number for URD /OVH Crews[3]	Number for URD Crews[4]	Total Number	Estimated Cost for Each[5]	Total
6.6 ton scissor-type cutter	*URD only*	*10*	*36*	*46*	*$3,033*	*$139,518*
Gear-driven 2” jaw cutter (slower than 6.6 ton cutter)	*URD only*	*0*	*27*	*27*	*$1915*	*$51,705*
12 ton press	*URD only*	*4*	*0*	*4*	*$3500*	*$14,000*
6 ton press (dedicated URD version is closed jawed, OVH is open jawed)	*URD and OVH*	*0*	*16*	*16*	*$2271*	*$36,336*
Scissor-type overhead 1 3/16” dia.	*OVH*	*5*	*0*	*5*	*$2678*	*$13,390*
					Total Cost = $254,949	

[1] OVH = overhead
[2] URD = underground residential distribution (direct-buried cable)
[3] Cross-trained crews that do both URD and OVH
[4] Dedicated URD crews
[5] Rounded estimate

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

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Introduction

Each construction jobsite has a unique size and set of working conditions. Typical construction environments are comprised of multiple resources such as construction personnel, equipment and materials. These resources perform dynamic construction activities in a defined space, and they often are in close proximity to each other. A hazardous situation can exist when heavy construction equipment is operating in close proximity to ground workers. Contact collisions between ground workers and heavy construction equipment can increase the risk of injuries and fatalities for construction personnel.

Previous research efforts have reported construction statistics on injuries and fatalities due to collisions between construction equipment and workers. Because construction projects often involve many repetitive tasks, construction workers can experience decreased awareness and loss of focus (Pratt et al. 2001). Equipment operator visibility, specifically operator blind spots, also contributes to contact collisions between construction equipment and ground workers (Fullerton et al. 2009).

A real-time proximity detection and warning system capable of alerting construction personnel and equipment operators during hazardous proximity situations is needed to promote safety on construction jobsites. It is assumed that the construction industry can realize significant improvements in safety if technology is applied while implementing safety management practices (Fullerton et al. 2009).

A lack of scientific evaluation data currently exists for new and existing construction safety technologies. Minimal information exists to demonstrate how commercially-available technology can be used to warn construction personnel of the presence of hazards in real-time, specifically proximity issues. Emerging safety technology for construction needs to be thoroughly evaluated through experiments simulating conditions in the construction environment. Analysis of the data can reveal the validity and effectiveness of these emerging technologies.

Pro-active safety technologies using secure radio frequency (RF) were reviewed for effectiveness in the construction environment.

Real-time Pro-Active Proximity Warning and Alert Technology

Pro-active safety technologies implemented on construction jobsites are capable of providing alerts to construction workers and equipment operators in real-time when a hazardous proximity issue is present (Teizer et al. 2010). Existing safety technologies can potentially create a safety barrier providing workers with a “second chance” if previous safety best practices are deficient (Teizer et al. 2008). This new information and warning system can promote safety in construction and provide new data sources.

Ruff (2001) found several proximity warning systems including RADAR (Radio Detection and Ranging), sonar, Global Positioning System (GPS), radio transceiver tags, cameras, and combinations of the mentioned technologies. The study found each of these technologies to have limitations such as availability of signal, size, weight and feasibility in the construction environment (Ruff 2001).

The construction industry needs a wireless, reliable and rugged technology capable of sensing and alerting workers when hazardous proximity issues exist. Teizer et al. (2010) demonstrated that radio frequency (RF) can satisfy the jobsite safety requirements.

Objective of Evaluating Proximity Warning and Alert Technologies

The objective of this research is to promote and increase construction jobsite safety for workers during heavy equipment operations by using radio frequency technology for real-time pro-active proximity warning devices. If two or more construction resources are in too close proximity to one another, the sensing technology will activate alarms to warn workers through devices called Equipment and Personal Protection Units (EPU and PPU).

The radio frequency technology was evaluated using two different experimental configurations. The experiments were designed to measure the performance of the technology in a simulated outdoor construction environment. The experiment tested the device's ability to detect and alert equipment operators of hazardous proximity issues.

Experiments and Results

Each experiment was designed to evaluate the effectiveness of proximity detection technology in the construction environment. Each experiment attempted to simulate a typical construction environment and test the proximity detection devices in the created environment. The proximity detection system utilized for the experiments used a secure wireless communication line of Very High Frequency (VHF) active Radio Frequency (RF) technology near 700 MHz (Teizer et al. 2010).

