

NATIONAL CENTER FOR CONSTRUCTION SAFETY AND HEALTH
The Center for Construction Research and Training - P.I. Cain
U60 OH0009762-10 ♦ September 1, 2018 – August 31, 2020 Final Reports

(Six projects received a No-cost extension for Year 10 and are referenced. Remaining projects ended August 31, 2019)

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Administrative Core
CPWR – The Center for Construction Research and Training, PI: Cain
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2020
(NCE awarded for Small Studies)

ADMINISTRATIVE (LEADERSHIP, MANAGEMENT AND PLANNING) CORE

1. SPECIFIC AIMS

CPWR made excellent progress in Year 5 of its National Construction Center cooperative agreement with CDC/NIOSH, continuing to build on our experience administering the program since 1990. In our application for this agreement, we proposed to advance the work of our Construction Center and construction industry safety and health by: (1) building on our current base of knowledge and intensifying and accelerating the identification and adoption of evidence-based best practices throughout the industry; (2) responding to the NIOSH Strategic Plan, Construction Program Expert Panel Review recommendations, and NORA Construction Sector Council goals; (3) continuing our focus on research to practice (r2p), sharing more broadly our support and resources with others; (4) being prepared to respond rapidly to emerging issues and trends, and industry technical assistance requests; (5) disseminating our findings in new and more innovative ways; and (6) tracking and evaluating changes in the industry and in safety and health practices and outcomes.

1.1 Mission, Objectives and Aims

As proposed, CPWR's Administrative Core is responsible for the coordination and management of all research projects and activities that make-up our Construction Center. Taken together, the Construction Center is comprised of the following functional areas:

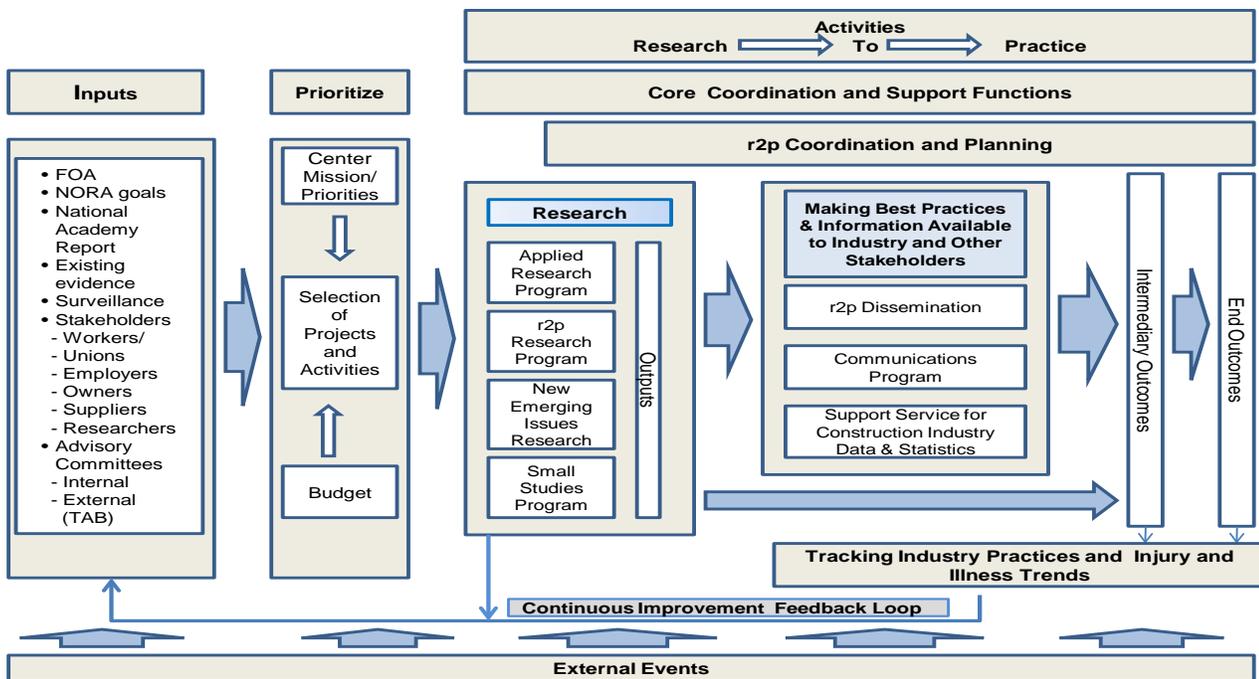
- Strategic Planning: The PI, with support from Construction Center PDs and Advisory Committees (see below) leads continuous planning in the following areas: (1) research development; (2) r2p coordination; (3) emerging issues; (4) Center-wide coordination; and (5) promotion/ marketing/ communications.
- CPWR and Consortium Partner Research: The Construction Center is comprised of several programs that cover: (1) Applied Research; (2) Translation/r2p Research; (3) New Emerging Issues Research; and (4) Support Services for Construction Industry Data and Statistics Program.
- Small Studies Program: The Construction Center administers a very successful Small Studies program to support innovative pilot safety and health research projects.
- International Collaboration/ Coordination: The Construction Center participates in and coordinates international construction safety and health activities through ISSA and ICOH.
- Strategic Coordination: Activities are coordinated within the Construction Center; with NIOSH; with OSHA; with construction industry stakeholders; and with the NORA Sector Council.
- Outreach/ Partnerships: The Construction Center develops and facilitates relationships between researchers and the industry, including unions, employers and their associations, owners, insurance industry, and government agencies to promote adoption of best practices in the industry.
- Advisory Committees: The Construction Center has an internal steering committee, an internal advisory committee, an external advisory committee, and two standing industry committees.
- Performance Monitoring and Reporting: The PDs monitor their projects; the Director of Evaluation and Research oversees all external projects; the Deputy Director oversees all internal projects; the Business Official monitors contract compliance and accounting; the Technical Advisory Board (external advisory committee) monitors scientific quality; the Institutional Review Board monitors ethics; and the PI is responsible for overall reporting of all of these activities to CDC/NIOSH.

Logic Model

CPWR has developed a logic model that guides its administration of the Construction Center. In Year 5 CPWR carried-out its internal projects/activities and external (consortium) projects following this model. It is derived from the NIOSH Construction Research Program logic model and supplements it. It is the responsibility of the Administrative Core to assure that the Construction Center adheres to this model in its decision-making. The model flows like this:

- **INPUTS** that guide program development include the NIOSH Funding Opportunity Announcement (FOA), NORA Construction Sector goals, National Academy construction review committee recommendations, evidence from published research, advice from stakeholders and CPWR’s internal and external (TAB) advisory committees, and feedback from our tracking and surveillance activities. In Year 5 the Construction Center has also been guided by the NIOSH Strategic Plan and Construction Program Expert Panel Review recommendations.
- **PRIORITIZE** to select projects and activities to be included in the Construction Center. This is performed by the Internal Steering Committee and the External Advisory Committee (TAB) based on peer review of proposed projects and activities, consideration of program priorities and available budget.
- **ACTIVITIES** are the projects and other activities that are included in the Construction Center.
- **TRACKING** of industry adoption of best practices and changes in injury and illness rates.
- **FEEDBACK** from our activities is used to provide inputs to the continuous improvement process that is built into the Construction Center, and has guided the systematic and logical evolution of the Construction Center.

CPWR CONSTRUCTION CENTER LOGIC MODEL



This whole process is subject to a range of external events, which often are unpredictable, and the Construction Center has been designed to be flexible and responsive to such events.

2. PROGRESS REPORT

2.1 Staff

Having partnered with NIOSH since the beginning of the construction research initiative in 1990, CPWR has assembled an outstanding staff to manage and direct all proposed research projects and activities in this agreement. CPWR’s Executive Director and Construction Center Principal Investigator is Chris Trahan Cain, who has worked with CPWR for more than 20 years including as former Deputy Director. Dr. Richard Rinehart was hired in June 2018 as Deputy Director. He has had long-term engagement with CPWR and construction sector researchers and practitioners while working with OSHA and NIOSH and through international activities. With appropriate planning and a core of senior level directors in place, our Construction Center has made excellent progress in its proposed Year 5 projects and activities.

Program	Investigator
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Administration, Planning and Outreach	Chris Trahan Cain, CIH, PI, Executive Director Richard Rinehart, ScD, Deputy Director Mary Tarbrake, MBA, Assoc Dir Finance/Bus Official
Applied Research Program	Linda Goldenhar, PhD, Co-PD, Director of Evaluation and Research
Translation/r2p Research Program	Eileen Betit, BA, Co-PD, Director of r2p Research Bill Wright, MA, Co-PD, Communications Director
Construction Solutions Project IRB Functions	Babak Memarian, PhD, Co-PD, Director of Exposure Control Technologies Research Ruth Ruttenberg, PhD, IRB Co-Chair Scott Schneider, MS, IRB Co-Chair
Support Service for Construction Industry Data & Statistics (Data Center) and Surveillance Research	Xiuwen (Sue) Dong, Dr. PH, Co-PD, Director Data Center
Emerging Issues Program	Bruce Lippy, PhD, CIH, CSP, Co-PD, Director of Safety Research

2.2 Planning and Coordination

Based on our background and experience, CPWR has developed the highest level of administrative capacity and organizational structure to administer and plan all aspects of the activities supported under this agreement. The Administrative Core is responsible for ensuring the whole is greater than the sum of the individual parts that make-up our Construction Center, and has therefore been responsible for all Year 5 fiscal and programmatic activities.

In our Construction Center application to NIOSH, CPWR proposed several ways in which it would plan and coordinate proposed activities internally, with NIOSH, and with industry stakeholders.

2.2.1 Internal Coordination

One of the strengths CPWR brings to the Construction Center is the coordination that has led to synergies created over the years among construction safety and health research, training, and medical screening programs. CPWR's main federally-funded construction safety and health programs, and their strategic connections, are reflected in the figure below:

CPWR Program Areas: Designed for Synergy



As proposed in our Construction Center application, in Year 5 CPWR continued to engage a number of advisory boards/steering committees to support planning and coordination activities, as follows:

Internal Steering Committee. An Internal Steering Committee, comprised of all CPWR research directors and Co-PDs, met monthly throughout Year 5 as a matter of routine, with subgroups meeting in between as needed. The meetings were chaired by CPWR's Executive Director Cain, and also include

directors from other CPWR programs for coordination purposes and to develop linkages among research, training, and our medical services programs, as described above in the figure.

Internal Advisory Committee. An Internal Advisory Committee, which consists of the Construction Center’s Internal Steering Committee and the consortium project investigators (PIs), was established in Year 1. We held our Year 5 consortium meeting in conjunction with our fifth annual r2p workshop/partnership meeting in June 2019 with NIOSH intramural researcher participation in our Construction Center activities. This meeting theme centered on: *Continuing the Work: Moving Completed Research into Practice*. NIOSH researchers, all internal and consortium researchers, OSHA, private companies, the insurance industry, external researchers, and other stakeholders participated in the two-day meeting. We also included a special interactive session in the workshop that explored ways to reach vulnerable workers, taking advantage of an external advisory meeting for our NIEHS-funded Environmental Career Worker Training Program (ECWTP) that occurred the same week. The leaders from the ECWTP updated our consortium members on their unique program that identifies, trains, and gives construction employment opportunities to unemployed/under employed workers, and facilitated productive roundtable discussions that benefited both programs.

External Technical Advisory Board (TAB). The TAB is responsible for the review of the scientific quality of CPWR’s research projects/activities, providing guidance to the Construction Center PI and Co-PDs. In Year 5, it met in November 2018. Pete Stafford, former CPWR Executive Director/P.I., chairs the TAB. Several representatives from the TAB also attended our consortium/ r2p workshop in June 2019. The TAB meeting agenda, presentations, and other support materials are not appended to this report, and are available upon request.

As reflected in the table below, we established a TAB r2p Evaluation Sub-committee midway through the five year cooperative agreement, which worked closely with CPWR’s r2p Director and our Director of Evaluation and Research assisting with the development of evaluation plans, protocols and methods for the duration of the Construction Center agreement. In Year 5 an internal final guidance document was produced from this interaction, which has helped us refine the evaluation plan for r2p activities to focus greater attention on outcomes. This TAB Sub-committee Membership of the TAB is listed below:

CPWR Technical Advisory Board (External Advisory Committee)	
Erich (Pete) Stafford , Chair, Retired – Executive Director, CPWR – The Center for Construction Research and Training	Henry A. Anderson, MD , Retired – Chief Medical Officer, Wisconsin Division of Public Health
Dr. Eula Bingham , Professor Emeritus, Dept. of Environmental Health, Univ. of Cincinnati Medical Center	*Steven Hecker, MSPH , Emeritus Director of Occupational Health Extension Service, Univ. of Washington
*Dr. Letitia Davis , Retired – Director, Occupational Health Surveillance Program, Massachusetts Department of Public Health	Mark Fullen, EdD, CSP , Extension Director, Safety and Health Extension, West Virginia University
Denny Dobbin, MsC, CIH , Retired – Director, Worker Education and Training Program, NIEHS	*Dr. Harry Shannon , Retired - Professor, Dept. of Clinical Epidemiology and Biostatistics, McMaster University
Melvin Myers, MPA , Associate Professor, Univ. of Kentucky and Emory University – Retired – Director, Office of Program Planning and Evaluation, NIOSH	Robert Herrick, MS, SD, CIH , Retired - Deputy Director, Harvard Education and Research Center, Harvard School of Public Health

* Tab r2p Evaluation Sub-committee

2.2.2 Coordination with NIOSH

Throughout Year 5, CPWR continued to coordinate activities with NIOSH in many ways. Examples include:

- ongoing coordination with multiple intramural investigators;
- monthly meetings with NIOSH Acting Director for the Office of Construction Safety and Health, Scott Earnest;
- monthly meetings with CPWR’s NIOSH OEP Program Official, Sharon Chiou, including monthly

- coordinating calls with our CDC Grants Management Specialist;
- planning, co-chairing, and participating in NORA Construction Sector Council meetings;
- routinely invited NIOSH representatives to various Advisory Committee meetings and other stakeholder meetings;
- routinely involved the NIOSH Construction Office Director in monthly meetings of North America's Building Trades Union (NABTU) Safety and Health Committee and NABTU/Employer Association Safety and Health Committee meetings;
- participating in NIOSH-supported conferences and meetings;
- participating in the annual meeting with the NIOSH FACE program and state partners;
- reviewing and writing letters of support for multiple NIOSH intramural construction research project proposals;
- co-chairing with NIOSH the CPWR-NIOSH Engineering Controls Work Group;
- joining with NIOSH in meetings with OSHA to engage that agency in r2p planning activities, including the CPWR/NIOSH/OSHA r2p Workgroup and the conduct of the national falls campaign;
- continuing to assist NIOSH investigators gain access to construction sites and worker populations in support of NIOSH intramural studies;
- providing technical expertise to NIOSH investigators through participation of advisory committees and review committees;
- continuing extensive collaboration between our Construction Center and NIOSH on nanotechnology research;
- Presenting and participating in the 2019 NIOSH Centers Directors' Meeting in August in Cincinnati; and
- continuing collaboration across sectors by hosting virtual meetings with the NIOSH Pittsburgh Mining Research Division and the NIOSH Construction Safety and Health Office, and continuing to update a dedicated page on CPWR's main website: <http://www.cpw.com/research/mining-resources-construction>.

2.2.3 Coordination with Industry Stakeholders

The Construction Center has brought together a growing and increasingly diverse community of organizations and key individuals among employers, unions, suppliers, owners, and government agencies, and has facilitated effective cooperation between them and researchers. In Year 5 CPWR's Executive Director/PI, Deputy Director, and Co-PDs have routinely met with a range of industry stakeholder groups individually and have at meetings and conferences. For instance, CPWR staff plans and participates in monthly NABTU Safety and Health Committee meetings and participates in quarterly NABTU Apprenticeship and Training Committee meetings. CPWR's Executive Director/PI chairs the NABTU Opioids Task Force and serves on a number of stakeholder safety and health advisory committees. CPWR Executive Director and staff also participate in the ANSI A10 standards committee. CPWR Directors and Co-PDs participate on an on-going basis with construction industry stakeholders in a variety of forums, as described in their individual project reports and as evidenced by the number of presentations included in the *Publications/Presentations* section of this submission.

2.2.4 Coordination of Construction Jobsite Visits in Response to Technical Assistance Requests

Over the years, as the presence of our Construction Center has grown, an increasingly important Administrative Core function has been coordinating responses to a growing number of technical assistance requests from construction industry stakeholders, particularly in the form of jobsite visits/assessments. Depending on the particular jobsite and specific area of focus, our Construction Center has assembled site assessment teams, including our researchers and other subject matter experts as needed. An excellent example can be found in a follow-up request from Kiewit Power's TVA Allen Project, for which we conducted an initial field survey in January 2017 in Tennessee. Per Kiewit's request, a follow up project was conducted in August to September 2018 to explore best practices that resulted in 1.5 million workhours with zero recordable injuries. Three CPWR researchers conducted phone interviews in a two-week period with 15 staff members from different trades and management levels who worked on the project. We also did a site assessment at the Pennsylvania Chemical Cracker Plant Project – General Contractor: Great Arrow Builders/Bechtel – in Monaca, PA, April 3-4, 2019. Four CPWR researchers conducted 70 employee surveys (45 workers, 27 foremen, and 8 general foremen). This coordinating function, which is being spread by word of mouth among contractors, has proven extremely valuable for many reasons and has elevated the profile of our Construction

Center within the U.S. contractor community, providing us the opportunity to advance our construction safety and health research generally, and our r2p efforts specifically.

2.3 Networks and Partnerships

A major role of CPWR's Administrative Core is to facilitate relationships between researchers and the industry, and to promote adoption of best practices by the industry. To do this, we work with construction unions, employers and their organizations, owners, casualty (liability and workers comp) insurance companies, and government agencies. We have formalized two industry partnerships under our r2p program: (1) a masonry industry partnership that is now self-sustaining; and (2) a roofing industry partnership (see *Partnership* progress report). We also proposed to participate in two other networks as part of our Administrative Core planning activities, as described below.

2.3.1 International Activities

Our Construction Center maintains a small and carefully designed program of international networking focused on (1) improving the scientific basis for construction safety and health; and (2) improving the adoption of best practices. CPWR's international activities are primarily carried out through participation in two organizations which form a natural r2p linkage:

Research: CPWR participates in and supports the Scientific Committee on Occupational Health in the Construction Industry of the International Commission on Occupational and Environmental Health (ICOH), which brings together scientists in construction safety and health for the purpose of defining the state of evidence-based best practices.

Practice: CPWR participates in and supports the Construction Section of the International Social Security Association (ISSA), a non-governmental organization (NGO) affiliated with the International Labour Organization (ILO), which brings together leaders of construction safety and health organizations world-wide to share policy and program experience with the aim of raising the practice of safety and health in the construction industry.

Accomplishments in Year 5

In Year 5 the following work was accomplished:

- **ICOH Scientific Committee on Occupational Health in the Construction Industry**
 - Adopted new leadership. Dr. Knut Ringen, CPWR Senior Science Advisor stepped down as chair after 12 years due to term limits and was replaced by Dr. KN Sen from India.
 - Supported an ICOH Statement on Occupational risks for cancer caused by silicosis exposures.
 - Continued effort to protect migrant workers.
- **ISSA Construction Section**
 - CPWR is a Vice President and Treasurer of ISSA's Construction Section and serves on its Board.
 - Transferred Secretariat from France to Germany.
 - Planned a new program focused on delivering relevant tools and services to members and finding ways to create collaboration between them.
 - Established a new website for ISSA-C. See <https://ww1.issa.int/prevention-construction>
 - Transferred implementation of the CPWR International Virtual Solutions Network to the ISSA-C Secretariat. See <https://ww1.issa.int/prevention-construction/best-practice>
 - Continued engagement in the *Vision Zero* Movement which ISSA is spearheading in collaboration with ILO and WHO, and presented CPWR's approach to improving safety culture at ISSA-C symposia in Santiago, Chile and Mumbai, India.
 - Participated in Vision Zero Strategy Meeting and Training Session, Berlin, Germany January 9-12, 2019
 - Reported on study tour of COSH in Japan, May 2019, with a focus on automatization and application of robots in construction.
 - Participated in Board meetings in Paris, France.

For Additional Information

ICOH and ISSA materials are maintained by CPWR and are available upon request and at these websites:

ICOH Scientific Committee: <http://www.scohici.org>

ISSA Construction Section: <https://ww1.issa.int/prevention-construction>

2.3.2 The Institute for Construction Economics Research (ICERES)

The Institute for Construction Economics Research (ICERES), an outgrowth of CPWR's Construction Economics Research Network, has been incorporated as its own not-for-profit research institution now housed at Michigan State University. As its Executive Director states "The construction industry and its stakeholders face pressing long term issues regarding workforce sustainability, safety, productivity and integration of technology. The purpose of the Institute is to support the industry in finding and disseminating an understanding of and pragmatic solutions to these and other construction issues. To this end, the Institute will undertake and support non-partisan research on issues facing the industry collaborating with existing construction researchers and attracting new investigators into the field of construction research. The Institute will also work to develop a network of researchers with ongoing programs on construction issues."

To foster collaboration and coordination between our Construction Center and ICERES, CPWR's Executive Director/PI serves on the ICERES Board of Directors. In Year 5 she assisted ICERES in expanding its network of researchers by engaging academics on CPWR's mailing list as well as planning its annual meeting to be held on November 15, 2019. This is a major achievement, in that the ICERES is supported by resources independent of the CPWR/NIOSH cooperative agreement while our Construction Center still has direct access to this group of social and economics scientists for its construction safety and health research program. In the past year, examples of studies conducted by ICERES include construction employment in the pharmaceutical and pipeline industries and prevailing wage laws.

2.4 Small Study Program

CPWR first instituted the Small Study Program in 1993 to help define problems and identify needed policy changes or potential interventions. In the 25 years of its operation, the Small Study Program has received 284 letters of intent and funded 119 studies (42%). The funded studies have provided an impressive diversity in terms of scientific aims, applicant organizations, and geographic representation. Each study is expected to last one year and is funded at a maximum of \$30,000.

The Small Studies Program is intended to generate projects focused on:

- Getting best practices adopted – research to practice (r2p)
- Addressing emerging issues and exploring new technologies
- Safety culture and safety climate
- Disseminating safety and health information to specific audiences
- Exploring innovative or new directions in construction sciences
- Reaching high risk sectors: small employers, vulnerable workers, residential and light commercial construction

Small studies can include, but are not limited to:

1. Providing initial support for investigators to develop new or innovative approaches/lines of investigation especially addressing NORA construction agenda goals, emerging issues, and r2p;
2. Exploring innovative or new directions representing a significant departure from ongoing funded projects in construction sciences; and
3. Encouraging investigators from other fields of study to apply their expertise to construction safety and health issues and NORA national goals e.g., psychology, "consumer" marketing/sciences, economics, applied computer sciences, work organization, or communication sciences.

Since the start of this cooperative agreement (September 2014), the Small Study Program has received 76 letters of intent and funded 21 studies (28%). The remaining letters of intent either did not receive high enough marks to proceed or funding was not available. The table below summarizes the projects funded.

Small Studies Activities			
Status	Title	Organization	Current Status
Funded	Effectiveness of OSHA outreach training on rates of construction work-related injury rates	Duke University Medical Center	Complete
Funded	Near miss information visualization tool in BIM for construction safety	University of Alabama	Complete
Funded	USGBC's PtD Pilot Credit: Evaluating effectiveness and building a foundation for implementation	East Carolina University	Complete
Funded	Improving work zone safety utilizing a new mobile proximity sensing technology	Georgia Tech	Complete
Funded	Applying PtD to solar systems in small buildings	University of Washington	Complete
Funded	Mistakeproofing the design of construction processes using inventive problem solving	University of California Berkeley	Complete
Funded	Aluminet: An intervention for heat-related illness among construction workers	Auburn University	Complete
Funded	A pilot study on nanoparticle levels and field evaluation	Georgia Southern University	Complete
Funded	Reducing highway construction fatalities through improved adoption of safety technologies	Oregon State University	Complete
Funded	Nanotechnology: Assessing awareness/training needs among California construction trades	State Building Trades Council of California	Complete
Funded	Holographic visual interaction and remote collaboration in construction safety and health	West Virginia University	Complete
Funded	iSafe: Using panoramic augmented reality to create a virtual safety training environment	University of Florida	Complete
Funded	Development of sustainable workforce model for construction	Oregon State University	Complete
Funded	Ergonomic stressors and back injury risk factors in construction glass and glazing work	University of Nebraska-Lincoln	Complete

Funded	Recent trenching accidents, analysis of causes and recommendations to reduce them	Ruth Ruttenberg & Associates	Complete
Funded	Insights from workers' compensation data	University of Tennessee	Complete
Funded	Embodied safety awareness system: Embodied cognition through an artificial sensor system for improved awareness for hazards	University of Nevada Las Vegas	Complete
Funded	PtD to make solar-ready houses safe for solar workers	University of Washington	Complete
Funded	Impacts of policy changes on worker safety outcomes in NYC construction sites	Cornell University	Complete
Funded	Application of end-of-shift respirable crystalline silica monitoring to construction	Zefon International	Complete
Funded	UAS4Safety: Using unmanned aerial systems for automated fall hazard monitoring in high-rise construction projects	University of Florida	Complete

All funded proposals and final reports have been forwarded to NIOSH. Completed/funded studies are summarized below.

Effectiveness of OSHA outreach training on construction work-related injury rates (Duke University).

Study Complete. In a nine-year (2000-2008) cohort of approximately 17,000 union carpenters in Washington State, the effectiveness of OSHA Outreach Training on rates of workers' compensation injury claims and related outcomes was explored. OSHA Outreach Training resulted in a 13% (non-significant) reduction in rates of injury overall. The effect was more pronounced for carpenters in their apprenticeship years, drywall installers, and with increasing time since training. Key findings and the full study report can be found on CPWR's website.

Near miss information visualization tool in BIM for construction safety (University of Alabama).

Study Complete. This study looked at a framework for near miss data collection and visualization within a BIM platform. A near miss database was created in commercially-available BIM design software to allow construction site personnel to report near misses and visualize them within an existing BIM. Algorithms were created to enable filtering for visualization based on user input properties of each near miss. Key findings and the full study report can be found on CPWR's website.

USGBC's PtD Pilot Credit: Evaluating effectiveness and building a foundation for implementation (East Carolina University).

Study complete. Prevention through Design (PtD) incorporates elements into building design that will reduce safety and health risks for the workers who will construct and maintain the building. In 2015, the US Green Building Council launched a PtD pilot credit as part of the LEED (Leadership in Energy and Environmental Design) certification program. The research team examined early implementation of the pilot credit. Using case studies of two European construction projects that pursued the credit, and surveys and interviews with domestic building industry stakeholders, they explored why U.S. adoption of the credit has been limited. Key findings and the full study report can be found on CPWR's website.

Improving work zone safety utilizing a new mobile proximity sensing technology (Georgia Tech). Study complete. Struck-by injuries are one of construction's "fatal four" leading causes of death on the job; collisions between heavy equipment and workers on a busy jobsite are all too frequent. To reduce this risk, researchers designed and tested a proximity sensing and alert system using Bluetooth Low Energy (BLE) technology. The system monitors the location and direction of moving equipment and alerts both equipment operators and workers on the ground to collision hazards. Key findings and the full study report can be found on CPWR's website.

Applying PtD to solar systems in small buildings (University of Washington). Study complete. Solar technology has grown cheaper and more economically attractive in recent years, and a growing number of homeowners are having rooftop solar panels installed. Employees of the small to mid-sized contractors performing this work face unique safety hazards. The research team interviewed workers, contractors, and engineers in the industry to identify choices during the design process that can reduce worker exposure to injury during construction. Based on the findings, the team created a short guide for industry use – Safety Protocol: Prevention through Design for Safety in Solar Installations. Key findings and the full study report can be found on CPWR's website.

Mistakeproofing the design of construction processes using inventive problem solving (UC Berkeley). Study complete. The researchers looked at the concept of mistakeproofing and its application specifically to improve safety performance in the construction industry, to explain its underlying principles, and to provide examples to illustrate how it is used in practice. They conducted descriptive research of theory and practice and reviewed the academic and professional literature for references on the principles and examples of mistakeproofing. Key findings and the full study report can be found on CPWR's website.

Aluminet: An intervention for heat-related illness among construction workers (Auburn University). Study complete. In this study, researchers tested a new aluminum-fiber ("Aluminet") vest designed to reflect heat. A population of 15 concrete and landscaping workers wore the Aluminet vest for one day, and conventional garments for on another day, while working in similarly hot and humid conditions. The research team measured the workers' body temperatures and heart rates and solicited worker feedback on the product. Key findings and the full study report can be found on CPWR's website.

A pilot study on nanoparticle levels and field evaluation (Georgia Southern University). Study complete. Researchers positioned a manikin wearing a N95 respirator on multiple construction sites and used a commercially available nanoparticle counter to measure exposures and respirator efficiency by collecting samples from inside and outside the mask. The team tested two respirators (one pleated and one foldable) on sites near concrete drilling and grinding activities, earthmoving operations, and wood cutting during frame carpentry. Key findings and the full study report can be found on CPWR's website.

Reducing highway construction fatalities through improved adoption of safety technologies (Oregon State University). Study complete. Highway construction is commonly associated with high rates of worker accidents. Nevertheless, the diffusion of safety technologies such as work zone intrusion alert technology (WZIAT) within the highway construction industry is limited due to concerns about technology effectiveness, cost implications of adopting a technology, and failure to perceive potential safety and cost benefits. This study attempts to develop tools and identify effective processes that could be used to improve the adoption of work zone safety technologies using work zone intrusion technology as a case study. Key findings and the full study report can be found on CPWR's website.

Nanotechnology: Assessing awareness/training needs among California construction trades (State Building and Construction Trades Council of California). Study complete. This study explored the current understanding and use of nanotechnology applications in heavy industrial/commercial construction among union leaders, apprenticeship program staff, and construction contractors. Researchers surveyed 253 contacts representing 24 construction crafts to learn about their knowledge, attitudes and beliefs concerning nano-enabled construction products and about existing health and safety training addressing nanotechnology in construction. Findings found that study participants knew very little about nanotechnology in construction. Nearly one in five survey respondents said they had never heard of "nanotechnology" and "nanoparticles".

Only 25% were aware of their use in construction materials. Key findings and the full study report can be found on CPWR's website.

Holographic visual interaction and remote collaboration in construction safety and health (West Virginia University). Study complete. This study evaluated the feasibility of applying an emerging mixed-reality technology in ameliorating safety and health communication on construction jobsites. Results showed that the mixed-reality technology has potential to enhance safety risk communication in construction workplace through improvement of the performance of accuracy, efficiency, ease of use, and acceptability benchmarked with the existing methods (i.e., emails, phone calls, face-to-face talk, and video conferencing). This study established a positive and quantifiable relationship between communication effectiveness and the mixed-reality technology and study participants showed a great degree of immediate willingness to adopt this technology and actively provided feedback and suggestions for improvements. Key findings and the full study report are posted on CPWR's website.

ISafe: Using panoramic augmented reality to create a virtual safety training environment (University of Florida). Study complete. As a construction occupational safety training tool, traditional Virtual reality (VR) simulations can provide workers safe and controlled experiences of unsafe scenarios. However, they are expensive and time-consuming to develop and often do not offer true representations of real-world conditions. The research team used augmented panoramic captured images of real construction jobsites to create PARS (PANoramas of Reality for Safety), a hazard-identification training tool based on panoramas of reality, which enables learners to navigate, observe, and identify hazards in the complex context of real construction sites. The team then tested its performance against those of a traditional VR-based system. Key findings and the full study report are posted on CPWR's website.

Development of sustainable workforce model for construction (Oregon State University). Study complete. Relative to other sectors, the construction workforce has experienced high turnover rates and poor safety performance over the last few decades. The industry has also struggled to retain existing workers and recruit new ones to construction careers. Using the Delphi method, the authors interviewed industry professionals and academics to identify the characteristics of a sustainable construction workforce and to create an instrument construction employers could use to assess workforce sustainability. Key findings and the full study report are posted on CPWR's website.

Ergonomic stressors and back injury risk factors in construction glass and glazing work (University of Nebraska-Lincoln). Study complete. Construction glass and glazing (CGG) workers have high rates of work-related musculoskeletal disorders (WRMSDs). For this study, the researchers conducted interviews with CGG workers and worksite observations to identify problems leading to the higher rates of WRMSDs and to gather information about improvements that are needed to lower the risk of injury. CGG job tasks were classified in five categories, and ergonomic task-based estimates were done using the Posture, Activity, Tools, and Handling (PATH) method. The CGG workers' level of risk of developing musculoskeletal injuries was scaled using the Rapid Entire Body Assessment (REBA) method. The results of this study provided a baseline database for future evaluations of ergonomic interventions to reduce CGG workers' risk of injury. Key findings and the full study report are posted on CPWR's website.

Recent trenching accidents, analysis of their causes, and recommendations to reduce their occurrence (Ruth Ruttenberg & Associates). Study complete. The study analyzed data of recent trenching fatalities to better understand the reasons for the increases in fatalities. It collected and explored success stories and evaluated barriers to better safety. Key findings and the full study report are posted on CPWR's website.

Insights from workers' compensation data (University of Tennessee). Study complete. The inflated risk of injury for new employees in construction and other industries is well documented; however, less is known about the character and timing of those injuries. To fill this knowledge gap, this study analyzed 9,000 workers' compensation claims from the state of Tennessee having dates of injury in 2014 and 2015 to compare the characteristics of early tenure (i.e., less than or equal to 1 year with an employer) construction injuries with all construction injuries. The analyses examined the proportion of these early tenure injuries in various

dimensions including age, employer size, the severity, type and cause of injury, and the body part injured. Key findings and the full study report are posted on CPWR's website.

Embodied safety awareness system: Embodied cognition through an artificial sensor system for improved awareness for hazards (University of Nevada Las Vegas). Study complete. There is a need to find effective ways to communicate imminent hazards to workers. This project developed and tested a prototype Embedded Safety Communication System (ESCS) to respond to this need. Vibrating motors and sense of touch form the heart of this tactile based, wearable communication system, as direct vibrations are a more robust way to convey hazards in harsh construction environments than innate sensing, such as vision and hearing. After system development, the study conducted a series of tests to identify optimal spacing and configuration of motors embedded in the back of a waist belt worn by a worker. Additional field trials were designed to simulate scenarios representing situations where workers would be at high risk of being stuck by vehicles or caught between vehicles and equipment. The results of these trials were used to evaluate the ability of ESCS to improve worker hazard perception without relying on their innate sensing. Key findings and the full study report are posted on CPWR's website.

PtD to make solar-ready houses safe for solar workers (University of Washington). Study complete. Solar-ready designs have become a new standard for residential houses in preparation for the future installation of a solar system on the roofs. However, the current literature largely lacks considerations of the safety of solar installers, and the application of Prevention through Design (PtD) to solar-ready houses has been significantly limited. This study developed a PtD design checklist and BIM (Building Information Modeling) models for new solar-ready houses. The study involved interviews and a survey with industry professionals, and case studies of existing solar-ready houses. The results are expected to support designers to proactively get involved in promoting PtD for solar-ready houses to protect future solar installers from fall hazards and other safety issues—through the use of the checklist and BIM models. Key findings and the full study report are posted on CPWR's website.

Impacts of policy changes on worker safety outcomes in NYC construction sites (Cornell University). Study complete. This study evaluated the implementation and impacts of a construction safety policy enacted by the City of New York to abate incidence of injuries and fatalities, particularly among non-union and immigrant workers. The aim was to evaluate the implementation process of the new policy, Local Law 196, focusing on outcomes in two main areas: construction workplace safety and access to safety training for the target population. Using a mixed methods approach that combined exploratory quantitative and qualitative strategies, the study identified significant remaining barriers to program success in the areas of outreach to the target population, training capacity and delivery methods, and monitoring and enforcement systems. Key findings and the full study report are posted on CPWR's website.

Application of end-of-shift respirable crystalline silica monitoring to construction (Zefon International). Study complete.

This pilot project examined the effect of common construction dusts as interferences in a new portable end-of-shift (EoS), direct-on-filter (DoF) sampling and analysis method for RCS, in this case quartz. A new on-site, end-of-shift Fourier-Transform Infra-red Spectroscopy (FTIR) analytical method for quartz in respirable air samples developed by NIOSH for use in mines was tested on representative construction dusts in a pilot project with encouraging results that suggest a value in further research. Plaster, drywall, cement and brick were selected as potentially interfering dusts. Similar slopes with good correlations of FTIR absorbance against quartz loading were found for quartz alone, and in the presence of the dusts, singly and in combination. Key findings and the full study report are posted on CPWR's website.

UAS4Safety: Using unmanned aerial systems for automated fall hazard monitoring in high-rise construction projects (University of Florida). Study complete. The goal of this project was to use UASs as a data collection platform, combining the data with novel computer vision techniques to create an automated fall hazard detection and monitoring system. The specific objective was to investigate the practical implementation of UASs for monitoring guardrails near unprotected edges and openings. To achieve this

objective, a real-time video feed of the construction site was collected using an UAS, and then an image-processing algorithm was developed and tested for guardrails detection from true-color images. This project adopted a case study approach to investigate the technical development of the hazard identification system and then its implementation and testing in a high-rise construction project. The outcomes of the research illustrated that the proposed automated fall hazard recognition system could facilitate recognition of guardrails in high-rise construction projects. Key findings and the full study report are posted on CPWR's website.

2.5 Monitoring and Evaluation

The Administrative Core is responsible for the conduct of the entire Construction Center. The Co-PDs monitor their projects; the Director of Evaluation and Research oversees all external projects; the Deputy Director oversees all internal projects; the Business Official monitors contract compliance and accounting; the Technical Advisory Board (external advisory committee) monitors scientific quality; the Institutional Review Board monitors ethics; and the PI is responsible for overall reporting of all of these activities to CDC/NIOSH.

As proposed in the Construction Center application, CPWR has developed an evaluation plan based on the framework developed for the National Academies' review of NIOSH programs, and focuses on measuring:

- **Relevance** is defined as the extent to which each project addresses, and the Construction Center as a whole addresses, NORA Construction goals and the findings of the National Academy review. This is performed by the External Technical Advisory Board (TAB) when it meets. In Year 5 it met in June 2019.
- **Impact**, which is defined as the extent to which projects achieve the intermediary outcomes for the NORA goals (or Academy findings) they are addressing, and the extent to which the Construction Center as a whole contributes to improvements in national outcomes. There are two monitoring activities:
 - Monitoring of each project and activity, whether the PDs are CPWR staff or external consortium participants. CPWR required regular progress reports and monthly brief written updates, initiated and completed two rounds of “touch base calls” with each PD, held monthly meetings of its Internal Steering Committee, and held one annual meeting of its Internal Advisory Committee (internal CPWR PDs and consortium partner PDs), in June 2019.
 - Evaluating impact of the Center as a whole for intermediary outcomes, as observed in terms of worksite practices, or outcomes as measured in exposure levels, and injury and illness data. This is done continuously using a wide range of measures and particularly through our Data Tracking activities, including periodic assessments of construction industry employer programs/policies/practices. To this end we have joined with McGraw-Hill Construction (now Dodge Data & Analytics) to survey U.S. construction industry employers every other year, which gives us a new surveillance tool to measure construction contractor industry safety and health improvements. We've been partnering with Dodge Data & Analytics on a series of surveys since 2012 to add to our understanding of safety trends in construction from a business perspective. We use the results from these surveys to help us identify areas where there are gaps in awareness, trends, research needs, and opportunities to improve communications efforts. In May and September, 2018, two supplemental surveys were administered with Dodge's contractor panel, which resulted in the publication of a Smart Market Brief: *Contractor Use of Safety Best Practices*, released in January 2019 at the World of Concrete convention in Las Vegas. The respondents were separated into two groups: those working for general contractors and those working for specialty trades contractors. We also disaggregated the data by company size, by revenue and by number of employees. An important topic covered was Safety leadership and the frequency with which



companies provide health and safety-related mentoring to subcontractors. Not surprisingly, large companies were more likely to mentor subcontractors. However, it is notable that a considerable percentage of small companies mentor subcontractors. Overall, mentoring is a good practice that can be more widely used in the construction industry. Respondents were also given a list of options and asked what they believe small contractors need the most. The responses from small companies suggest that contractors do not always provide what they need most. What was most striking is the difference between large contractors' perceptions of what small contractors need to improve safety – and what small contractors say they need – particularly the finding that the item small contractors said would be most helpful – materials on site-specific hazards – was considered by large contractors as the item small contractors would find least helpful. This result reinforced for us how important it is to hear directly from target audiences about their needs and concerns.

2.6 Conclusion

The overarching goal of our Construction Center is to foster research to improve working conditions and to ensure that interventions proven to be effective are adopted by the industry. All our knowledge is intended to be "open source" and none is proprietary. Our purpose is to deliver accurate and updated statistics and information on construction safety and health to all stakeholders. We publish or post on the web all our findings as soon as they are completed and have passed review. We solicit widely for consortium participants and share all our information freely. We invite researchers to join our consortium and working groups, participate actively in the NORA Construction Sector Council, and engage with other industry activities and professional societies. We respond to requests for research assistance from any qualified entity or person.

In Year 5 of our Construction Center cooperative agreement, CPWR's Administrative Core continued to be responsible for the administration, accounting, management, and oversight for all CPWR internal research projects and external consortium member projects. Having the staff, infrastructure, resources, and facilities in place to carry-out the scope of the program proposed in our cooperative agreement application, all funded research projects, as highlighted in this report, made excellent progress in Year 5. CPWR has brought together an impressive network of collaborative organizations with our Construction Center, which together is large and comprehensive and is an integral part of the NIOSH Construction Research Program.

Presentations:

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Enhancing Safety Climate through Leadership
CPWR – The Center for Construction Research and Training, PI: Goldenhar
Final Year 5 Progress Report
September 1, 2018 – August 31, 2019

OUTPUTS: Foundations for Safety Leadership (FSL)

- *Video of the FSL course taught by two experienced trainers as part of a suite of trainer resources*
<https://www.cpwr.com/foundations-safety-leadership-fsl-train-trainer-resource-materials>
- Brief article and table posted on FSL webpage presenting the relationship between the Lean principle of reducing waste and the FSL skills
- 30-second mini promotional videos and infographics to target four audiences: owners, trainers, unions, foremen (English and Spanish)
- Six skill sheets and three-minute skill videos that can be accessed using a QR code embedded in the skill sheet (QR codes also added to toolbox talks)
- Posts for social media platforms (Facebook, LinkedIn, Twitter) on the availability of additional resources (English and Spanish)
- CPWR Impact Card
- CPWR Key Findings of published articles
- Eleven FSL-related presentations to industry stakeholders and/ or academics
- Two FSL trainings at construction companies by the PI
- Seven publications

OUTPUTS: SAFETY CLIMATE

- CPWR Impact Card
- CPWR Key Findings of published article
- 9 Safety climate related presentations conducted for construction companies, construction safety conferences
- One publication

OUTCOMES: Foundations for Safety Leadership (FSL)

- Dissemination Effectiveness Follow-up - Estimated # of FSL-trained individuals (Dec 2016-present)

16 of 27 OSHA Ed Centers (30-hour or 500-level)	33,614
Authorized outreach trainers survey (30-hour, stand-alone)	11,248
Attended the 2016, 2017, or 2018 CPWR webinar	5,273
Downloaded FSL materials and completed survey	600
Attended an FSL presentation at a safety/health conference	5,481
Emailed CPWR directly to learn more about the FSL	4,671
Continued using FSL after participating in evaluation study	273
Participated in a company/union training session we conducted	705

Total 63,339*

*this is most likely an undercount since only 16 of 27 Ed Centers provided data and we had an 18% response rate to our request to provide information on FSL use.