Technology Tested

Radio frequency (RF) technology was employed for each of the proximity detection experiments. The EPU component of the proximity detection device contains a single antenna, reader, alert mechanism and can be powered by the existing battery on the piece of equipment. The PPU is a handheld device that can be installed on a hard hat of a construction worker. This device contains a chip, battery and alert mechanism. A signal broadcasted by the EPU is intercepted by the PPU when the devices are in close proximity of one another. The proximity range can be manually modified by the user to lengthen or shorten the range in which an alert is activated. When the PPU intercepts the radio signal, it immediately returns a signal and both the EPU and PPU alarms are activated instantaneously in real-time.

These proximity detection devices can have up to three different alarm methods: audible, visual and vibratory. The proximity detection system selected for this research only provides the equipment operator a visual and audible alert. The alert is only provided to the equipment operator because he/she ultimately has control to stop or correct the hazard. Alerts are not provided to ground workers to prevent double-correction (both operator and worker avoiding the hazard in the same direction) and to prevent workers from placing themselves in a more hazardous situation.

Equipment operators are warned through audible sounds and visual flashing lights located on the device inside the equipment cabin. The audible alerts create ample noise so that workers and operators wearing hearing protection are still able to hear the alert. Because construction workers can become desensitized to audible alerts, the vibration and visual alerts provide more alert options (Orbitcoms 2010). The visual and audible alert method was received by only the equipment operator and was held constant for both field trials.

Experiments and Results with Proximity Warning Devices

A proximity detection device system was used based on the safety needs of the construction industry. This system was evaluated in two different experimental settings, both evaluating the different capabilities of the system including its ability to perform in the construction environment.

Limitations, Future Work and Application Areas

The stated objective of this research was to evaluate the effectiveness of proximity detection and alert technologies on heavy equipment in the construction environment. If the devices are found to be effective in the construction environment, then criteria can be developed on which to base further investigation. As with all experimental research, each of the proximity detection and alert experiments had limitations. After evaluating the feasibility of the proximity detection and alert devices in the construction environment, many other parameters and potential influences on the system should be evaluated through future experimentation. Future studies should include, but not be limited to:

- Effects of temperature, humidity, precipitation and other ambient influences
- Mounting positions of the EPU and PPU devices including location of devices on workers and equipment
- Worker's and operator's reaction to using the devices including added weight of the device and its effect on their ability to complete construction tasks

Future research efforts should also address the following issues, as they were not addressed in the experiments performed in this paper:

- Calibration of the alert distances with respect to each specific piece of construction equipment including operator reaction and brake distance times as well as equipment stopping times
- Sensitivity analysis can be performed on a detection systems capable of calibration to a pre-defined numerical alert distances
- Investigate and assign appropriate proximity detection distances for specific construction activities
- Long-term construction field trials should be conducted with the devices
- Develop an effective implementation strategy including a cost-benefit analysis for the technology
- Collect and record "close-calls" or "near-misses" data to further educate construction workers on proximity issues in construction

Accidents on construction jobsites not only involve fatalities or injuries of workers, they can become very expensive after calculating medical costs, insurance costs, productivity decrease resulting from time lost, and possible litigation costs.

Some of these costs could potentially be avoided by implementing emerging safety technologies such as real-time pro-active proximity detection and alert systems.

Conclusion

The construction industry desires to eventually obtain an accident free jobsite including a zero fatality rate for each construction project. Statistics specific to proximity issues in construction demonstrate that current safety practices in construction are insufficient. The preliminary results of the described experiments propose that real-time pro-active proximity detection systems can promote safety in construction.

The proximity detection and alert device prototype demonstrated its ability to detect the presence of heavy construction equipment. The tested construction equipment included a wheel loader, forklift, scraper, dozer, excavator, motor grader, personnel mover, articulated dump truck, crane and pick-up truck. Once detected, the system simultaneously activated an alarm to warn the workers and equipment operators of the hazardous proximity issue. The system demonstrated its ability to warn construction personnel that they were too close to other construction resources. The audible alerts were loud enough to be heard over back up alarms and general construction noise.

The proximity detection and alert system also demonstrated its ability to measure and record when a proximity alert is activated. This collected data can later be used to analyze “close-calls” or “near-misses.” New safety concepts and training could evolve from the analysis of “near-miss” data collected from a construction project. Workers could be notified of historical hazardous project conditions and construction activities.