- We have not conducted another extensive follow-up with users, but based on conversations with corporate safety professionals and OSHA trainers we know that many more have been trained over the past year and estimate that over 100,000 have participated in the FSL training either as part of the OSHA 30-hour and also as free-standing training courses at unions and companies.
- A number of consulting companies have asked if they can use some or all of the FSL material. We gave them permission but asked that they acknowledge CPWR as the developers. All have said they would.

- Downloads of key materials **(September 1, 2018 - August 31, 2019 ONLY)**

Primary FSL Teaching Materials	
PowerPoint	5,235
Instructor Guide	2,336
Student Guide	1,898
Additional FSL Resources	
Wallet Card	793
Hard Hat Sticker	376
Toolbox Talks (English)	2,318
Toolbox Talks (Spanish)	516
Train the Trainer Power point	1,019
Train the Trainer Instructor Guide	325
FAQ	586
Scenario Facilitation Table poster	714
Leadership Skills Poster	1,176
Handbook	474
Create Your Own Scenario	296
Additional Scenarios PowerPoint	1,799
Additional Scenarios Instructor Guide	582
Additional Scenarios Student Guide	521
Pre and Post Test Survey	359
Leadership Self-Assessment	296
Infographics	926
Emotional Waste - FSL Table	163

- Refresher videos and skill sheet downloads - These were all posted after the grant cycle ended, but since they are reported as outputs I'm including the number of downloads between September 1- October 1, 2019

Refresher videos

Lead by Example	107
Engage and Empower	43
3-way-Communication	36
Active-Listening	30
Recognize Crew	29
Develop Crew	26

Skill sheets

Lead by Example	133
Engage and Empower	80
3-way-Communication	65
Active-Listening	59
Recognize Crew	73
Develop Crew	84

- Social Media - Periodic postings via CPWR's properties between December 2016 and May 2019 generated nearly 65,000 impressions on Twitter and more than 17,000 on Facebook. The data from LinkedIn showing just under 9,000 impressions is actually only from November 2017 to May 2019

because LinkedIn does not archive post information longer than a year, which we did not realize until a year after our initial posts, so our reach on that platform was actually greater

- Lean Principles related to FSL skills paper and table - AGC LEAN forum group is using it in their work and Dimeo Construction and BrandSafway have incorporated it into their safety leadership training efforts <https://www.cpwr.com/sites/default/files/research/CPWR-Emotional-Waste-and-FSL-Final.pdf>
- A number of construction management programs have incorporated aspects of the FSL into their curricula including Virginia Tech, Keene State, Washington State ERC, School of Building Construction at Georgia Tech, Roger Williams University.
- Other industry sectors have been using or adapting the FSL including Department of Energy (FSL4DOE), Oil and Gas, Forestry, Residential construction, Agriculture, and Mining.
- The FSL is being used by companies in other countries including Mexico, Canada, Oman, Saudi Arabia.
- The FSL has been translated into Turkish by a new Turkish Health and Safety company.

OUTCOMES: SAFETY CLIMATE

- Worksheets and a Rating Tool to Help You Strengthen Jobsite Safety Climate: A total of 8,700 hard copies of workbooks have been distributed.
- Downloads of S-CAT material **(September 1, 2018 - August 31, 2019 ONLY)**

Safety Climate Workbook	1,024
Individual S-CAT Worksheets (Word Doc + PDF) V.2	3,590
Spanish S-CAT	76

- One hundred thirty companies have requested a unique code(s) to be able to administer the S-CAT to their employees via www.safetyclimateassessment.org. Some have requested multiple codes to be able to conduct the S-CAT in different departments and compare results.
- There are currently over 6,239 responses in the database.
- Included as a resource In James Roughton's book: Safety Culture: An Innovative Leadership Approach <https://amzn.to/2QCS5uP>
- The S-CAT is being used by companies in other countries including Mexico, Canada, Oman, Saudi Arabia and has been translated into Arabic, Urdu, Hindi, and Dutch.
- We shared the Safety Climate website code with Professor Adri Fritjers who works at a University in the Netherlands. He and his group want to create a Dutch S-CAT website. If he is able to do this and collect data from Dutch companies, we will conduct a comparison study.

SPECIFIC AIMS - FSL project

- **Specific Aim 1** *Produce a transformational leadership training program that will become an OSHA 30-hour elective designed to provide frontline supervisors the skills they need to create and maintain a positive safety climate on construction worksites.*
 - **This Aim was achieved at the end of year 2 (article published in Year 5)**
- **Specific Aim 2:** *Evaluate the effectiveness of the leadership training module on safety climate and improved hazard awareness and prevention with union and non-union construction sites/workers.*
 - **This Aim was achieved at the end of year 4 (article published in Year 5)**

- **Specific Aim 3:** *Ensure the evidence-based leadership training module is made widely available to industry stakeholders by using currently available infrastructures, mechanisms, and research to practice (r2p) principles and methods.*
 - **This Aim was achieved by the end of year 5 as evidenced by data reported above in the outcome section above and published CPWR report on dissemination.**
<https://www.cpwr.com/wp-content/uploads/publications/RR2019-FSL-training-program.pdf>

STUDIES & RESULTS

- Our evaluation study provides evidence that the Foundations for Safety Leadership (FSL) training module improves supervisor understanding of and practices around safety leadership skills. Across all leaders in our study who took the FSL course, we observed significant improvement in self-reported safety leadership understanding and practices at two- and four-weeks after the training.
- Quantitative data from the follow-up study showed that between December 2016 and January 2019 over 63,000 individuals have participated in the FSL training.
- Qualitative data from follow-up study support the quantitative numbers. We have over 30 pages of quotes from company owners, foremen, trainers etc. which we summarized into a document and posted on the FSL webpage which the reader can access here:
<https://www.cpwr.com/sites/default/files/FSL-Quotes-FINAL-5-30.pdf>

After the document was prepared the Field Safety Manager from Tremco Incorporated sent an email with the following feedback.

“We utilize the FSL program in the OSHA 30 hour but extend it to the 6-hour maximum allowed by OTI. It is the first topic covered after Intro to OSHA and is the theme throughout the entire 30 hour program. All topics covered utilize concepts from and reinforce the 5 leadership skills defined in the FSL training.”

SIGNIFICANCE

The outcome and output information reported above provides clear evidence that the construction industry is embracing the FSL and S-CAT and is using these tools to assess their safety climate maturity and to help ensure their frontline leaders have the leadership skills they need to strengthen job site safety climate and improve safety outcomes.

PUBLICATIONS

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Construction Solutions
CPWR – The Center for Construction Research and Training, PI: Memarian
Final Yr 5 Progress Report
September 1, 2018 to August 31, 2019

Outputs:

- Presentation on the Exposure Control Database (ECD) September 24, 2018 at the International Occupational Hygiene Association (IOHA) International Scientific Conference in Washington, DC.
- Webinar on the ECD November 14, 2018.
- Abstract on resources available to construction stakeholders related to silica and noise hazards accepted for the 2020 Construction Expo and Safety Conference in Oakbrook Terrace, IL.
- Guest lecture on construction safety and risk management November 29, 2018 at George Mason University in Fairfax, VA.
- Presentation on the ECD February 5, 2019 at the North America's Building Trades Unions Safety and Health Committee meeting in Washington, DC.
- Presentation on the ECD March 6, 2019 at the Ohio Safety Congress in Columbus, OH.
- Presentation on the Construction Solutions Program April 23, 2019 at Texas A&M University in College Station, TX.
- Keynote speech discussing "The Global Vision Zero Strategy as an Effective Tool for Improving Fall Protection" June 13, 2019 at the International Society for Fall Protection Symposium in New Orleans, LA.
- Presentation on the ECD and Construction Solutions Database (CSD) June 18, 2019 at the CPWR r2p Seminar and Partnership Workshop in Silver Spring, MD.
- Manuscript on the development of the ECD submitted August 1, 2019 to the Professional Safety Journal, a publication of the American Society of Safety Professionals (ASSP), and it is currently under review.
- Report to evaluate the impact of the information provided by the Return on Investment Calculator (ROI) developed.
- Twenty-five Solutions added to the CSD.

Outcomes:

- The CSD had 78,015 users, 89,966 sessions, and 157,079 page-views.
- The ECD had 1,803 users, 2,623 sessions, and 10,109 page-views.
- 190 online participants attended the "Predicting Exposure to Hazards Using the Exposure Control Database" webinar on November 14, 2018.
 - There have been 99 views of the recording as of August 31, 2019.

Specific Aims:

Specific Aim 1: Improve knowledge and increase adoption of evidence-based Solutions for falls, struck-by injuries, and Prevention through Design (PtD).

We successfully completed all outputs under Aim 1 in Year 4.

Specific Aim 2: Systematically develop an exposure and control database that will be an important resource for the construction industry and lead to Solutions for four key health hazards.

A total of 12 new Solution Records for Aim 2 were completed and released to the public. With these new Solutions, listed below, we successfully completed the objective to develop 24 Solutions for Aim 2.

1. Abrasive Blasting Media that Reduce Exposure to Silica
2. Alternative Saw Blades
3. Audiometric Testing
4. Autonomous Abrasive Blasting Robot
5. Dozers with Cab Filtration System
6. Fume Extraction MIG Welding Gun
7. Handheld XRF Gun for Lead Testing
8. Lead Encapsulating Compounds
9. Lead Safety and Compliance Program
10. Non-electronic Level-dependent Hearing Protectors
11. Selecting Proper Welding Processes to Reduce Fume Exposure
12. Vacuum Blasting

The ECD is an interactive, online system that uses objective exposure measurements to estimate exposure to four hazards including silica, welding fumes, noise, and lead. As reported last year, development of this database was completed, and the database was released to the public on August 30, 2018. Three presentations and one webinar were given during the reporting period to outline the ECD's purpose and applications. The webinar was given on November 14, 2018. The first presentation was given at the Ohio Safety Congress on March 6, 2019, in Columbus, OH. The second was given at the International Occupational Hygiene Association on September 24, 2019 in Washington, DC, and the third was given at the North America's Building Trades Unions Safety and Health Committee meeting on February 5, 2019 in Washington, DC.

During the reporting period, 187 new measurements were added to the silica branch of the database and 37 new measurements were added to the noise branch, bringing the total number of measurements across all four hazards to 1,013.

Specific Aim 3: Make the Construction Solutions more relevant and accessible to industry decision makers by (a) creating real-world examples for the ROI calculator and (b) developing a stand-alone website on one high priority hazard to facilitate task analysis and jobsite safety and health planning.

During this reporting cycle, six new ROI Calculator examples were developed and posted to the www.safecalc.org website, which brought the total number of examples in the ROI Calculator to 18. These new examples are: (1) Jackhammer & Vibration Reduction, (2) Battery Operated Power Drill - Vibration & Noise, (3) Using Gloves - Cut/Puncture Injuries, (4) Using Gloves - Dermal Hazards, (5) Roof Anchors to Prevent Falls, and (6) Roof Parapet Wall to Prevent Falls. With these new examples, we successfully completed Aim 3 objectives.

To evaluate the impact of the additional cost information provided by the ROI Calculator on users' decisions to adopt a safety and health intervention, we first developed two versions of a factsheet for the solution "Drill-Powered Wire-Stripping Machine." Version A contained only technical information about the product, while version B contained the same information with additional ROI information. The information on these factsheets was adapted from the actual solution found in the CSD and condensed into a one-pager. We then recruited participants, all general contractors, through the CPWR Contacts list. In addition, three participants were

recruited from the ANSI-A10 meeting for a total of 679 participants. We randomly formed two groups of participants and presented them with one of the two versions (A or B) of the factsheet. Participants were asked to read the information and complete a short survey about the degree to which the information provided in each factsheet could influence their intention to adopt the safer alternative Solution. We hypothesized that the Version B factsheet with additional ROI information would positively influence user intentions to purchase the Solution. To test the hypothesis, the results were compared using a non-parametric Mann Whitney U statistical test at a level of 95% statistical significance. The Studies and Results section below presents the findings.

Specific Aim 4: Maintain and strengthen the Construction Solutions Database by developing and incorporating additional evidence-based Solutions.

A total of 13 new Solution records for Aim 4 were completed and released to the public. With these new Solutions, we completed Aim 4's objective to develop 76 new Solutions, which brings the grand total number of Solutions in the CSD to 326.

1. Garage Spring Winding Wrench
2. Ladder Safety Base System
3. Magnetic Nail Holder
4. Pipe Rack Cart
5. Portable Mortar Tub Cart
6. Powered (Concrete) Buggy
7. Powered Carpet Puller
8. Powered Rebar Bender Workstation
9. Real-time Monitoring Through A Connected Jobsite Platform
10. Roofing Lift Trailer
11. Self-Propelled Platform Truck
12. Welding Cylinder Truck
13. Wire Dispensing Cart

Software Change

Over the course of the year, there have been several software changes made to the website. The most significant change was to relocate the "Expand Solution" button on our Solution records to make it more apparent to users that there is more information available on the page. On the backend, we have made several modifications to the hazard and Solution duplication algorithms. This was to make them more robust and, hopefully, speed up the workflow for the website administrator in posting new Solutions, linking Solutions to hazards, making changes, and modifying the existing Solutions.

Because they were originally developed independently as distinct CPWR products, the CSD, elcosh (elcosh.org), and the ECD operate on different versions of the same framework and have different database structures. This reporting year, we have continued the process of rebuilding these three sites so that they have similar database structures that operate off of the same version of the framework. This framework operates off of a stack of software often referred to as "LAMP" (Linux, Apache, MySQL and PHP). Over time, these pieces of software are updated by the teams that manage them. For years, the CSD has operated on an older version of PHP (5.3). This year we started taking steps to upgrade the site to be compatible with PHP 7 in order to keep up to date with industry standards.

Studies and Results:

Aim 2. An external industrial hygiene consultant was contracted to perform an audit of the data in the ECD. This audit focused on the silica branch because it is currently the largest in the database. The three major aims of the audit were:

1. Randomly select 20% of the silica measurements.
2. Check the 20% against the source documents to capture any potential discrepancies.
3. Check the exposure calculations on the ECD to capture any potential discrepancies

This audit was initiated in August 2019 and was completed on December 15, 2019. Findings of the audit include:

1. There were no discrepancies for the silica concentrations for all selected measurements that were above the limit of detection.
2. There were minor discrepancies for the silica concentrations for five of the selected measurements that were below the limit of detection (LOD). These errors were corrected.
3. There were minor discrepancies for Project Type for four of the selected measurements. These errors were corrected.
4. There were no discrepancies found in the exposure calculations on the ECD.

An analysis of the first-year performance of the ECD was also undertaken using Google Analytics metrics. CPWR's internal users were filtered using Internet Service Provider (ISP) so that all metrics represented the behavior of external users only. The average number of users per month was 148. The analysis also showed that although the number of monthly page-views of a results page fluctuated during the first eight months of the database's release (Aug 2018-April 2019), they stabilized starting May 2019 (Figure 1). From May-August 2019, the average number of monthly page-views of a results page was 141. Two significant spikes in usage in November 2018 and January 2019 can be attributed to webinars and presentations conducted by CPWR.

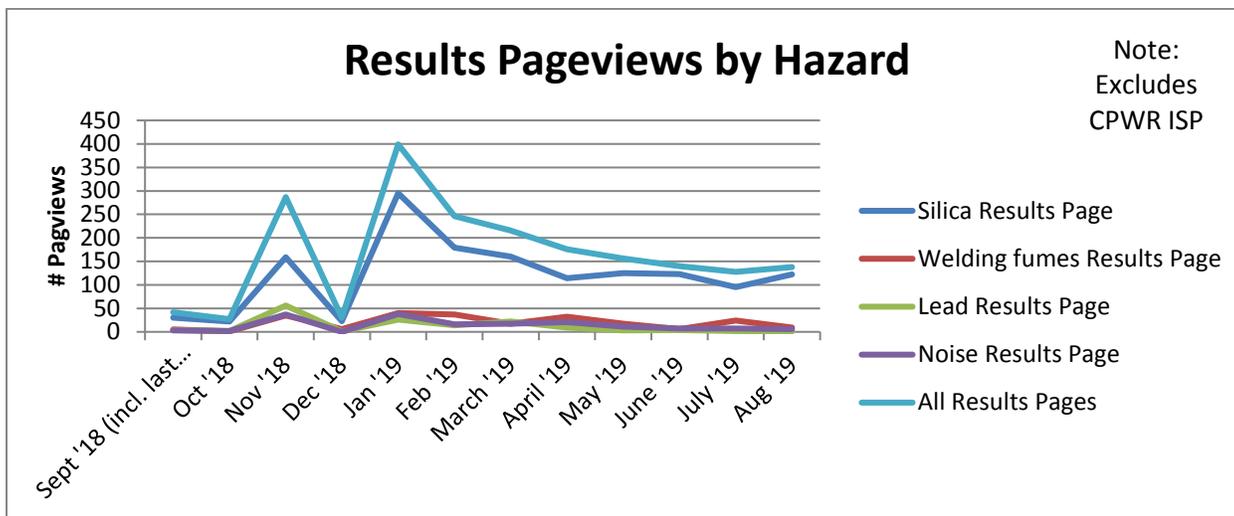


Figure 1: The ECD's first year performance

Aim 3. As mentioned above, to test the ROI information, we sent 335 email invites to a group of contractors with Version A (no ROI information) and 341 contractors with Version B (ROI information included). Nineteen surveys were completed for each group, which yielded a six percent response rate. In addition, we received one completed survey for Version A and two for Version B at an ANSI-A10 meeting on July 16th, 2019 in Washington, D.C. The primary goal for this impact evaluation was to analyze the degree to which respondents agreed or disagreed with whether the factsheet they received provided sufficient information to allow them to make a decision about purchasing a Drill-powered Wire Stripping Machine. To determine whether differences between the degrees of responses were statistically significant, a two-tailed Mann-Whitney U test was performed at alpha 0.05. The first two (“Strongly Disagree; Mostly Disagree”) and last two (“Mostly Agree; Strongly Agree”) response choices were grouped together for a total of 3 choices in each group. After the analysis was run, Version A received a rank sum score of 408 with a U-statistic value of 198 while Version B received a rank sum score of 453 with a U-statistic of 222. As the lowest U-statistical value was still greater than the U-critical value of 134 ($\alpha=0.05$; $n_1=20$, $n_2=21$), there was no statistically significant difference between the ranks of each factsheet. This may in part be due to the low response rate (6%) achieved for each group. Although we believe that more targeted and rigorous assessment of the ROI information might yield more

accurate results, this further assessment will require substantial financial and time commitment. Thus, we do not recommend continuation of the ROI Calculator in its current format.

Aim 4. We have continued to monitor the CSD's analytical data, available in the table below. "Users," "Sessions," and "Page Views" are common metrics often reported when analyzing traffic to websites. Additionally, CPWR has developed two metrics specific to the CSD, "Solution Records Reached" and "Availability Out-links Clicked." The primary goal of the website is to drive users in a specific direction - from Hazard Analyses (based on specific construction work-tasks) to specific Solutions. "Solution Records Reached" is the metric for reporting this primary goal; i.e., how many users reached a specific Solution record in the database. Included in the "Availability" section of each Solution record are out-links to specific instances of the Solutions. These out-links are external links to (a) specific products (e.g., tools, equipment, or PPE) that users might purchase, (b) guidelines for safe work practices that might be employed (e.g., checklists, forms, toolbox talks), or (c) other resources related to the Solution. The "Availability Out-links Clicked" is a count of the number of times that users clicked on an Availability Out-link. Here is the Google Analytics for Year 5 (Table 1):

Table 1: CSD's Year 5 Performance

Month	Sessions	Users	Page Views	Solution Record Page Views	Availability Out-links Clicked
September 2017	5,429	6,071	10,523	2,656	226
October 2017	6,425	7,217	12,365	3,240	210
November 2017	5,798	6,452	10,088	3,109	202
December 2017	4,834	5,423	8,530	2,380	153
January 2018	5,066	5,706	10,164	2,797	190
February 2018	5,469	6,028	10,824	3,044	209
March 2018	6,860	7,647	13,690	3,695	289
April 2018	7,406	7,241	13,488	3,750	240
May 2018	6,813	7,564	13,115	3,387	288
June 2018	6,748	7,283	11,669	3,552	168
July 2018	5,787	6,419	10,491	2,933	220
August 2018	6,145	6,714	11,059	3,279	245
Period Total	70,498	80,799	136,006	37,822	2,640

Significance:

The Construction Solutions Project has produced several high-quality online resources that are available to contractors and other stakeholders in the construction industry at no cost. The CSD, a collection of hazard analyses and related evidence-based solutions, has remained a source of quality content development. Over the project's history, 1,984 hazard analyses have been developed and released across different lines of work

and tasks within construction. Currently, 326 Solution records are available for public access. It is important to note that a single Solution may be linked to many of these work-task-hazard combinations.

The ECD is an interactive online tool that allows health and safety professionals to estimate exposure to four hazards (silica, welding fumes, noise, and lead) based on objective exposure data. This is expected to assist employers and workers in incorporating hazard controls in project planning, communicating potential exposure risks, selecting personal protective equipment, and assessing engineering controls effectiveness. The ECD now contains 1,013 measurements across all four hazards. These measurements have been accessed by 1,803 users.

Publications:

Memarian, B., Brooks, S. B., and Trahan Cain, C. [2020]. Health Hazards in Construction: An Evidence-Based Approach to Estimating Exposure. *Professional Safety Journal: A Publication of the American Society of Safety Professionals (ASSP)*, Page 28-32.

Presentations:

Brooks, S. [2018]. Predicting Construction Workers' Exposure to Jobsite Hazards with The Exposure Control Database. The 11th International Occupational Hygiene Association (IOHA) International Scientific Conference, Washington, DC. September 24.

Memarian, B. [2018] Construction Safety and Risk Management. George Mason University, Fairfax, VA. November 29.

Memarian, B. and Brooks, S. [2018]. CPWR Webinar: Predicting Exposure to Hazards Using the Exposure Control Database. November 14.

Brooks, S. and Memarian, B. [2019]. CPWR's Exposure Control Database. North America's Building Trades Unions Safety and Health Committee Meeting, Washington, DC. February 5.

Memarian, B. and Brooks, S. [2019]. Exposure Predictions and Solutions in Construction. Ohio Safety Congress & Expo, Columbus, OH. March 6.

Memarian, B. and Rinehart, R. [2019]. CPWR – The Center for Construction Research and Training: An Overview. Texas A&M University, College Station, TX. April 23.

Memarian, B. [2019]. Filling Gaps in the Hazard & Control Toolbox. CPWR r2p Seminar and Partnership Workshop, Silver Spring, MD. June 18.

Memarian, B. [2019]. The Global Vision Zero Strategy as an effective tool for improving fall protection. Keynote Speaker, International Society for Fall Protection Symposium, New Orleans, LA. June 13.

CPWR – The Center for Construction Research and Training, PI: Dong
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

Outputs:

- Six CPWR Data Reports (published)
- Two peer reviewed-journal articles (published)
- Ten presentations completed

Outcomes:

Our data products and research findings are frequently cited by researchers and stakeholders within the construction industry and beyond. Selected citations are listed below:

- **Fatal injuries among small construction establishments** (Third Quarterly Data Report in 2018):
Total page views = 497; total downloads = 679
 - Safety + Health Magazine. 2018. Fatality rates on the rise among small construction companies: CPWR. <https://www.safetyandhealthmagazine.com/articles/17762-fatality-rates-on-the-rise-among-small-construction-companies-cpwr>
 - Equipment World. 2018. CPWR: Deaths rise at small construction companies, drop at larger firms. <https://www.equipmentworld.com/cpwr-deaths-rise-at-small-construction-companies-drop-at-larger-firms/>
 - Myosh. 2018. Fatality Rate Rising Among Small Construction Companies. <https://myosh.com/blog/2018/11/29/fatality-rate-rising-among-small-construction-companies/>
 - Ohio Bureau of Workers' Compensation. 2018. Safety Update: Ohio BWC Library. <https://www.bwc.ohio.gov/downloads/blankpdf/SafetyUpdateDec2018.pdf>
 - National Association of Home Builders. 2018. Fatal Injuries on the Rise for Small Residential Construction Firms. <http://nahbnow.com/2018/11/fatal-injuries-on-the-rise-for-small-residential-construction-firms/>
 - The USGlass Magazine. 2018. Small Companies Account for Larger Share of Construction Fatalities. <https://www.usglassmag.com/2018/12/small-companies-account-for-larger-share-of-construction-fatalities/>
 - Schweickert Ganassin Krzak Rundio, LLP. 2019. Illinois Attorneys Discuss the High Rate of Construction Worker Deaths Within Small Companies. <https://www.ganassin.com/posts/illinois-attorneys-discuss-the-high-rate-of-construction-worker-deaths-within-small-companies/>
- **Nonstandard work arrangements in the construction industry** (First Quarterly Data Report in 2019):
Total page views = 153; total downloads = 147
 - The Seattle Times. 2019. Human error? Stop blaming workers for their own deaths. <https://www.seattletimes.com/opinion/human-error-stop-blaming-workers-for-their-own-deaths/>
 - Asphalt Pro. 2019. Nonstandard Work in Construction Impacts Safety. <https://theasphaltpro.com/articles/nonstandard-work-construction-safety/>
 - Business Insurance. 2019. Many construction workers in nonstandard arrangements. <https://www.businessinsurance.com/article/20190501/NEWS08/912328208/Many-construction-workers-in-nonstandard-arrangements-Center-for-Construction-Re>
 - Construction Superintendent. 2019. New Study Explores Types of Nonstandard Work Arrangements in Construction. <https://consupt.com/2019/05/new-study-explores-types-of-nonstandard-work-arrangements-in-construction/>
 - Webinar: Total attendees = 89; total views = 91.
- Occupational fatalities of Hispanic construction workers (cited by 224)
https://scholar.google.com/scholar?cites=4874716431357984620&as_sdt=20000005&scioldt=0,21&hl=en

- Fatal falls among Hispanic construction workers (cited by 118)
https://scholar.google.com/scholar?cites=2424997878795299622&as_sdt=20000005&scioldt=0,21&hl=en
- Injury underreporting among small establishments in the construction industry (cited by 77)
https://scholar.google.com/scholar?cites=10262825855727804023&as_sdt=20000005&scioldt=0,21&hl=en
- Chronic diseases and functional limitations among older construction workers in the United States: A 10-year follow-up study (cited by 47)
https://scholar.google.com/scholar?cites=10762193682414244889&as_sdt=20000005&scioldt=0,21&hl=en
- Respiratory cancer and non-malignant respiratory disease-related mortality among older construction workers — Findings from the Health and Retirement Study (viewed 7,821 times and downloaded 72 times on www.EScienceCentral.org)

Specific Aims and Study Results for Year Five

Aim 1: Hispanic construction workers

We continued to monitor Hispanic employment in construction. We found that the number of Hispanic construction workers increased dramatically after the economic recovery. In 2017, Hispanic employment in construction reached 3.2 million, exceeding its level in 2007 before the recession. As a result, Hispanic workers accounted for 30% of construction employment in 2017, the highest level since 1990. Compared to non-Hispanic workers, Hispanic construction workers are more likely to hold a temporary job, have nonstandard work arrangements, and be employed in high risk occupations. Although the gap in injury rates between Hispanic and non-Hispanic workers somewhat narrowed in recent years, we found that Hispanic construction workers, in particular Hispanic immigrant workers, still have a higher risk of fatal falls than their white non-Hispanic counterparts. Moreover, the risk of heat-related deaths doubled for construction workers born in Mexico. These findings were reported in CPWR Quarterly Data Reports and peer-reviewed journal articles. Considering the rapidly increasing Hispanic employment in construction, targeted surveillance and intervention among this vulnerable worker population is essential.

Aim 2: Young construction workers / Aim 3: Older construction workers

Our research shows that employment trends and patterns of workplace risks varied by age. We found that the construction workforce is increasingly aging. In 2017, the average age of construction reached 42.6 years, and jumped 6.4 years in three decades, exceeding the average age of the overall U.S. workforce. This trend will continue since baby boomers (those born between 1946 and 1964) will remain in the workforce longer than their predecessors. By 2028, about one of four (25.1%) U.S. workers will be 55 or older, more than double the percentage (12.4%) in 1998. At the same time, workers under 25 years old will only account for 11.5% in 2028, dropping about 28% from its level (15.9%) in 1998.

This aging workforce trend is directly reflected in the injury and illness data. Proportion of fatalities among construction workers aged 55 years and older more than doubled in 2017 compared to 1992. Rate of fatal falls increased with age and was the highest for those aged 65 years and older. The types of injuries are also different between younger and older workers. While older workers had a higher rate of fatal injuries, younger workers had a higher rate of nonfatal injuries. Older workers had more fatal falls from ladders, but younger workers had more fatal falls from roofs. Older workers are also more likely to have musculoskeletal disorders and chronic conditions than younger workers. These findings are frequently requested and presented at national and international conferences and webinars by invitation.

The aging workforce has brought many challenges to the construction industry given the high physical demands of this industry. In addition to tracking trade-specific age trends within the construction industry, we also worked with stakeholders to identify union experiences and interventions. Union leaders described barriers, such as age discrimination and the loss of previously available light tasks, as well as current and potential solutions through union contract language requiring the inclusion of older workers, or establishing limits for lifting. Other solutions included career pathways for training and safety, with their attendant limitations; mentoring/pairing opportunities with apprentices; and the potential opportunities and training needs for site management positions. These findings are published in a peer-reviewed journal article.

Aim 4: Temporary workers

Temporary jobs and nonstandard work arrangements are very common in construction. In fact, few construction jobs are under the “standard work arrangement” typically found in manufacturing and other industry sectors. Despite the importance, data sources that can be used to measure risks among workers employed in different work arrangements remain scarce, and definitions of “standard” and “nonstandard” work arrangements are inconsistent in existing data sources and studies. Despite the data limitations and constraints, we provided updated data by analyzing the most recent Contingent Worker Supplement (CWS) to the Current Population Survey (CPS) in order to provide updated information to stakeholders. Using the CWS definitions, we estimated that about 30% of construction workers were employed in alternative work arrangements; 22% were independent contractors and 8% were in other types of alternative arrangements, such as temporary workers, day laborers, on-call workers, and workers provided by contract firms. Half of the construction workers in alternative arrangements would have preferred a different work arrangement. Our findings show that workers in alternative arrangements were more likely to be Hispanic, foreign born, less educated, and were less likely to have health insurance from any source, employer-sponsored health insurance, and retirement benefits. These findings were included in the CPWR Quarterly Report in 2019.

Aim 5: Small construction establishments

Safety and health among small construction establishments is one of our focuses in Year 5. To obtain detailed information on small construction establishments, we conducted stratified analyses by establishment size in all of our studies and reports if the size information was available. Specially, we examined fatal occupational injuries in construction by establishment size over time. We found that from 2003 to 2016, 5,155 fatalities were reported in establishments with 1-19 employees, accounting for 56.6% of fatalities with known establishment size. The fatality rate for establishments with 1-19 employees was significantly higher than those with 20 or more employees. The fatality rate rose 57% for establishments with 1-19 employees from 2008 to 2016, while the rate decreased by about 30% for establishments with 20 or more employees during the same period. We also analyzed fall injuries by establishment size. Our findings show that small employers (1-19 employees) accounted for 75% of fatal falls, which was disproportionately high given that they made up less than 40% of payroll employment in construction. These findings were reported as the Quarterly Data Reports in 2018 and 2019, and presented at conferences and webinars. Selected findings on small construction employers were also included in [“Construction Safety and Health in the USA: Lessons From a Decade of Turmoil”](#), an article published in Ann Work Expo Health.

Our research results have been disseminated through regular online publications, online databases, online maps, national fall prevention campaigns, training classes, conference presentations, webinars, peer-reviewed journal articles, trade magazines, data requests, statistical consultations, Twitter, Facebook, ResearchGate, safety and health blogs, CPWR website, NIOSH website, citations by other researchers, stakeholders, and the media.

Publications:

CPWR. [2019]. Quarterly Data Report, Third Quarter - Trends of Musculoskeletal Disorders and Interventions in the Construction Industry <https://www.cpwr.com/wp-content/uploads/2020/06/Quarter3-QDR-2019.pdf>

CPWR. [2019]. Quarterly Data Report, First Quarter - Nonstandard work arrangements in the construction industry https://www.cpwr.com/wp-content/uploads/publications/Quarter1-QDR-2019_0.pdf

CPWR. [2018]. Quarterly Data Report, Third Quarter - Fatal injuries among small construction establishments <https://www.cpwr.com/publications/third-quarter-fatal-injuries-among-small-construction-establishments>

Peer-reviewed journal articles

Dong XS, West GH, Holloway-Beth A, Wang X, Sokas RK. Heat-related deaths among construction workers in the United States. *Am J Ind Med.* 2019 Dec;62(12):1047-1057. doi: 10.1002/ajim.23024. Epub 2019 Jul 22.

Sokas RK, Dong XS, Cain CT. Building a Sustainable Construction Workforce. *Int J Environ Res Public Health* 2019 Oct 30;16(21). pii: E4202. doi: 10.3390/ijerph16214202.

Presentations:

Dong XS, Wang X, Katz R. [2018]. Inequity in health insurance coverage and healthcare utilization among US construction workers. APHA Annual Meeting and Exposition 2018: San Diego, CA, November 10-14.

Dong XS, Wang X, Katz R. [2018]. Fatal injuries among small construction establishments in the US. APHA Annual Meeting and Exposition 2018: San Diego, CA, November 10-14.

Sokas R, Dong XS, Cain TC. [2018]. Building a Sustainable Construction Workforce. APHA Annual Meeting and Exposition 2018 San Diego, CA, November 10-14.

Dong XS. [2018]. Employability among Older Construction Workers in the United States. Employability in the 21st Century: Provinciehuis Vlaams Brabant, Leuven, Belgium, September 13.

Dong XS. [2019]. Safety and Health Among Older Construction Workers in the United States, presented in the Construction Series Webinars by invitation from Work Wellness and Disability Prevention Institute (WWDPI), Vancouver, Canada, March 20.

Dong XS. [2019]. Fatal Injuries among Contracted Workers in the U.S. Construction Industry. APHA Annual Meeting & Expo 2019, Philadelphia, PA, November 2-6.

Dong XS. [2019]. Nonstandard Employment Arrangement in the U.S. Construction Industry. APHA Annual Meeting & Expo 2019, Philadelphia, PA, November 2-6.

West G, Dong XS, Sokas R. [2019]. A Trend Analysis to Examine the Effects of Climate Change On Heat-Related Illnesses and Deaths among U.S. Construction Workers. APHA Annual Meeting & Expo 2019, Philadelphia, PA, November 2-6.

Interventions to Improve Safety Climate and Ergonomics in Construction SME
Washington University, St. Louis – PI: Ann Marie Dale
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

The following is a summary of the grant activities performed during year 5 of the research project.

Outputs:

- “Subcontractor safety management programs and worker perceived safety climate in commercial construction projects” Presented at the National Injury and Occupational Research Symposium, Morgantown, West Virginia, October 2018.
- OSHA-30 ergonomics training model delivered to Clayco superintendents, safety personnel, and project managers, St. Louis, MO (25 attendees); December 7, 2018.
- "Incorporating Ergonomics into a Construction Safety Management Program." Webinar sponsored by CPWR, February 28, 2019.
- “Connecting contractor safety management programs and worker perceived safety climate in commercial construction projects” Presented at the 27th International Epidemiology in Occupational Health (EPICOH) conference 2019, Aotearoa, New Zealand, April 30-May 2, 2019.
- “Integrating Ergonomics into a Safety Program for Musculoskeletal Disorder Prevention.” CPWR’s Research to Practice Seminar and Partnership Workshop, June 19, 2019.
- “Flow down of safety influenced by working on commercial construction projects” Presented at the 10th International Conference on Applied Human Factors and Ergonomics, Washington D.C., July 25 2019.
- “Ergonomic training to reduce risks for soft tissue injuries among construction workers” a ‘train-the-trainer’ ergonomics program delivered to United Allied (UA) Trainers in Ann Arbor, MI; August 14, 2019
- “Opioids prescribed to manage musculoskeletal pain often lead to opioid use disorder among construction workers.” Presented at Tenth International Scientific Conference on the Prevention of Work-Related Musculoskeletal Disorders, Bologna, Italy, September 2-5, 2019.
- BUD Program (Building Union Diversity) Construction Training Program. Ergonomics Training, St. Louis, MO, September 13, 2019.
- Dale AM. A Model Ergonomics Program for Construction: Integrating Ergonomics into the Safety Management Program. Presented at the St. Louis Safety Council Conference, October 17, 2019.
- Dale AM, Evanoff B, Macomber M, O’Reilly M, Rosen J, Schneider S. Can ergonomics programs help solve the opioid crisis? Preventing Pain Is the Key. The Synergist. May 2019; <https://synergist.aiha.org/the-synergist-may-2019>
- Versteeg K, Bigelow P, Dale AM, Chaurasia A. Utilizing construction safety leading and lagging indicators to measure project safety performance: A case study. Saf Sci. 2019 Dec; 120:411-421. doi: 10.1016/j.ssci.2019.06.035. [Epub ahead of print]
- Dale AM, Colvin R, Barrera M, Strickland JR, Evanoff BA. The association between subcontractor safety management programs and worker perceived safety climate in commercial construction projects. Journal of Safety Research 2020 July; doi.org/10.1016/j.jsr.2020.06.010 [Epub ahead of print].
- Dale AM, Barrera M, Colvin R, Strickland JR, Evanoff BA. Flow-down of safety from general contractors to subcontractors working on commercial construction projects. . Under review at Safety Science.

Outcomes and r2p:

- "Contrasting Prevalence of Health and Safety Risks and Controls between Residential and Commercial Construction" webinar sponsored by Work Wellness and Disability Prevention Institute (WWDPI); February 12, 2019 <https://www.wwdpi.org/Webinars/Pages/Webinar.aspx?wbID=223>
- NIOSH Research Highlights for Ann Marie Dale’s CPWR-funded work on musculoskeletal disorders and construction workers: <https://www.cdc.gov/niosh/oep/stateofthesciencehighlights/default.html>

- Clayco Applies Academic Rigor, Technology to Construction Safety. Construction Forum STL May 2019. <https://www.constructforstl.org/clayco-applies-academic-rigor-technology-to-construction-safety/>
- United Association Safety News, June 2019: "New Ergonomics Training to Reduce Risks for Soft Tissue Injuries Among Construction Workers; Pilot Training Presented to Plumbers Local 130 Apprentices"
- "Creating a contractor ergonomics program to reduce soft tissue injuries among construction workers" webinar delivered to the Mechanical Contractor Association of America (MCAA) members, September 26, 2019 and to MCAA Annual conference, January 22, 2020. Final version of the webinar in production with CPWR.

Specific Aim 1: Explore the effects of participation in general contractors' safety programs on the safety performance and safety culture of small and medium sized subcontractors.

Our goal for Aim 1 was to learn about flow-down of safety programs from general contractors with exemplary programs to subcontractors employed on their projects. We hypothesized that small and medium sized subcontractors would improve their safety climate and the safety performance of their workers when employed on projects managed by general contractors with exemplary safety programs. This change in safety climate would be influenced by the adoption of safety practices required by the general contractors, and small and medium sized subcontractors would have to adopt a greater number of safety practices as their own safety programs would be less robust than large subcontractors. For this study, we recruited 78 subcontractors employed by six general contractors on one of their large commercial construction projects. We interviewed the general contractor to learn about their safety program, and expectations for safety practices of the subcontractors on the projects. The selected general contractors (GC) with exemplary safety programs were identified by safety representatives from the regional Associated General Contractors of Missouri (AGCMO) and the Carpenters Union. We selected 3 large GC (more than 500 employees) and 3 small GC (500 or less). We recruited all trades in all projects and categorized the subcontractor (SC) size as large (more than 200 employees), medium (50-200 employees), and small (less than 50 employees). Each subcontractor participated in interviews and provided a copy of their safety documents; we used this information to code 18 safety elements from a model program checklist of the AGCMO for each subcontractor. We also asked SC to describe the changes in safety practices they had to make to meet the GC expectations on the current project, and whether they intended to continue the safety practices after leaving the project. Workers completed two surveys, during project orientation and after 30 days on the project, to report the safety climate of the GC (past and current) and of their SC, and the safety performance of their coworkers, crews, and themselves (past and current projects).

Studies and Results for Aim 1:

For analysis, we examined 1) the relationship between the scores of 18 safety program elements and the SC safety climate on the current project (cross-sectional analysis) using hierarchical linear regression models (HLM), 2) the difference between GC safety from exemplary GC (current project) and all other GCs (past project) to the worker perceived safety climate of the past and current GC using HLM, and 3) whether there were differences in the safety programs and safety climate or safety performance by the size of the GC and by the size of the SC. We further explored the differences in adoption of safety practices of small, medium, and large-sized SC, working on projects of the 3 large or 3 small-sized GCs.

In the cross sectional study with 78 SC employed on six commercial construction projects, we found striking differences in safety program scores (number of safety elements) between small, medium, and large SC ($p < 0.001$). We observed only weak relationships between safety program scores and SC safety climate score reported by 746 workers of these SCs ($\beta = 0.09$, $p = 0.04$ by HLM). We saw no differences in worker reported SC safety climate and safety behaviors by contractor size. This cross-sectional study found the safety program score only weakly predicted the safety climate score of SCs, yet there were large differences in the quality and content of safety programs by size of SCs. Specific safety program elements were less likely to be present in small SCs including having a designated safety representative, conducting project audits, and seeking worker input for improvement of safety. Many safety elements were less formal for small SCs, such as lacking documentation and standard procedures for equipment inspections and worksite audits. In contrast, large SCs more often had safety elements related to management commitment and worker involvement such as regular safety committee meetings that included workers, monitoring progress toward safety goals with leading

indicators, and a budget for safety resources. This manuscript is under review with the Journal of Safety Research.

For the longitudinal analysis, we asked workers about the GC safety climate on their previous project (on the baseline survey) and on the current project working under exemplary GC (on the follow-up survey). Worker-perceived safety climate of exemplary GCs was higher than from the GCs on past projects on which they worked ($p=0.0006$). There were significant differences in mean safety climate scores between past and current GC among large and medium-sized SC ($p=0.0004$ and $p=0.003$ respectively) but not small SC ($p=0.34$). We also found the differences in mean scores of GC safety climate, with significantly higher scores for large sized GC, but not smaller sized GC ($p < 0.0001$ and $p=0.68$ respectively).

To study the flow-down of safety elements from GC to SC, we assessed the association between the number of SC safety program changes required by the exemplary GC on the current project to the worker perceived GC safety climate and showed a significant relationship (beta 1.59; $p=0.003$); this means there was a 1.6 point improvement in worker-perceived GC safety climate for each additional safety program element change made by the SC. That is, a change of 6 safety elements was associated with a 10-point change in the safety climate score. All of these safety activities required by the GC exceeded federal regulations. For example, most of the SCs safety programs did not include a 100% tie off in scissor lift policy and mandatory participation in daily stretch and flex, regardless of SC size. A large proportion of small SCs were required to add a daily pre-task planning document and equipment inspection checklist (72% and 54% respectively), yet many fewer had to add weekly contractor toolbox talks or had to create a written safety program document (27% and 9% respectively). Medium and large-size SCs had to make similar number of changes but many fewer compared to small-sized SC.

General contractors with strong safety programs are perceived to have stronger safety climates on construction projects than general contractors with less robust safety programs. Because smaller subcontractors typically have less comprehensive safety programs they are expected to make more significant changes than medium and large sized subcontractors to work for general contractors with exemplary programs. This study showed that the addition of more safety elements to meet GC expectations were associated with improvements in perception of GC safety climate. This manuscript is in preparation and will be submitted to the Safety Science journal at the end of November.

Specific Aim 2: Evaluate the effectiveness of incorporating ergonomics into an overall construction safety management system on promoting changes in MSD prevention behaviors (i.e. “Focus Five”).

Musculoskeletal disorders (MSDs) are the leading cause of non-fatal injuries among construction workers, yet ergonomic programs for MSD prevention are often “add-ons” to safety and are rarely sustained or integrated into on-going safety programs. This study set out to help one general contractor develop their ergonomics program to make it at the same level as the other primary Focus Four- thus creating a Focus Five safety program. The general contractor, Clayco Inc., is a large commercial contractor with construction builds across the U.S. We used a pre/post design, initially collecting baseline data over a 9-month period on three construction projects to serve as the pre-intervention (control) sites. We collected the company safety program documents and worker surveys from the projects. A review of the safety program documents showed that this GC had a well-developed safety program with safety integrated into each aspect of the construction process; however, there was little reference or attention to ergonomics in the safety program. Clayco’s vice-president of safety, regional directors, the safety education program manager in partnership with the research team developed a plan to focus on three ergonomic issues related to the overexertion injuries in their injury log: manual material handling, working below knee in a bent forward posture, and working with hands above the head. The planned revision of the program was to incorporate ergonomics language/information into all safety documents, worker trainings, and all meetings, to expand the knowledge of ergonomics and discussion about ergonomic issues. This intervention was evaluated by adding ergonomics as a category in worksite audits, in daily pretask planning documents, and as an expanded list of topics in the injury forms. Ergonomic program changes and delivery throughout the company occurred over a 16-month period, with evaluation on three projects during intervention period (post). The research team collected independent observations on construction projects to identify ergonomic hazards and controls, similar to the issues that would be logged on the pretask planning documents. The observations were collected throughout the pre intervention (on control projects) and post intervention on intervention projects. We evaluated the pre-post change in the researcher-

collected observations and worker completed pretask planning documents to evaluate the efficacy of the ergonomics program.

Studies and Results for Aim 2:

Table 1 shows some of the elements that were modified during the project and the degree that each was delivered in as part of the safety program during the evaluation period. We also examined the proportion of Toolbox talks and precon meetings that mentioned fall hazards to compare to the proportion that addressed ergonomic hazards.

Data showed a substantial increase in training and a greater number of toolbox talks on ergonomics among employees in the intervention group. There was no change in ergonomics discussion in Preconstruction (Precon) meetings but large improvement in subcontractor meetings and safety meetings. Overall recordable rate of sprains and strains decreased over time.

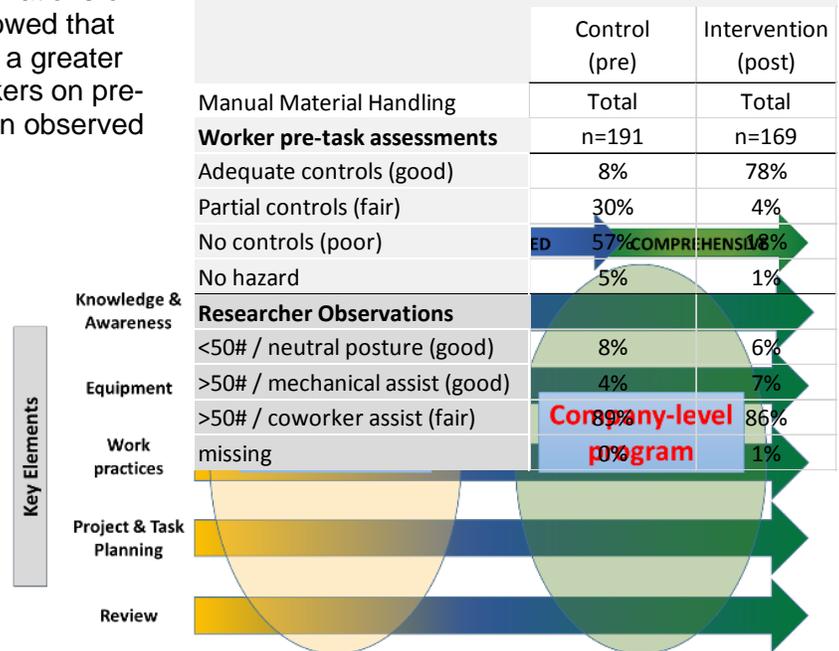
			Control (pre)		Intervention (post)	
Program category	Elements	Period	I	I	II	III
		Dates (# of mos)	(07/2015-04/2016)	(07/2017-01/2018)	(02/2018-07/2018)	(8/2018-11/2018)
			9	6	6	4
Train	Annual training	% trained (GC)	0%	90%	---	94%
	Toolbox talk topic	Ergo	5%	9%	21%	19%
Falls		12%	61%	73%	48%	
Plan	Precon meeting	Ergo	33%	0	33%	n/a
		Falls	100%	78%	100%	n/a
Communi- cate	Sub meeting	Notes	6%	20%	29%	93%
	Safety Comm mtg	Notes	17%	50%	50%	67%
Review	Sprain/strain recordable rate ^{&}	Project injury logs ^{&}	1.63	1.42	0.93	1.29

* Data were from 6 construction projects: Control period = Projects 1-3, Interv. 1: Project 4 &5, Interv.2: Project 5 & 6, Interv 3: Project 6. Company injury data: all company projects (>6) during the period.
[&]From injury log of all workers on projects (GC and Subs); Rate=number of injuries/200,000 man-hours

Table 2 shows the proportion of items related to manual material handling by level of controls (good, fair, poor) in ergonomic specific work tasks identified by workers on pretask assessments and by researcher observations on control and intervention projects. Results showed that compared to control, intervention projects had a greater number of good controls identified by the workers on pre-task assessments but there was little change in observed behaviors over time during the study.

In summary, the review of baseline project data showed ergonomics was not an important part of Clayco's safety program. They used their injury records to focus on three ergonomic issues in the worker's tasks. Specifically, their written safety documents were revised to include ergonomics educational information with a requirement to train their employees in ergonomics. The revised documents and safety elements were delivered to all Clayco construction projects as they were created, over the 16-month intervention period. The results were reviewed periodically by the team.

Table 2. Safe material handling controls identified by worker pretask assessments and by researcher observations on control and intervention projects



Early improvements were observed but then progress slowed; Clayco held an ergonomics campaign during one month toward the end of the study. This added effort led to greater improvement in discussion about ergonomics during subcontractor and safety meetings. Based on the findings from our study, the recommended model program should include: 1) hazard identification to address common ergonomic risks faced on the jobsite and 2) five key elements to a good ergonomics program, include a) proper planning to mitigate hazards, b) define work process for high risk tasks c) process to make proper equipment available d)

train employees to be aware of and understand ergonomic processes and e) ongoing review of safety metrics (trainings, audits, injuries). Development of an ergonomics program may begin with project level activities, but progress to become a company-level program as the company formalizes their ergonomic processes and practices. A graphic of this model created from the Aim 2 project is proposed here (see Figure 1).

Significance:

Aim 1 of this project demonstrated that GCs can be effective intermediary organizations for improving safety practice and safety climate among smaller sub-contracting (SC) firms. While it is not known whether the observed improvements in safety practices will be sustained when SCs move to a project with a less rigorous GC program, our findings provide some evidence that owners and GCs would benefit from requiring sub-contractors to have strong safety programs as part of the contract when they are hired. Doing so will improve safety climate and safety outcomes on their sites and has the added benefit of creating a pool of SCs with better safety practices.

Aim 2 showed that integration of ergonomics into a contractor's safety management program resulted in changes in worker knowledge with no change in observed behaviors during the 16-month intervention period of this study. Musculoskeletal disorders are the most common non-fatal injury in construction, yet preventive efforts are often minimal and inconsistent. This disconnect can be addressed by integrating ergonomics into the safety management systems that have been successful in reducing other hazards in construction.

Incorporating ergonomics into an existing safety program takes time. Workers will utilize their ergonomic knowledge as they become more comfortable with the information and after repeated trainings. Frequent reminders of ergonomics on multiple forms and during meetings helps to keep ergonomics foremost on everyone's mind. Incorporating ergonomics into the safety management system ensured that ergonomic issues received sustained attention and became an expected norm rather than an "add on" to traditional safety topics.

The results from Aim 2 have been incorporated into the United Allied training program for plumber and pipefitter contractors (see MCAA training bullet listed under Outcomes).

Publications:

- Dale AM, Evanoff B, Macomber M, O'Reilly M, Rosen J, Schneider S. Can ergonomics programs help solve the opioid crisis? Preventing Pain Is the Key. The Synergist. May 2019; <https://synergist.aiha.org/the-synergist-may-2019>
- Versteeg K, Bigelow P, Dale AM, Chaurasia A. Utilizing construction safety leading and lagging indicators to measure project safety performance: A case study. Saf Sci. 2019 Dec; 120:411-421. doi: 10.1016/j.ssci.2019.06.035. [Epub ahead of print]
- Dale AM, Colvin R, Barrera M, Strickland JR, Evanoff BA. The association between subcontractor safety management programs and worker perceived safety climate in commercial construction projects. Journal of Safety Research 2020 July; doi.org/10.1016/j.jsr.2020.06.010 [Epub ahead of print].
- Dale AM, Barrera M, Colvin R, Strickland JR, Evanoff BA. Flow-down of safety from general contractors to subcontractors working on commercial construction projects. . Under review at Safety Science,

Assessment and Control of Exposures to Reactive Chemical Resins in Construction
University of Massachusetts, Lowell, PI: Dhimiter Bello
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

Outputs

- We developed, validated, and employed two brand new analytical methods to quantify:
 - Individual oligomeric species of epoxy formulations in air and glove samples by LC-ESI-MS/MS.
 - Total epoxy groups (TEG, as a new exposure metric) in air and gloves by ion chromatography (IC), and compared the TEG results to those calculated based on LC-ESI-MS/MS.
- Tested and evaluated novel biomarkers of epoxy species in the urine of workers applying epoxy coatings in metal structures and their association with airborne and dermal exposures. This is the first biomonitoring study for epoxy paints in occupational settings, including construction.
- Have worked collaboratively with Dr. Wisnewski (Yale School of Medicine) to discover and validate novel, specific biomarkers of exposures to aromatic MDI in animal and then workers' plasma and urine, and have started exploring similar strategies for aliphatic isocyanates in plasma and urine.
- Prepared summary of findings and recommendations to share with our partners for improving work practices and exposure controls.
- With help from CPWR-r2P staff, we have developed hazard alert cards and Toolbox Talk for isocyanates exposures in spray polyurethane foam (SPF) jobs.
Major findings from this project were presented in several peer-reviewed publications, webinars, and presentations, as outlined below.

Outcomes and r2p for the project

1. NIOSH Research Rounds October 2018: "Garment provide varying degrees of protection from spray foam". <https://www.cdc.gov/niosh/research-rounds/resroundsv4n4.html>
2. Overall, our peer-reviewed publications in Years 4 & 5 have 500 reads and 26 citations. Year 5 webinar that presented on exposures among industrial painters had 107 participants.
3. A successful story of research - industry collaboration from our work with Anchor Insulation Inc. was the foundation for an *Impact Card* that was recently developed by CPWR.
4. We continue to provide ongoing technical support to our partners on health and safety issues related to SPF and metal structure coating activities (e.g. cartridge change out schedules of Powered Air Purified Respirators (PAPR) used for SPF installation, post spraying emission testing), answering questions and addressing their Health & Safety concerns.

Specific aims

Specific Aim 1- Identify tasks and application conditions, which produce higher reactive chemical exposures among construction workers using air, skin and biomarker measurements and field observations.

Exposures to isocyanates SPF and industrial coatings. Over the past five years, we have been investigating workers exposure to isocyanates and epoxies during SPF installation, industrial steel structure coatings, and flood coating. Our study design included personal task-based inhalation and dermal exposure assessment, as well as urinary biomonitoring pre- and post-shift. The field sampling campaign ended in November 2018, and sample and data analysis continued for isocyanates and epoxies in industrial coatings until the end of July 2020. Table 1 summarizes the total number of samples collected, stratified by sample type and trade.

Main results:

Work practices varied considerably across different construction sectors and sites. In the SPF industry, only the larger companies had a dedicated professional safety/hygiene officer and required workers to adhere to best industry practices. In industrial coating applications, regardless of paint chemistries, the predominant type of respiratory protection was a full or half-face OVC respirator (61%). During mixing and roller/brush applications, painters did not wear any type of respirators in half of the cases observed as part of our study. The predominant type of dermal protection was thick cotton gloves with a polymer coating on the palmar side (36%) or plain thick cotton gloves (18%). Both types are particularly problematic because they provide little chemical protection and serve as sponge/reservoir for paint ingredients.

During roller/brush applications, especially during hot summer days when most of this work would take place, workers were frequently seen wearing thin cotton or synthetic short sleeve shirts. Considerable skin contamination over the hands, forearms, head and neck area was noted on a regular basis.

Personal inhalation exposures: Airborne exposures to pMDI during SPF found in this study were 4-10 times lower than values reported one or two decades ago, which we believe is related to SPF product reformulation for much faster cure (seconds to minutes tack-free touch). Overall, 16% of personal samples exceeded the NIOSH STEL of 50 µg/m³ and 34% of all PBZ samples exceeded the UK Health and Safety Executive (UK HSE) total NCO standard of 20 µg NCO/m³. Inhalation exposures to aliphatic isocyanates during bridge coating appear to higher than in the SPF cohort, with ~25 % and 35 % of samples exceeding the NIOSH REL and UK HSE total NCO standard, respectively.

Dermal exposure: Potential isocyanate dermal exposures to 4,4'-MDI measured with the glove dosimeters are summarized in Table 2. Sprayers had higher 4,4'-MDI exposures compared to helpers. Overall, the amount of 4,4'-MDI deposited on glove samples had a GM of 343.3 (GSD=2.9) µg/pair/30 min. The HDI monomer and oligomers load on glove samples collected in metal coating sites ranged from 0.2-60,823 µg/pair of gloves. The higher oligomers of HDI biuret and isocyanurate were in the mg/pair range. These data indicate very high potential for dermal exposures on hands.

Urinary biomonitoring: Urinary biomonitoring results for SPF and industrial coating are presented in Table 3. Approximately 25% of all urine samples exceeded the biological monitoring guidance value of 1 µmol MDA/mol creatinine. Post-shift MDA values normalized to specific gravity (SG) were higher than pre-shift (a 15% mean increase for 1-2 hrs. of spraying), even in the presence of SARs. Furthermore, 58% of post-shift urine samples collected during industrial coating applications with pHDI, exceeded the 1 µmol HDA/mol creatinine guidance value, suggesting that controls are inadequate.

Table 1. Summary of field investigations on exposures to part A, isocyanate- and epoxy-based resins, in various construction activities.

ACTIVITY	Number of samples			
	Sites	Air	Gloves	Urine ^a
Spray Polyurethane Foam, SPF • Retrofit; new construction; injection	16	41, P 43, A	38	87
SPF trimming	2	10	n/a	5
Metal structure coating <i>ISOCYANATE-based mid- or top coats</i> • Bridges; Tanks; Wind turbines	9	21	21	49
EPOXY-based mid-coat in bridges	4	9	11	31
Floor coating, isocyanate based	3	6	5	8
TOTAL	34	130	75	180

^a Includes pre- and post-shift; P, personal; A, area

Table 2. Summary of potential for dermal exposure (µg/pair/30min)

Isocyanate species ^b	GM (GSD)	
	Sprayers (n=31)	Helpers (n=6)
4,4' MDI	397.0 (2.8)	144.5 (2.4)
MDI trimer	55.1 (14.5)	78.8 (3.2)
Phenyl isocyanate	3.8 (9.7)	7.0 (5.2)
Estimated total NCO	214.5 (2.8)	132.6 (1.6)

^a Duration of glove sampling: median 40 min (range 8 -123 min). ^b Data on 2,4- and 2,2'-MDI isomers are omitted.

Table 3. Urinary isocyanate biomarker (MDA and HDA) among SPF insulation and bridge painting workers:

Statistics	Urinary biomarker, normalized to specific gravity (µg/L)			
	MDA (SPF)		HDA (Ind. coating)	
	Pre-shift	Post-shift	Pre-shift	Post-shift
N	45	49	27	26
Mean	2.8	3.2	4.7	6.7
GM (GSD)	2.0 (3.3)	2.5 (2.4)	1.9 (4.8)	4.7 (2.7)
Max.	8.2	12.3	15.6	14.7

Exposures to epoxy paints:

Major findings related to the study of epoxy in coating applications include:

Personal airborne and dermal exposures sampling results

1. About 75-95% of commercial epoxy resins are based on bisphenol A diglycidyl ether (BADGE) in the pre-polymeric or polymeric form comprised of epoxy monomers (BADGE) and oligomers (dimers and trimers).
2. A summary of exposure monitoring results is presented in Table 4 below.
3. Airborne exposures measured in the breathing zone of the painters during mid-coat applications indicate the highest exposures during spraying inside enclosed bridges at 3,850 µg/m³ for BADGE and 478 µg/m³ and 326 µg/m³ for dimer and trimer, respectively. Overall, airborne exposures to BADGE monomer had a GM of 802.7 (GSD 3.2) µg/m³ and were higher compared to the dimer (GM 26.4 µg/m³, GSD 7.2) and trimer (GM 13.1, GSD 10.2).
4. BADGE and dimer were detected in 100% of samples (n=9 air, n=11 gloves), while trimer was detectable in 89% of samples.
5. In air samples, the total epoxy group exposure metric calculated from the results of LC-ESI-MS/MS analysis (TEG) was highly correlated with the calculated total epoxy values (TEG) from the IC method (R²=0.94), but accounted for only ~68% of TEG. In dermal samples, the agreement between the two methods was within 3%. This indicates that polymerization proceeds relatively fast in the air samples and LC-ESI-MS/MS will underestimate the TEG by ~40%. In contrast, dermal exposure appears to be occurring from contact with pure epoxy component (raw material, contaminated tools, etc.).
6. Spraying was associated with higher epoxide exposures compared to rolling or brushing.
7. There is evidence of high potential for dermal exposure. The amount of epoxy accumulated on the glove dosimeters was as high as 1,963 mg/pair for BADGE, 70.7 mg/pair for dimer, and 23.0 mg/pair for trimer.
8. Hand exposures during rolling were higher than spraying due to emission, transfer and deposition mechanisms, including contact with raw material and contaminated surfaces and tools.
9. Direct skin contact with the paint was observed frequently for several body parts, such as head, forearms and hands, which was more noticeable when workers wore short sleeve shirts.
10. Inadequate PPEs (e.g. wrong types of gloves relative to recommendations) or no PPEs (no gloves or coveralls) were common.

Epoxy biomonitoring results

We measured the urinary concentration of three urinary biomarkers of BADGE, as summarized in Table 5.

- Overall, urinary biomarkers levels in post-shift samples were higher compared to pre-shift samples indicating substantial body uptake. The ratio of median post-shift to pre-shift BADGE *2H₂O values were 3.2x. These results suggest that current workplace controls in place are insufficient to prevent exposures.

Table 4: Personal breathing zone (PBZ) and dermal exposures to epoxy measured during metal structure coating in construction with two new analytical methods: LC-ESI-MS/MS for individual species and Ion chromatography (total epoxy group, TEG).

Epoxy Species	Inhalation exposures					Dermal exposures					
	Non-detects (%)	Breathing zone concentrations (µg/m ³)			Non-detects (%)	Glove loading (mg epoxy/pair)			Glove loading (mg epoxy/pair/min)		
		GM	GSD	Range		GM	(GSD)	Range	GM	(GSD)	Range
BADGE MW=340.4	0	802.7	3.2	111-3,850	0	547.2	(2.9)	55-1,963	8.9	(3.3)	0.6-34.2
Dimer	0	26.4	7.2	1.6-478	0	10.7	(4.5)	0.5-70.7	0.2	(6.0)	<0.1-1.3

MW=624.7											
Trimer MW=909.1	11	13.1	10.2	nd ^c -325.8	9	8.3	(3.0)	0.6-23.0	0.1	(5.0)	<0.1-1.3
Total epoxy IC	0	276.9	3.9	30-1,551	0	173.1	(3.0)	18.4-752	2.8	(3.3)	0.2-10.2
Cal. total epoxy by LC	-	211.8	3.4	28.6-1, 044	-	141.1	(2.9)	14.0-506	2.3	(3.3)	0.2-8.9

Table 5: Summary statistics of epoxy urinary biomarkers among metal structure coating painters.

Biomarker	N (% detects)	Normalized to specific gravity (ng/ml)		Normalized to creatinine (nmol/mol creatinine)	
		pre-shift	post-shift	Pre-shift	Post-shift
		Median (range)	Median (range)	Median (range)	Median (range)
BADGE.2H2O	31 (100%)	1.17 (0.5-4.7)	3.74 (0.8-49)	79 (24-365)	187 (13-3,227)
BADGE.HCl.H2O	31 (84%)	0.5 (0.2-7.4)	0.5 (0.1-1.4)	21 (8-576)	23 (3-130)
BADGE.H2O	31 (19%)	0.69 (0.5-0.9)	0.9 (0.8-1.1)	23 (11-36)	26 (18-61)

Part B exposures

Flame retardants in SPF: In years 3 and 4 we investigated exposures and urinary biomarkers of the main flame retardant TCIPP in the subgroup of SPF insulation workers who adhered to best industry practices (SARs, nitrile gloves, Tyvek® coveralls, full skin coverage, and active ventilation on site). Airborne and dermal exposures to TCIPP reflect high potential for exposures, both via inhalation of airborne SPF particles and through dermal exposure. The TCIPP loading on gloves was in the 1-200 mg range. Post shift urinary biomarkers of TCIPP, namely bis(1-chloro-2-propyl) phosphate (BCIPP) and 1-hydroxyl-2-propyl bis(1-chloro-2-propyl) phosphate (BCIPHPP) were on average ~ 13.4 and 1.7 times higher than pre-shift, respectively, and 26-35 times higher than levels measured among US adults. Dermal exposure was strongly associated with urinary biomarkers, suggesting that skin exposure was likely the main exposure pathway to TCIPP. Another important finding from this work, is that SPF workers are exposed to other flame retardants not reported in SDS. Urinary concentrations of diphenyl phosphate (DPPH) and isopropyl diphenyl phosphate (ip-DPPH), the corresponding biomarkers of triphenyl phosphate (TPHP) and isopropyl triphenyl phosphate (ip-TPHP) were also elevated several fold compared to the general population, although they did not change post-shift (post-shift to pre-shift GM ratio, 1.0). This suggests that exposure to these OPFRs occurred on other sites.

All of these results and their implications are reported in [six publications](#) (4 listed below for the current period and two published in Year 4). Two [additional manuscripts](#) are in the process of publication: (i) LC-ESI-MS/MS and ion chromatography analytical methods development and application to exposure assessment, has been accepted with minor revisions; and (ii) urinary biomonitoring results have been summarized and are ready to be submitted shortly.

Specific Aim 2 - Evaluate control options for reactive chemical exposures

The work for Aim 2 was conducted in years 2-4, and results were published partly in years 3-5. One additional manuscript related to this aim is currently under review (Mellette et al. 2020, *Evaluation of Disposable Protective Garments Against Epoxy Resin Permeation and Penetration from Anti-Corrosion Coatings*).

Dermal Permeation Panel Study: In response to findings of high potential for dermal exposures and the lack of relevant permeation data for various gloves and garments used in SPF and other coating applications under realistic use, we modified an earlier permeation panel model developed by Prof. Yost (UW) for auto body shop paints. The permeation panel tests have been used to test gloves/garments in pMDI SPF applications and, more recently, for isocyanate- and epoxy-based industrial coatings on bridges using a new panel design. Breakthrough was found in many gloves and coveralls. Nitrile gloves performed the best, whereas latex, the worst.

Similarly, for industrial paint formulations, nitrile gloves were much more resistant than latex gloves and were not permeated by the finish coating until after 15 minutes. The PP/PE coverall provided the most consistent resistance to both coatings, while the Tyvek coverall was readily permeated by the primer. The cotton t-shirt was rapidly permeated by the primer during the first five minutes of exposure. Additionally, the fixed-position spraying technique used during this second study [9] demonstrated a significant reduction in loading variability within each batch of test cells when compared to manual spray application. Overall nitrile gloves demonstrated superior resistance to both isocyanate-containing coatings in comparison to latex gloves. Although both coverall materials were resistant to permeating isocyanate, the PP/PE coverall provided more consistent resistance to both coatings. Cotton t-shirts exhibited high rate of penetration with both coatings and are only recommended as a secondary barrier. Permeation panel results for epoxies have not been summarized yet.

Specific Aim 3. Introduce Controls and Re-Evaluate Exposures

Results from field investigations to date indicate that skin exposure to isocyanates is substantial in some trades, especially in industrial painters, where the overall level of awareness to risk and adherence to PPE is lower than in SPF insulators. Dermal contact with contaminated tools and painted surfaces is a major exposure source. We will continue to emphasize these findings to our partners by providing technical expertise and reports, as well as developing and distributing hazard alert flyers. In collaboration with CPWR, the results of our dermal exposure panel study will be added to the “Choose Hand Safety” website which will help contractors chose the better option from available choices, while they shop the online database for glove products.

Specific Aim 4. Publicize and Disseminate Findings

As we have been generating the data necessary to guide specific recommendations, our focus has been on identifying target audiences and building long-lasting partnerships. The most important target audiences have been industry organizations such as the Center for Polyurethane Industry, American Chemistry Council, Spray Polyurethane Foam Alliance, local contractors/distributors and training centers such as Spray Foam Distributors of New England; Mass Energy Lab, manufacturers; contractors and workers participating in our study.

As we've obtained study results, we have worked hard, particularly in Year 5 to transfer the knowledge gained. Specifically, we have done that through:

- Scientific publications in peer reviewed journals
- Industry wide presentations and webinars.
- Presentations in scientific meetings and seminars.

Studies and Results

Summarized in the above section.

Significance

The ultimate goal of our work is to reduce exposures to reactive isocyanates, epoxies and other harmful agents in construction settings. We believe this work has been and will continue to be significant in terms of:

1. Targeting reduction of dermal and inhalation exposures in high exposure settings, such as industrial spray painters, by introducing improved work practices guided by facture data;
2. Providing recommendations for gloves and other coveralls the field that are efficient for reducing exposures to isocyanates;
3. Increasing hazard alertness among industry groups and educate workers on the proper use of protective equipment;
4. Developing analytical methods suitable for routine bio/monitoring of epoxies and isocyanates;
5. Expanding this research towards part B components such as flame retardants and amine catalysts.

Assistance and consultancy services to partners: Throughout the years we established and maintained long-term partnerships with our industry partners and are currently responding to partners' needs and requests for technical assistance on an on-going basis. Such activities include answering questions or concerns they may have about safe work practices, interpreting exposure data, discussing adequacy of their gloves and other PPE

selections, policies on bystanders, or assisting them and home-owners with any concerns they may have about post SPF-application exposure and risks.

Publications, abstracts and presentations accomplished during the current project year.

Peer-reviewed publications for the current project year:

1. Bello A, Xue Yalong, Gore R, Woskie S, Bello D. (2020) "Exposures and urinary biomonitoring of aliphatic isocyanates in construction metal structure coating." *International Journal of Hygiene and Environmental Health*. Volume 226, PMID: 32120250 DOI: [10.1016/j.ijheh.2020.113495](https://doi.org/10.1016/j.ijheh.2020.113495)
2. Bello A, Xue Y, Gore R, Woskie S, Bello D. (2019) Assessment and control of exposures to polymeric methylene diphenyl diisocyanate (pMDI) in spray polyurethane foam applicators. *International Journal of Hygiene and Environmental Health*. 222 (5), 804-815. PMID: 31076286 DOI: [10.1016/j.ijheh.2019.04.014](https://doi.org/10.1016/j.ijheh.2019.04.014)
3. Mellette M, Xue.Y, Bello A, Bello D, Woskie S. (2019) Evaluation of disposable protective garments against isocyanate permeation using fixed-position spray application method for polyurethane anti-corrosion coating. *Annals of Work Exposures and Health*. 62 (6), 754-764. PMID: 29762654 doi: [10.1093/annweh/wxz032](https://doi.org/10.1093/annweh/wxz032)
4. Wisnewski AV, Nassar AF, Liu J, Bello D. (2019) Dilysine-Methylene Diphenyl Diisocyanate (MDI), a Urine Biomarker of MDI Exposure? *Chemical Research in Toxicology* 32:557-565. PMID: 30724074doi:[10.1021/acs.chemrestox.8b00262](https://doi.org/10.1021/acs.chemrestox.8b00262)

Manuscripts accepted/minor revisions

1. Xue Y, Bello A, Bello D. (2020) "Characterization of personal exposures to epoxy paints in construction by LC-ESI-MS/MS and ion chromatography." *Annals of Work Exposures and Health*. Accepted with minor revisions, August 5th, 2020.

Manuscripts submitted/under preparation

1. Mellette M, Bello D, Xue.Y, Bello A, Woskie S. *Evaluation of Disposable Protective Garments Against Epoxy Resin Permeation and Penetration from Anti-Corrosion Coatings*. *Journal of Occupational and Environmental Hygiene*, Submitted June 30, 2020.
2. Bello A, Xue Y, Gore, R, Hyvner K, Bello D. Urinary biomonitoring of occupational exposures to resins among construction painters in metal structure coatings. *Journal TBD*. Target submission date, September 2020.

Webinars:

1. Bello Dhimiter. (2019) Assessment and control of exposures to isocyanates in industrial coating applications. CPWR Webinar. March 21, 2019.

Presentations:

1. Dhimiter Bello. (2019) *Isocyanates and Health: Decades of Progress in Perspective*. Keynote presentation at the 34th Czech Congress of Occupational Medicine, Mariánské Lázně, Czech Republic, September 23-26, 2019.
2. Dhimiter Bello (2019). *Assessment and control of Exposures to reactive chemicals: Outputs and impact*. CPWR's Research to Practice (r2p) seminar and partnership workshop. Silver Spring, MD. June 19, 2019.

3. Bello Anila , Xue Y, Zhang Y, Woskie S, Bello D. (2019) *Characterization of isocyanate exposures among painters during metal structure coating tasks*. American Industrial Hygiene Conference (AIHce) Minneapolis, MN, May 23, 2019.

Development and Evaluation of Contractor Safety Pre-Qualification Tool
Northeastern University, PI: Jack Dennerlein
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2020
(NCE Awarded)

Outputs:

- Tools: In year 5, we have completed our user's manual for the ACES prequalification survey and reviewed it with several stakeholders.
- Website: We updated the ACES project website (www.acesprequal.org) throughout year 5. It serves as the foundation for our R2P activities. Updates included new research publications, conferences and events, and webinars.
- Publications:
 - Manjourides, J., & Dennerlein, J. T. (2019). Testing the associations between leading and lagging indicators in a contractor safety pre-qualification database. *American Journal of Industrial Medicine*. doi: 10.1002/ajim.22951
 - Liu, K. H., Tessler, J., Murphy, L. A., Chang, C. C., & Dennerlein, J. T. (2018). The Gap Between Tools and Best Practice: An Analysis of Safety Prequalification Surveys in the Construction Industry. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, 28(4), 683–703. doi: 10.1177/1048291118813583
 - Dennerlein JT, Weinstein D, Huynh W, Tessler J, Bigger L, Murphy L, Manjourides J. Associations between a safety prequalification survey and worker safety experiences on commercial construction sites. *Am J Ind Med*. 2020 Sep;63(9):766-773. doi: 10.1002/ajim.23143. PMID: 32515080
 -
- Presentations:
 - Dennerlein, J. (September 2018). Assessment of contractor safety (ACES) through prequalification organizational surveys. CPWR's Informational Webinar Series.
 - Dennerlein, J. (June 2019). Construction Worker Safety, Health and Well-being: Ten years of research in New England Commercial Construction Industry. OSHA Safety Roundtable at Suffolk Construction.
 - Dennerlein, J. (June 2019). Development and Evaluation of Contractor Safety Pre-Qualification Tool - ACES: Assessment of Contractor Safety. Presentation, CPWR Annual R2P in Construction Conference
 - Carpenito, T, Dennerlein, J.T., Manjourides, J.T. (November 2020) The ecological fallacy of safety on commercial construction worksites. APHA 2020. The Annual Meeting of the American Public Health Association.
 - Dennerlein JT (October 2020, postponed to Fall 2021) Validation of organizational surveys of leading indicators for safety pre-qualification for construction contractors. World Congress on Safety and Health at Work. Toronto.

Outcomes and R2P:

- Outcomes: Year 5 was dedicated to finalizing data collection with worksite follow up injury data, data processing, and data analysis as well as submitting and revising manuscripts. There are no immediate outcomes to report at this stage of our research.
- R2P: Our data collection activities have provided us with numerous opportunities to share the goals and objectives of this research with a wide range of commercial construction firms, professional organizations, insurance companies and safety consultation firms. We provided feedback to each subcontractor on their ACES survey through a dashboard providing them with a ranking compared to other companies in our data base. In addition, we provided them a list of resources to find out how they can improve their practices reflected in the dashboard.

Specific Aims:

Aim 1: Determine and develop an assessment procedure that captures the values of contractors that result in improved worker health and safety performance. We will compile a checklist/survey-type of assessment procedure through (1) Qualitative Evaluation (see below) and (2) Quantitative analysis (see below).

Studies and Results:

All work for Aim 1 was completed in years 1-4 and reported in our previous progress reports. Major result, findings, and outputs were:

- We completed a review of existing publicly available pre-qualification organizational surveys
 - 112 individual questions were identified.
 - Gaps in these surveys included hazard prevention and control, program evaluation, employee involvement, and communication
 - Publication Liu KH, Tessler J, Murphy LA, Chang CC and Dennerlein JT. The Gap Between Tools and Best Practice: An Analysis of Safety Prequalification Surveys in the Construction Industry. *New Solut.* 2019; 28: 683-703.
- We completed cross-sectional analysis of Construct Secure database of 2198 companies testing associations between leading and lagging indicators.
 - Increased Safety Management scores were related to lower injury rates
 - Safety programs did not show consistent associations with injury outcomes.
 - Having additional Special Elements related to drug and alcohol programs was associated with lower injury rates.
 - Publication: Manjourides J and Dennerlein JT. Testing the associations between leading and lagging indicators in a contractor safety pre-qualification database. *Am J Ind Med.* 2019; 62: 317-24.
- We developed the ACES Prequalification Organizational Survey with 63 items.
 - ACES Includes constructs missing in many existing surveys.
 - We tested face validity through iterative review by researchers and safety managers.
 - Final design arrived after three rounds of in the field cognitive testing.
 - Publication: Dennerlein, J.T., Weinstein, D., Huynh, W., Bigger, L. M., Di Cillis, E., Tessler, J., Murphy, L. & Manjourides, J.M. Associations between an organizational prequalification survey and worker safety experiences on commercial construction sites. Internal Review – to be submitted to AJIM

AIM 2: Evaluate the performance of the developed assessment procedures (ACES) on 25 projects.

Studies and Results

In year 5 we completed all data collection mainly the follow up worksite data recording the injury data after the ACES and worker surveys were completed in the prior years. We have completed data analysis from Aim 2, and are now preparing a manuscript describing the findings.

Overall, we completed data collection on 25 sites. Data from the sites included ACES prequalification survey data from subcontractors on these sites, individual worker survey data, and worksite injury data. Two adjacent sites managed by the same general contractor employing many of the same subcontractors and consisting of different portions of the same project were combined into one site for analysis for a total of 24. We received recordable injury data from 21 of those sites.

From subcontractors working at these 24 sites, 64 organizational ACES prequalification surveys were completed from 43 unique companies who were contracting on 23 of the 24 worksites. From these worksites, we collected 1,426 individual worker surveys.

Results:

Associations of ACES with Safety Climate and Worker Injuries

For each site we calculated an average ACES score from the individual ACES scores of the subcontractors who were performing work on that site (Table 1). For each site, we also averaged the safety climate scores at the group (subcontractor) and organizational level (Worksite). Positive and significant correlations were found between worksite ACES prequalification scores and both safety climate scores. Correlations between ACES

prequalification scores for each subcontractor and their average worker safety climate scores were not significant, suggesting no linear association between these measures.

Adjusted linear models indicated statistically significant associations between worksite-averaged ACES prequalification scores and worksite-level and subcontractor-level safety (Table 3). ACES scores and safety climate were adjusted for presence of female worker on site and previous participation in a prequalification survey (other than ACES). No significant associations were found in models relating subcontractor prequalification scores to worksite and subcontractor-level safety climate

At the worksite level, ACES prequalification scores were not significantly correlated with injury outcomes. However, adjusted linear models indicated statistically significant associations between average worksite ACES prequalification scores and worksite-level and subcontractor-level safety climate (Table 2).

Table 1 - Descriptive data of the worksites where the data were collected and the subcontractor companies that completed the ACES survey. Values reported are mean (standard deviation) unless otherwise noted.

	Worksite (N=24)	Subcontractor (N=43)
Square Footage (1000s)*	246 (359) [21]	--
Full Time Equivalents (FTEs)	116 (124) [19]	181 (208) [15]
Project Cost (\$ Millions)*	116.80 (215.82) [20]	--
% Project Completion*	77% (30.57) [21]	--
Dedicated safety person [N (%)]*	6 (29%) [21]	--
ACES Score	43 (4) [23]	42 (7) [43]
Safety Climate		
Organizational (Worksite) level	4.1 (0.3) [24]	4.1 (0.4) [43]
Group (subcontractor) level	4.1 (0.3) [24]	4.1 (0.4) [43]
Experience Modification Rate (EMR)	--	0.86 (0.27) [32]
OSHA Violations [N (%)]		
0	9 (45%)	18 (95%)
1	5 (25%)	1 (5%)
2	0	0
3 or more	6 (30%)	0
OSHA recordable injuries (per 100 FTEs)	3.1 (4.9) [18]	2.0 (2.31) [12]
DART injuries (per 100 FTEs)	1.5 (2.8) [17]	2.4 (3.3) [13]

* Item not applicable for subcontracting companies

Table 2– Pearson correlations coefficients ([95% confidence interval]) between ACES Score and safety outcomes and worker experiences.

	Worksite (N=24)	Subcontractor (N=43)
EMR	--	-0.26 [-0.56, 0.10]
OSHA violations	0.17 [-0.31, 0.58]	-0.37 [-0.70, 0.10]
Worker Experiences		
Safety Climate		
Worksite level	0.58 [0.23, 0.80]**	0.03 [-0.28, 0.32]
Subcontractor level	0.58 [0.22, 0.80]**	0.12 [-0.18, 0.41]
OSHA recordable injuries (per 100 FTEs)	0.14 [-0.37, 0.58]	-0.41 [-0.79, 0.22]
DART injuries (per 100 FTEs)	-0.07 [-0.55, 0.44]	0.35 [-0.25, 0.75]

*p<0.05, **p<0.01, ***p<0.001

Table 3 – Regression coefficients ([95% confidence interval]) from linear models testing for associations between ACES and Worker Experiences. Models are adjusted for square footage, project cost, project completion percentage, FTEs, and presence of a dedicated onsite safety person.

	Worksite	Subcontractor
	(N=24)	(N=43)
Safety Climate		
Worksite level	0.072 [0.02, 0.12]*	0.002 [-0.018, 0.022]
Subcontractor level	0.052 [0.01, 0.10]*	0.005 [-0.012, 0.023]
OSHA recordable injuries (Per 100 FTEs)	-0.11 [-0.24, 0.034]	--
DART injuries (Per 100 FTEs)	-0.32 [-0.46, -0.18]***	--

Worksite: *p<0.05, **p<0.01, ***p<0.001

Significance: These results indicate that the ACES prequalification survey captured worker safety climate as well as injury outcomes at the worksite level. The results suggest by having the right subcontractors on site, safety performance can be improved. In addition, it appears that workers experiences correlated more with all sub-contractors on site and not just their own employer in this multi-employer environment.

Manuscripts preparation:

We have published three papers and have started work on a fourth paper lead by a independently funded graduate student.

- Carpenito, T. Dennerlein, J.T., & Manjourides, J.M. The ecological fallacy of safety on commercial construction worksites – to be submitted to New Solutions.

Plans for the future: Specific Aim 2:

- Present the project tools and preliminary results to project partners, and at regional professional organizations, OSHA roundtables, and professional conferences and meetings.
- Complete secondary analysis of Data from Aim 2 determining which constructs in ACES best correlated with worker experiences.
- Complete longitudinal data analyses of Construct Secure data. We have five years of data now downloaded and can therefore see if the questions asked in say year 1 predicted lagging indicators in follow up years expanding our previously published cross-sectional data analysis.

r2p Coordinating Project
CPWR – The Center for Construction Research and Training, PI: Betit
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

Outputs:

- 19 presentations: 5 covered both the work under this project and the r2p Prevention Partnership project, and 14 focused on specific r2p initiatives under this project
- 6 abstracts accepted for presentations
- 4 Evaluation Reports & Methods: [CPWR r2p Concept Mapping Report; Using Delphi Panels to Assess Construction Safety Research to Practice: A Narrative Review; Exploring potential methods to evaluate impact and outcomes of construction safety and health research;](#) and CPWR r2p Evaluation & Tracking Plan 2014-2019
- 3 Guidance Tools & Resources: **Revised r2p Roadmap Tool and Guide; Written Fall Protection Plan;** and **2019 Stand-Down Social Media Guide**
- 2 sections of online safety book: **Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction**
- 13 Products: 2019 Stand-Down Hard Hat Sticker; [Stand-Down 5-Day Plan](#); Spanish [Silica-Related Questions & Answers](#); 4 [Physicians' Alerts](#) (Spanish versions of Physicians' Alerts for Silica and Work-Related Asthma, and English and Spanish Physicians' Alert for Pain Management) <https://www.cpwr.com/publications/physicians-alerts>; and 6 Return on Investment Examples developed or adapted for CPWR's online Return on Investment Calculator (www.safecalc.org – see Solutions project)
- Spanish version of the Construction Noise and Hearing Loss Prevention Training Program <https://www.cpwr.com/research/research-practice-library/r2p-and-p2r-work/preventing-hearing-loss>
- **12 infographics: Falls - 2** updated and 4 new (English & Spanish); 3 Nail Guns (Spanish); and 1 Lightning (English)
- 2 Impact Cards
1 Video
- 3 Reports -- TRU-Net Noise Survey for Workers (Apprenticeship & Journey-level Trainees) Survey Results; [2015-2019 Summary Report - Research to Practice \(r2p\) In Construction: Science, Strategies & Partnerships to Advance Safety & Health](#); [Using Mobile Phone Marketing Technology to Increase Safety Meeting Frequency among Small Residential Construction Companies – Oregon Fatality Assessment and Control Evaluation \(OR-FACE\)](#)
- Construction Safety & Health Research: A Social Network Analysis Primer
- **Developed, fielded and analyzed a Survey on Trench Hazards and Prevention**
- Updated, re-launched, and translated www.nailgunfacts.org into Spanish
- 1 [Blog Post](#) for OSHA's My Safe Summer Jobs campaign
- 2 Peer-reviewed publications – 1 paper published and contributions to the peer-reviewed seventh edition of *Patty's Industrial Hygiene & Toxicology* sections on noise, silica, and training.

Outcomes:

- The annual touch base calls with each research team on the status of their project and the annual r2p Roadmap calls focused on their dissemination plan led to the development of new translational products and dissemination initiatives. For example, for the project *Test Bench for Evaluating Concrete Drilling Methods*, a joint webinar was arranged with ASSP and a workshop held at the 2019 World of Concrete to promote this project's findings and other CPWR related tools and resources (e.g., the silica-safe.org website, the Exposure Control Database, and the Construction Noise and Hearing Loss Prevention Training Program) with safety and health professionals and contractors. In addition, a video on the findings, *A Controlled Comparison of 2 Concrete Drilling Methods* in [English](#) and [Spanish](#), was developed for ongoing use with contractors and workers to explain the findings. This video has been used in presentations and viewed 324 times in Year 5. Critical connections were made with OSHA state plans and a webinar was conducted in support of the *Assessing Public Policy Intervention Impacts on Construction Fatality Rates* project. Impact cards were developed for the *Assessment and Control Exposures to Reactive Chemical Resins in Construction* and the *Foundations for Safety Leadership (FSL)* projects that

highlight use of and the benefits this research. We also supported the *Nanomaterials in Construction: Tracking Product Diffusion and Measuring* project by assisting with the development and promotion of a series of toolbox talks on this emerging issue. In addition, based on direct input from internal and external researchers and a communication from NIOSH researchers on use of the original r2p Roadmap Tool and Guide, they were redone to improve usability. The new version is being used for all CPWR internal and external research projects in the 2019-2024 grant cycle, and is available online for use by other researchers.

- In support of the joint OSHA-NIOSH-CPWR National Campaign to Prevent Falls in Construction (Falls Campaign) and associated Safety Stand-Down, several new resources were developed, including 4 new infographics and 2 updated ones in English & Spanish co-branded with NIOSH, a template for creating a company-wide [fall prevention plan](#), and a [social media guide](#). The following metrics provide an indicator of stakeholder use of the resources: the infographics were downloaded 7,322 times; all 350,000 hard hat stickers printed were distributed; and 313,832 print versions of fall-related Hazard Alert Cards were distributed. The website developed and maintained in support of the Campaign (www.stopconstructionfalls.com) recorded 92,148 sessions, 754,640 page views, and 205,294 downloads. Infographics and resources on the Falls Campaign were also used in publications and presentations, including, for example an eBook: [Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction: Raising Awareness of Best Practices to Prevent Falls in Construction](#). The recommendations from the Social Network Analysis (SNA) pilot project influenced 2019 Campaign activities. Presentations on the SNA were made on the findings and approach to research audiences, and a *Social Network Analysis Primer* was published to help researchers decide when and how to apply this method to evaluate their research projects.
- CPWR partnered in the OSHA Safe + Sound Campaign to promote workplace safety and health programs, and the national My Safe Summer Jobs social media campaign to reach young workers. In support of the Safe + Sound effort, a dedicated page for the Campaign was maintained on cpwr.com, and the Campaign was promoted through social media, the online Construction Safety & Health Network (S&H Network), and an article in the CPWR UPDATE e-newsletter. For the My Safe Summer Jobs campaign, CPWR posted a blog on the Campaign site, [Injuries are Preventable!](#), and promoted the campaign through an article in CPWR's Update, and 6 messages posted on Twitter, LinkedIn, and Facebook that resulted in 16,950 impressions, 67 likes, and 31 shares. We also posted weekly for all five weeks of the campaign on the S&H Network.
- The resources in the Construction Noise & Hearing Loss Prevention Training program were downloaded 2,260 times during the year and the related infographics were downloaded 2,033 times. The entire program has also been posted by national unions (e.g., the United Union of Roofers, Waterproofers, and Allied Workers) on their internal online training sites. A [report on the worker survey results](#) was released and the findings from this report and the earlier trainer survey were referenced in trade and safety and health publications, including the seventh edition of *Patty's Industrial Hygiene and Toxicology*. The new survey findings and the training program were also the subject of presentations to a variety of audiences, including, for example, APHA's 2018 Annual Meeting and the 2019 World of Concrete.
- The trench survey conducted through the OSHA-NIOSH-CPWR r2p Working Group and in partnership with United Rental found gaps in use of safe practices and a need for greater training on trench hazards, OSHA requirements, and prevention. An abstract was accepted, and the findings were presented at the September 2019 National Safety Congress Expo.
- In response to recommendations from the NIOSH Program Review panel to develop materials for use by the growing Spanish-speaking construction workforce, the [Construction Noise and Hearing Loss Prevention Training Program](#), the [Nail Gun Safety](#) online resource, and the [Physicians' Alerts](#) were translated into Spanish, and the r2p resource [CPWR Resources on Latino Workers, Young Workers, and Small Businesses in the Construction Industry](#) was updated. We also continued to translate other products into Spanish, including Toolbox Talks, infographics, and Hazard Alert cards. To raise awareness of their availability, a webinar on CPWR's Spanish resources was conducted on August 21, 2019 and recorded in English and Spanish. This webinar had 67 participants and has been accessed on-demand 50 times. In addition, two new research studies contributed to researchers' understanding of barriers to and methods for reaching at-risk populations: [Using Mobile Phone Marketing Technology to Increase Safety Meeting Frequency among Small Residential Construction Companies](#) and [Pilot-testing the Safety Climate Assessment Tool \(S-CAT^{SC}\) for Small Hispanic Construction Firms](#) (See Prevention Partnerships project).

- CPWR’s Work Safely with Silica website (www.silica-safe.org) continued to be widely recognized, used, and promoted in the industry. In addition to those outcomes already mentioned in the Roadmap discussion, presentations were made to other groups, including, for example, the 2019 Oregon GOSH Conference, NASA, and the Bureau of Certified Safety Professionals Inaugural Research and Innovation Summit. New audiences were also reached through articles in trade publications, including the [Construction Financial Management Association](#) and a chapter in an eBook, [Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction: Are You Prepared to Work Safely with Silica? Free Resources from CPWR Can Help](#). At the request of NIOSH’s Oil & Gas Division, the site was adapted for construction stakeholders who work in that sector and are covered by the silica standard for general industry. New resources continued to be developed, including Spanish versions of the Physicians’ Alert for respiratory diseases (silica and work-related asthma) and the Questions & Answers. The website recorded 167,085 sessions, 251,601 page views, and 16,445 downloads during the year. The planning tool alone was accessed more than 26,000 times. The CPWR Silica Hazard Alert Card (English and Spanish) continued to be one of the most requested cards, with 10,351 hard copies distributed and more than 600 copies downloaded, and the joint OSHA-CPWR webinars on the standard were among the most frequently viewed webinars on-demand with 832 views during the year. The survey of IUOE trainers identified gaps in awareness of how to identify and use cab filtration systems to prevent silica exposure. A paper, *Operating Engineers and the OSHA Silica Standard: A Survey of Union Trainers*, has been accepted by a peer-reviewed journal for publication.
- The fifth annual r2p Seminar and Partnership Workshop brought together an interdisciplinary group of 80 NIOSH and CPWR researchers, government, insurance, and construction industry representatives to discuss r2p approaches, opportunities, and challenges. The agenda topics and speakers were shaped by the synergy between projects identified during the r2p Roadmap calls and discussions with key personnel at NIOSH. Ninety-eight percent (98%) of respondents to the evaluation survey rated the Seminar and Partnership Workshop as “good” to “excellent,” 100% said the learning objectives were met, 98% said it was relevant to their work, and 98% said the information provided ideas to improve their own r2p efforts. A new resource was developed for use by researchers that documented what was learned at the 2019 and past meetings and workshops: [2015-2019 Summary Report - Research to Practice \(r2p\) In Construction: Science, Strategies & Partnerships to Advance Safety & Health](#).

Specific Aim 1: Plan and prioritize research translation.

(a) Work with current National Construction Center and NIOSH researchers to develop and follow up on r2p “Roadmaps” to ensure a proactive approach to dissemination of results.

We participated in two rounds of calls with CPWR internal and external researchers – one focused on the status of their project and one focused on their r2p Roadmap and provided support as they refined and implemented their r2p Roadmaps. This included developing translational products (e.g., Impact Cards, videos, ROI examples) and supporting dissemination activities (e.g., arranging and conducting webinars and presentations, producing articles for trade magazines, and connecting researchers with individuals and groups needed for the success of their projects) (see Aim 4 and Outcomes). During this period, nine of the 13 CPWR webinars arranged and facilitated as part of the r2p program focused on current CPWR research projects (see Communications project). We finalized a new version of the r2p Roadmap Tool and Guide based on lessons learned and input from researchers to make this resource more intuitive and easier to use. The new version is available online and will be used for all CPWR internal and external projects in the 2019-2024 grant cycle.

(b) Review recently completed National Construction Center and NIOSH research activities to identify and prioritize (“triage”) findings and tested solutions that are ready for broader dissemination into the construction industry.

We continued to follow up on the five cross-cutting issues identified through the triage of projects from earlier grant cycles (silica; training/ curriculum adoption; safety leadership; culture and climate; ergonomics; and hard-to-reach targets), as well as promising dissemination methods (education/training; communications products; coalition-building; outreach/marketing; policy development/influence; and technology transfer). For example, we renewed our focus on disseminating nail gun research findings by updating and re-launching NailGunFacts.org as a new online resource, “[Nail Gun Safety](#),” and translating it into [Spanish](#). The new version of the r2p Roadmap Tool eliminates the need for a separate triage instrument.

Specific Aim 2: Coordinate and actively disseminate high-priority research outputs. Together with the r2p Working Group (OSHA, NIOSH, CPWR), promote evidence-based interventions that have the potential for widespread application in the construction industry, but have not yet been broadly disseminated. Build the dissemination capacity of all three organizations.

During the year, the r2p Working Group met in person, held conference calls, and communicated via email in support of the dissemination efforts on the priority areas identified: falls, noise, ergonomics, silica, nail guns, and nanotechnology. The Work Safely with Silica website, one of the first joint undertakings by the Working Group, continued to be used as a primary dissemination vehicle for new research findings and interventions and is promoted by all three organizations and by industry stakeholders. An article on use of TRU-Net for a survey on trainers' awareness and industry use of cab filtration systems to control silica dust has been accepted for publication. In support of the falls priority, the Working Group used the findings from the SNA pilot to inform 2019 Falls Campaign activities, developed new materials, and shared information via social media, industry articles, presentations, training materials, and meetings with workers and contractors. A SNA primer was published for use by researchers and an article on the pilot and potential use of SNA in support of construction safety and health research is in internal review and will be submitted to a peer-reviewed publication. The noise priority led to the translation of the **Construction Noise and Hearing Loss Prevention Training Program into Spanish** (See Aim 3(a)) and continued use of this program by the industry. Earlier drafts of separate articles on the TRU-Net Noise Survey pilot have been combined into one article, which is undergoing an internal review before submission to a peer-reviewed publication. The ergonomics priority continued to be supported by the Ergonomics Community of Practice (see Prevention Partnerships project, Aim 2), and steps were taken to revitalize the industry's focus on nail gun safety (Aim 1b). Trenching was added as a priority this year, and a survey was conducted on this topic, and the data analyzed and shared. The findings from this survey are informing the Working Group and the NORA Struck-by Work Group's work. The Working Group also supported the second annual Safe + Sound Campaign.

Specific Aim 3: Expand infrastructure and resources for r2p.

(a) Build on existing training networks in construction to reach and engage a broad construction audience.

The formal (research) side of TRU-Net continued to be used by researchers and trainers to conduct surveys on various training needs, and to promote training programs, including a new ergonomics training program (See Prevention Partnerships project), solicit feedback, and track their use and effectiveness. Efforts to engage trainers in the online forum (the informal side of TRU-Net) were not successful, however the lessons learned from this online forum influenced development of the Construction Safety and Health Network (see Prevention Partnerships report – Aim 2), and are included in the r2p Partnership Toolkit (See Prevention Partnerships project).

(b) Identify and pilot test promising new channels to influence hard-to-reach target audiences – immigrant construction workers and the small contractors most likely to employ them.

As noted in the final Year 3 report, the preliminary report for the contracted study on use of the CPWR-NIOSH Toolbox Talk (TBT) series with small contractors who employ disproportionate workers showed promise, but the study's final report revealed problems with the researchers' adherence to the study protocol and raised concerns about the quality of analysis conducted. The problems with the TBT study delayed the scheduling of the next Roundtable meeting. A Partnership Workshop in 2019 (see Aim 4b), facilitated by staff from CPWR's ECWTP, and two new studies were supported to fill the gap. The two studies include one on the use of the Safety Climate Assessment Tool for Small Employers (S-CAT^{sc}) with Spanish-speaking workers and contractors and one on using a Toolbox Talk app with residential contractors (see Prevention Partnership report). The results of the Partnership Workshops are included in the r2p Summary Report, and the two new studies completed in Year 5 will be the focus of the next Roundtable meeting in November 2019 (see Prevention Partnerships project).

(c) Maintain, expand, and broadly promote resources to assist in r2p efforts, including online tools and an expanded outreach database.

We expanded the r2p sections and resources on CPWR's website (www.cpwr.com), including establishing Spanish versions of selected pages and materials, establishing an online resource on trench safety, and developing two new Impact Cards on CPWR research projects, 16 new or updated infographics, and Toolbox

Talks in support of CPWR's Nano project. In addition, we continued to promote safety and health research findings, new resources, and interventions through our expanding list of contacts in CONDOR and our coordinated digital and social media outreach program (Twitter, Facebook, and LinkedIn), which includes a monthly educational webinar series (see Communications project). In addition to promoting Research Consortium findings and products, we also used our webinar series to promote the results of one small study, fall prevention information and resources, and CPWR's Spanish language programs and materials. We continue to work towards co-branding the Toolbox Talk series with NIOSH and with stakeholders. To date, nine intermediaries are co-branding these materials and sharing them with their clients, and other groups have incorporated them into materials distributed to their target audiences, including a high school in Louisiana that is reportedly using them as part of their vocational education program. As a result, the number of stakeholders promoting use of research findings and products continued to expand. The process of co-branding 54 Toolbox Talks with NIOSH has required numerous levels of review over several years. They are now in the final review.

Specific Aim 4: Build linkages and synergy among r2p efforts.

(a) Coordinate all of the National Construction Center's proposed r2p projects to ensure maximum integration and shared learning.

The r2p staff's ongoing participation in the semiannual calls with researchers (the project touch base call and r2p Roadmap call), and the participation of the Research Consortium members and researchers from various NIOSH divisions and departments (e.g., Mining, Construction) in CPWR webinars and the annual CPWR r2p Seminar and Partnership Workshop (see Aim 4(b)), ensured maximum integration and shared learning during the year. The Work Group with NIOSH's Mining Division and a joint project with NIOSH's Oil & Gas Division are two examples. The Mining Work Group led to collaboration with OSHA's Alliance program, OSHA's Office of Standards and Guidance, and the Association of Equipment Manufacturers to address silica hazards faced by operating engineers. A paper on one part of this effort has been accepted for publication in a peer-reviewed journal, and jointly developed products for workers, contractors, and equipment dealers are in review. A joint project initiated by NIOSH's Oil & Gas Division resulted in the silica-safe website and planning tool (Aim 2) being adapted for that sector.

(b) Broadly promote effective r2p approaches among researchers, construction stakeholders, and governmental agencies through an annual seminar designed to provide r2p consultation, resources, and exchange of "promising practices" in r2p.

The 2019 r2p Seminar and Partnership Workshop, *Continuing the Work: Moving Completed Research into Practice*, was held June 18 and 19 in Silver Spring, MD. This event built on discussions from the prior four meetings, with a focus on ways to work with stakeholders to continue dissemination and implementation of r2p Roadmaps once the projects are completed, and how to reach and influence at risk workers. A final report was issued to share the lessons learned and results of these annual meetings.

Specific Aim 5: Evaluate r2p activities to assess progress, outcomes, and lessons learned.

Track all r2p activities. Measure results of "push" (the reach of dissemination efforts and evidence of adoption of best practices), and results of "pull" (the level of engagement of stakeholders in seeking out best practices and identifying research needs).

We finalized the r2p evaluation tracking model and used it to track r2p initiatives during the 2014-2019 grant cycle. In addition, we completed three new reports on evaluation methods (See Studies and Results), which are influencing CPWR's future efforts to evaluate r2p initiatives and outcomes.

Studies and Results:

- Three evaluation studies ([CPWR r2p Concept Mapping Report](#); [Using Delphi Panels to Assess Construction Safety Research to Practice: A Narrative Review](#); and [Exploring potential methods to evaluate impact and outcomes of construction safety and health research](#)) provided information on ways to better measure the reach and impact of research findings and interventions, and introduced new approaches that researchers can use to evaluate their own projects.
- The lessons learned from the annual r2p Seminars and Partnership Workshops and documented in the [2015-2019 Summary Report - Research to Practice \(r2p\) In Construction: Science, Strategies & Partnerships to Advance Safety & Health](#), and the r2p supported study, [Using Mobile Phone Marketing Technology to Increase Safety Meeting Frequency among Small Residential Construction Companies](#),

explored the barriers to reaching at-risk construction populations and ways to overcome those barriers and reach these audiences with safety and health research findings that could mitigate their risk.

Significance:

Our initial r2p focus responded to the National Academies' call for a greater emphasis on dissemination. Our efforts during the year aimed to expand, scale up, and broadly disseminate to key players the building blocks that were developed in phase 1 (2010-2014), with an added emphasis on pull factors and impact. These efforts helped build the needed "r2p infrastructure" that will further facilitate the movement of injury- and illness-preventing research into practice. These include: the r2p staff's support for researchers' development of r2p Roadmaps, translational products, and strategies to ensure their dissemination success; enthusiastic stakeholder engagement and sharing of information at the annual r2p Seminar and Partnership Workshop; use of the silica website to influence policy and increase contractor compliance with safer work practices; use of the formal side of TRU-Net in support of research activities that will strengthen r2p and practice to research (p2r); and increased co-branding, outreach, and collaborations with NIOSH researchers and other stakeholder groups that improve visibility and reach. Use of new evaluation approaches, including SNA and concept mapping, and the exploration of ways to establish and use evaluation panels will contribute to the broader body of r2p knowledge and evaluation in construction.

Presentations:

Bunting, J., Brooks, S. [2020]. Addressing Common Hazards with New Resources: Silica and Noise in Construction. 2020 Construction Expo & Safety Conference, Chicago, IL, March 3.

Betit, E., West, G., Barr, A. [2020]. Silica and Emerging Respiratory Hazards in Construction. World of Concrete, Las Vegas, NV, February 3 – 7.

Bunting, J. [2019]. Analysis of an Educational Webinar Series in Construction Safety & Health. Poster Presentation. American Public Health Association Annual Meeting, Philadelphia, PA, November 3.

Bunting, J. [2019]. CPWR Resources for Construction Contractors & Trainers. Texas Construction Safety Summit, Austin, TX, October 8.

Bunting, J. [2019]. CPWR Resources for Construction Contractors. Washington Metropolitan Area Construction Safety Association September Meeting, College Park, MD, September 11.

Betit, E., Wise, J. [2019]. Trench and Excavation Hazards: Insight on Newly Acquired Data and Managing the Risks. NSC 2019 Congress & Expo, San Diego, CA, September 10.

Tolentino-Gonzalez, K. [2019]. A Look at CPWR's Spanish Language Materials & Resources. CPWR Webinar, August 21. <https://youtu.be/un6plFaV6jE> (English) and https://youtu.be/P2DiuN2qn_I (Spanish)

Betit, E. [2019]. Work Safely with Silica: The Latest Research by CPWR. BCSP Foundation Inaugural Research and Innovation Summit, Indianapolis, IN, August 7.

Betit, E. [2019]. CPWR Research & Resources to Move Research into Practice (r2p). Presentation to Milwaukee Tools, Milwaukee, WI, July 10.

Betit, E. [2019]. Continuing the Work: r2p - Moving Completed Research into Practice. r2p Seminar/Partnership Workshop, Washington, D.C., June 18.

Bunting, J. [2019]. A Social Network Analysis of the National Campaign to Prevent Falls in Construction. Panel: CPWR Research: Improving Health and Safety in Construction. 2019 Ohio Safety Congress & Expo, Columbus, OH, March 6.

Barr, A. [2019]. Comparison of Productivity, Vibration, Dust, and Noise Between Pneumatic Rock Drill and an Electric Rotary Drill. Panel: CPWR Research: Improving Health and Safety in Construction. 2019 Ohio Safety Congress & Expo, Columbus, OH, March 6.

Fletcher, M.K. [2019]. Complying with the Silica Standard: New Resources. 2019 Oregon Governor's Occupational Safety & Health Conference, Portland, OR, March 5.

Betit, E., Laquidara-Carr, D. [2019]. Your Competitors' Safety Practices are Possibly Better than Yours. Dodge Data & Analytics Webinar, February 26.

Betit, E. [2019]. Complying with the Silica Standard: New Resources. ASSP Webinar, February 15.

Betit, E., Barr, A. [2019]. New Research & Resources: Controlling Silica, Vibration & Productivity During Concrete Drilling. World of Concrete, Las Vegas, NV, January 22.

Betit, E. [2018]. Construction Noise & Hearing Loss Prevention. ISEA Annual Meeting, Alexandria, VA, November 30.

Fletcher, M.K., Betit, E. [2018]. Self-Reported Receipt of Noise and Hearing Loss Prevention Training, Hearing Tests, and Hearing Loss Among Construction Workers. American Public Health Association Annual Meeting, San Diego, CA, November 14.

Barlet, G., Sokas, R., McCabe, B., Betit, E. [2018]. Operating Engineers: Union Trainers' Response to the Silica Standard. American Public Health Association Annual Meeting, San Diego, CA, November 13.

Betit, E., Rempel, D. [2018]. Comparison of Productivity, Vibration, Dust, and Noise Between Pneumatic Rock Drill and an Electric Rotary Drill. NOIRS 2018, Morgantown, WV, October 18.

Fletcher, M.K. [2018]. Tackling Old and Emerging Environmental Health Hazards in Construction: Research and Resources from CPWR. NASA EH ViTS, October 17.

Betit, E., Varda, D., Bunting, J. [2018]. A Social Network Analysis of the National Campaign to Prevent Falls in Construction. NOIRS 2018, Morgantown, WV, October 17.

Betit, E. [2018]. When Regulation Doesn't Work: Social Marketing to Increase Worker Adoption. NOIRS 2018, Morgantown, WV, October 16.

Betit, E. [2018]. Navigating the Silica Standard: Resources to Help. Work Place Material Handling & Safety Magazine Webinar, September 19.

Betit, E. [2018]. r2p in Construction: Resources & Tools to Advance Safety and Health. Western States Occupational Network 11th Annual Meeting, Denver, CO, September 14.

Publications:

Betit, E., Fletcher, M. [2021]. Industrial Hygiene Issues in Construction: Noise, Silica and Training sections. Patty's Industrial Hygiene and Toxicology, Seventh Edition, tentative publication February 2021.

Barlet, G., Sokas, R., Betit, E. [2020] Operating Engineers and the OSHA Silica Standard: A Survey of Union Trainers, NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, , 29(4), 530-535. <https://journals.sagepub.com/doi/full/10.1177/1048291119889006>.

Varda, D., Betit, E. [2019]. Construction Safety & Health Research: A Social Network Analysis Primer. <https://www.cpwr.com/sites/default/files/publications/SNA-Primer-Final-2019.pdf>

Betit, E., Bunting, J., Fletcher, M.K., Barlet, G., Tolentino-Gonzalez, K. [2019]. R2p Seminar & Partnership Workshop Summary Report: Research to Practice (r2p) In Construction: Science, Strategies & Partnerships to Advance Safety & Health June 2015 – June 2019. <https://www.cpwr.com/wp-content/uploads/2020/06/2015-2019-r2p-Seminar-Partnership-Workshop-Summary-Report-2019-Final.pdf>.

Bunting, J. [2019]. Raising Awareness of Best Practices to Prevent Falls in Construction. eBook: Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction, p. 23-24. <http://www.workplacepub.com/PDFs/ebook/Construction2019.pdf>.

Betit, E. [2019]. Are You Prepared to Work Safely with Silica? Free Resources from CPWR Can Help. eBook: Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction, p. 28-29. <http://www.workplacepub.com/PDFs/ebook/Construction2019.pdf>.

Olson, R. [2019]. Using Mobile Phone Marketing Technology to Increase Safety Meeting Frequency among Small Residential Construction Companies – Oregon Fatality Assessment and Control Evaluation (OR-FACE). https://www.cpwr.com/wp-content/uploads/publications/Oregon-Using-Mobile-Phone-Tech-to-increase-Safety-Meetings-CPWR-final-report-2019_11.1.19.pdf.

Fletcher, M.K., Betit, E. [2019]. CPWR Report: TRU-Net Noise Survey for Workers (Apprenticeship & Journey-level Trainees) Survey Results. May. <https://www.cpwr.com/sites/default/files/publications/RR2019-worker-noise%20survey-results.pdf>.

Mazzucca, S., Betit, E., Bunting, J., Tabak, R. [2019]. CPWR R2P Concept Mapping Report. April. <https://www.cpwr.com/sites/default/files/publications/RR2019-concept-mapping.pdf>.

Mazzucca, S., Betit, E., Tabak, R. [2019]. CPWR Report: Exploring Potential Methods to Evaluate Impact and Outcomes of Construction Safety and Health Research. April. <https://www.cpwr.com/sites/default/files/publications/RR2019-exploring-potential-methods-to-evaluate.pdf>.

Mazzucca, S., Weatherly, C., Morshed, A.B., Tabak, R. [2018]. CPWR Report: Using Delphi Panels to Assess Construction Safety Research to Practice: A Narrative Review. December. <https://www.cpwr.com/sites/default/files/publications/SS2018-Delphi-Panels-Narrative-Review.pdf>.

Betit, E. [2018]. Free Tools & Resources to Help with Silica Standard Compliance. Construction Financial Management Association: Industry News & Advocacy. November. <https://www.cfma.org/news/content.cfm?ItemNumber=6877>.

Prevention Partnerships in r2p
CPWR – The Center for Construction Research and Training, PI: Betit
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2020
(NCE Awarded)

Outputs:

- 20 Presentations: 5 covered both the work under this project and the r2p Coordinating project, and 15 were on specific r2p initiatives under this project, including the Roofing r2p Status Report (presentation format)
- 1 abstract accepted for presentation
- 26 articles in trade publications promoting research findings and products: 13 in Masonry r2p Partnership publications; 7 in Roofing r2p Partnership publications; 6 in UA publications
- Masonry r2p Partnership Status Report
- Masonry r2p Partnership survey of BAC members and analyzed results
- Maintained the ChooseHandSafety.org website (www.ChooseHandSafety.org)
- 2 Videos in English and Spanish
- 2 S-CAT^{sc} company-wide reports for small contractors
- Spanish version of online S-CAT^{sc} Assessment Tool (<https://tinyurl.com/S-CAT-sc-2018>)
- Report - Pilot-testing the Safety Climate Assessment Tool (S-CAT^{sc}) for Small Hispanic Construction Firms;
- Best Built Plans (BBP) Resources: [Spanish version of Planning Tool and resources](#) (e.g., infographics, spreadsheets); App-based version of Planning and Interactive Training and Coaching Resources; Ergonomics Training Program – Worker module, Trainer Guide, Contractor module; Spanish and English videos on use of planning resources. BBP Interview Protocol and Report - [CPWR Formative Research: Summary of Contractor Best Built Plans Interviews - 2019](#)
- Report - Summary Report for UA Apprentice Ergonomics Training
- Report - Summary Report for UA Train-the-Trainer Ergonomics Training
- [2015-2019 Summary Report – Research to Practice \(r2p\) in Construction: Science, Strategies & Partnerships to Advance Safety & Health](#)
- [Construction Industry r2p Partnership Toolkit \(updates\) – 3 Masonry r2p Partnership case studies and 1 Roofing r2p Partnership case study on lessons learned](#)
- 1 section of online safety book: [Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction](#)
- 16 infographics: 4 Heat (English and Spanish); 1 RF Radiation (English); and 11 Best Built Plans (Spanish)
- Maintained the Construction Safety and Health Network (safeconstructionnetwork.org)
- Maintained a dedicated section of cpwr.com on communities of practice (<http://www.cpwr.com/research/communities-practice>) and a related section focused on ergonomics (<http://www.cpwr.com/research/construction-ergonomic-research-solutions>)
- 2 Peer-reviewed publications – 1 paper published and contributions to the peer-reviewed seventh edition of *Patty's Industrial Hygiene & Toxicology*

Outcomes:

- The Ergonomics Community of Practice piloted the Best Built Plans (BBP) resources with a small group of contractors to get direct feedback on what works, what needs to be changed, and what other resources are needed. Their feedback, along with input from users who found the BBP website organically, led to the development of new stakeholder-driven resources. One of the new BBP resources is a comprehensive ergonomics training program that builds on the existing BBP interactive training and coaching resources. This new training program was developed at the request of the United Association of Journeymen and Apprentices of the Plumbing, Pipefitting and Sprinkler Fitting Industry (UA) and the Mechanical Contractors Association of America (MCAA). The worker module was piloted with 114 UA apprentices in May 2019. The majority of participants (95%) felt it was valuable. By the end of the training, 60% of the apprentices were able to correctly define ergonomics, 85% were able to identify sprain and strain injuries, and 95% correctly identified ergonomic hazards and ways to avoid them. In August, the program was piloted with 72 UA trainers. The results of the train-the-trainer pilot evaluation survey were also positive. Almost all

(98.6%) of the trainers strongly agreed (63.4%) or agreed (35.2%) that construction workers need the information in this training program. Roughly three out of four (74.3%) said they would use the training program in their classes (25.7% said they were not sure). In October, this training program was presented to a multi-trade audience during CPWR's Trainer Enhancement Program. Feedback from both the August and October meetings was used to revise and finalize the worker module. The contractor module in this comprehensive program was developed with input from the MCAA and piloted in September with a small group of MCAA contractors and with a larger group in January 2020 during the association's annual safety meeting. Surveys and interviews were used to capture feedback, which was used to finalize the program. The MCAA specific version of the contractor module was recorded and is being distributed by the association to its members. A version for use by contractors in all segments of the industry was also recorded and is available online with the worker module. The BBP program continued to be the subject of numerous articles in trade publications, including the Construction Financial Management Association magazine, [Building Profits](#), a section in the eBook [Workplace Material Handling & Safety: Keeping Your Workers Safe in Construction: Planning & Training Tools to Promote the Use of Safe Material Handling Practices](#), and referenced in the seventh edition of *Patty's Industrial Hygiene & Toxicology*. It has also been the subject of presentations to contractor associations, unions, and other target audiences including the BCSP, NASA, and the Ohio Safety Summit. The webinar conducted in Year 4 was viewed on demand 52 times this year. Evaluations of different aspects of the program are being done as part of two newly funded research projects. The web-section www.bestbuiltplans.org has had more than 10,000 page views; the PC-based and app versions of the program have been downloaded more than 600 times, the workbook/worksheets more than 900 times, the infographics more than 1,700 times, and the games more than 2,500 times.

- The Safety Climate Assessment Tool for Small Contractors (S-CAT^{sc}), which was developed as a Roofing r2p Partnership project, was downloaded or completed online 141 times during the year, and CPWR generated company-level reports for two small employers who used it with their employees. The workbook and online tool were also translated into Spanish, and a study was conducted on its use with Spanish-speaking contractors and their employees. This study, [Pilot-testing the Safety Climate Assessment Tool \(S-CAT^{sc}\) for Small Hispanic Construction Firms](#), provided important insights into reaching and communicating with these target audiences. The lessons learned from the study was the focus of an r2p Roundtable on reaching small employers and at-risk workers (See r2p Coordinating project).
- The Roofing r2p Partnership's #roofersafety365 social media campaign expanded the Partners' reach and helped keep the focus on ways to prevent falls and other hazards in this high-risk segment of the industry. This initiative resulted in 449 posts on Facebook, Twitter, and LinkedIn, and generated 439,854 impressions and 2,434 retweets, shares and interactions. The Partnership also developed a video, "Safe Ladder Practices in Roofing," in [English](#) and [Spanish](#), which was released to coincide with the 2019 Falls Campaign Stand-Down (see r2p Coordinating project). The video has been viewed 3,290 times.
- The Masonry r2p Partnership completed a survey of union masonry workers. The results indicate that dissemination initiatives to raise awareness and use of interventions are working, with increases in workers saying they *always* use engineering controls or PPE: use of gloves increased from 35% in 2011 (the baseline survey) to 62% in 2019; use of hearing protection increased from 30% to 60%; use of controls when engaged in silica-generating tasks increased from 19% to 69%.
- The fifth annual r2p Seminar and Partnership Workshop brought together an interdisciplinary group of 80 NIOSH and CPWR researchers, and government, insurance, and construction industry representatives to discuss r2p approaches, opportunities, and challenges. The agenda topics and speakers were shaped by the synergy between projects identified during the r2p Roadmap calls and discussions with key personnel at NIOSH. This year, one Workshop was held on reaching at-risk audiences and facilitated by staff from CPWR's Environmental Career Worker Training Program (ECWTP), and another Workshop was held on disseminating findings from current research projects and facilitated by industry stakeholders. Ninety-eight percent (98%) of respondents to the evaluation survey rated the Seminar and Partnership Workshop as "good" to "excellent," 100% said the learning objectives were met, 98% said it was relevant to their work, and 98% said the information provided ideas to improve their own r2p efforts. A new resource was developed for use by researchers that documented what was learned at the 2019 and past meetings and workshops: [2015-2019 Summary Report - Research to Practice \(r2p\) In Construction: Science, Strategies & Partnerships to Advance Safety & Health](#).

Specific Aim 1: Expand and evaluate model r2p partnerships by identifying factors that help and hinder construction contractors, workers, and other stakeholders in working together effectively to both promote and seek out evidence-based safety and health interventions.

(a) Masonry Partnership – explore the sustainability of an existing, effective partnership.

The Partnership's 2019 member survey was the fourth one conducted since the baseline survey in 2011, shortly after the Partnership was established. The results indicate that dissemination efforts on the top three priority areas have been successful. The Partnership's active engagement in the NIOSH research project on tuckpointing and the CPWR funded SAVE project was cited by both research teams as having been critical to the success of their projects. In the case of the SAVE project, for example, the Partnership incorporated the SAVE training program into their national training curriculum by delivering the training to over 100 trainers and making the full program available to all trainers nationwide. In addition, the Partnership continued to be a valuable resource for dissemination of other research findings and interventions, including, for example, the Noise and Hearing Loss Prevention Training Program (see r2p Coordinating project) and the Best Built Plans program. Lessons learned on how this partnership has been sustained through two grant cycles, and is continuing into this next cycle, are documented in case studies in the Construction r2p Partnership Toolkit. The status report on the Partnership's work was developed. Due to COVID-19 the meeting where this report would have been shared with members of the six BAC Labor Management Craft Committees was postponed.

(b) Roofing Partnership – explore the replicability and adaptability of the partnership model by developing a new r2p partnership in a high-risk construction sector that includes a broader demographic of workers and contractors.

The Roofing r2p Partnership continued to promote and learn from the S-CAT for Small Contractors (S-CAT^{sc}) about what resources small employers need to strengthen their safety climate. The S-CAT^{sc} was translated into Spanish, used as part of a study with Hispanic contractors and their employees, and modified to reflect the study findings. The modified version was made available online and promoted. The findings from this study were shared with the Partnership and were the focus of the Roundtable on reaching and influencing small contractors and workers at disproportionate risk (see r2p Coordinating project). In addition, the Partnership continued to disseminate information on its initial project, the Radiofrequency (RF) Radiation Awareness Program for the Construction Industry, as well as other CPWR programs, including the Noise and Hearing Loss Prevention Training Program (see r2p Coordinating project) and the BBP program. These efforts included articles, presentations, and promotion through the coordinated communications and social media campaign (#roofersafety365). This social media campaign is now an ongoing, year-round initiative. In addition, the RF Radiation research conducted through the Partnership was included in a section on this hazard in *Patty's Industrial Hygiene and Toxicology*. The joint initiatives successfully carried out by this Partnership demonstrate the value of using a formal partnership to engage a broader demographic – in this case union and non-union stakeholders – in identifying causes of injuries and fatalities and finding mutually agreeable and beneficial ways to address them. Lessons learned from this Partnership are documented in a case study in the Partnership Toolkit.

Specific Aim 2: Build a network of r2p partnerships to enhance and evaluate their ability to promote evidence-based safety and health interventions, overcome barriers to adoption, and identify research needs based on experience from the field.

Initiatives to build a network of r2p partnerships and create mechanisms to facilitate stakeholders coming together to advance r2p continued during the year. The Ergonomics Community of Practice (E-CoP) piloted the BBP program with a small group of contractors and used the feedback from participating contractors and other users of the program to fill gaps in the resources provided, creating an app version of the program, a video on use of the resources, Spanish versions of the planning and selected training resources, and a comprehensive ergonomics training program with worker and contractor modules and a trainer guide. This training program makes the connection between how preventing painful MSDs can help address another industry issue – the need for pain medication and risk for addiction. The E-CoP's work has been included in articles in various types of trade and industry publications, such as the Construction Financial Management Association, which reaches industry staff who have a direct impact on how a company's funds are spent. It has also been shared through presentations at industry and scientific meetings, including 2018 NOIRS, the Bureau of Certified Safety Professionals Inaugural Safety Innovation Summit, and the 2019 Ohio Safety Congress & Expo. An article for a peer-reviewed journal is currently in progress, and a presentation has been scheduled for BlueCross

BlueShield in 2021. This program has led to two newly funded research projects to evaluate its use on preventing strain and sprain injuries.

Our Alliance with OSHA was renewed for five years in recognition of its value to advancing both organizations' safety and health priorities. This Alliance provides another platform for disseminating research findings and products and reaching new audiences. Through our Alliance participation we have seen an increase in the promotion of CPWR research and resources by OSHA and members of the Construction Alliance Roundtable, and have developed co-branded products, including the trench infographic in English and Spanish. We have also used the Alliance to engage other OSHA departments and Alliances in the work of our Mining Work Group (see r2p Coordinating project) to address operating engineers' exposure to silica.

The Construction Safety and Health Network (SafeConstructionNetwork.org), launched in 2018, expanded during the year as industry stakeholders became more aware of the value of using this platform to share materials and make connections. At the end of August, the number of individuals who had registered in order to take advantage of the networking and notification features had increased from 136 to 180, and the site had 38 posts, 1,595 users, and 2,419 sessions during the year. A presentation on the network development was made at the 2018 NIOSH meeting.

The annual r2p Seminar and Partnership Workshop (see r2p Coordinating project) provided an opportunity to share information on partnership developments and gather new insights into how to work in partnership to advance r2p. The results of the 2019 Partnership Workshops are included in the r2p Seminar and Partnership Workshop [2015-2019 Summary Report - Research to Practice \(r2p\) In Construction: Science, Strategies & Partnerships to Advance Safety & Health](#). This report and two studies completed in Year 5, one on the use of a toolbox talk app (see r2p Coordinating project) and one on the Spanish S-CAT^{sc}, were the focus of the Roundtable meeting in November 2019 (see r2p Coordinating project).

Specific Aim 3: Develop, expand, maintain, and evaluate resources to assist r2p partnership efforts, including specific translational materials identified and developed by the partnerships.

We maintained and expanded the online resources and tools developed with support from our partnerships and collaborators, such as ChooseHandSafety.org, silica-safe.org, and the mast climber online resource (<http://www.cpwr.com/research/mast-climbers>), and developed new materials in support of industry partnerships (see Aims 1 and 2, and the r2p Coordinating project). Examples of translational products and tools developed include the new BBP program resources, the Spanish version of the S-CAT^{sc} online assessment tool, and the new video on ladder safety. The r2p evaluation tracking model was used to track r2p partnership initiatives during the 2014-2019 grant cycle (see r2p Coordinating project – Aim 5).

Studies and Results

- A discussion of the S-CAT^{sc} was included in a peer-reviewed article, [The Safety Climate Assessment Tool \(S-CAT\): A rubric-based approach to measuring construction safety climate](#), published in the *Journal of Safety Research*. In addition, a separate study on using the S-CAT^{sc} with small, Spanish-speaking contractors and their employees provided important lessons on how to engage and communicate safety and health information to these populations.
- The BBP pilot led to the development of new resources to fill stakeholder identified needs and resulted in a series of recommendations for increasing the program's use by contractors and their employees to reduce strain and sprain injuries. One of the recommendations was the development of a comprehensive Ergonomics Training Program with modules for workers and contractors that builds on the BBP message and resources.

Significance

The National Academies' review of the NIOSH Construction Research Program in 2007-2008 emphasized the need to "keep the worker and contractor in mind as the ultimate destination for its r2p efforts," and identified two critical research questions that should remain in the forefront of r2p efforts: 1) "How can the program get vital information to the worker 'in the trench' or 'on the steel'?"; and 2) "How does the program persuade

contractors and workers to effectively use the interventions that are developed through research?" This project's efforts expanded and institutionalized ongoing safety and health partnerships in the construction industry, furthered researchers' understanding of their importance and role in r2p, and created an integrated network of safety and health partnerships and organizations to expand our reach and capacity for r2p and p2r (practice to research). Examples of this expanded reach are reflected in: the work of the E-CoP and the stakeholder driven Best Built Plans program resources; the Roofing r2p Partnership's development and evaluation of a Spanish version of the S-CAT^{sc}; the Masonry r2p Partnership's progress in increasing use of safer practices (as documented in its survey results) and providing support for the successfully completed NIOSH p2r project on tuckpointing and the CPWR r2p SAVE project; and the creation of a new platform to share findings (e.g., the Construction Safety and Health Network).

Presentations

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Communications Plan
CPWR – The Center for Construction Research and Training, PI: Wright
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2020
(NCE Awarded)

Outputs:

- 1 conference presentation
- Hosted 13 webinars (see r2p Coordinating project)
- Two peer-reviewed journal articles
- One promotional mailing to key target audiences
- 811 CPWR tweets. This is up from 62 tweets the first year of the cooperative agreement
- Added 684 pages of content to eLCOSH (www.elcosh.org). Overall the website recorded 791,410 page views during 615,211 sessions
- Maintained and updated www.cpwr.com, which reported 231,741 sessions and 519,546 page views
- Added 36 new videos to CPWR's YouTube Channel; recorded 53,444 views for all videos during this time, including 2,655 on-demand views of CPWR webinars
- Produced CPWR's 2018 *Highlights* (annual report) and distributed 8,027 print copies; 171 copies were downloaded
- Produced 10 Media Fact Sheets
- Prepared 14 editions of the *CPWR UPDATE* e-newsletter
- Prepared 16 Key Findings from Research
- 16 reports: laid out and posted 4 *Quarterly Data Reports* (Data Center publications) and 12 additional CPWR reports
- Distributed 792,911 printed CPWR publications, flyers and products, including 429,937 Hazard Alert Cards
- Distributed CPWR publications and products at 10 national industry events
- Updated 13 Hazard Alert cards
- Market survey

Outcomes:

- CPWR research, products, and activities were covered in at least 89 stories in trade and union publications, including 4 stories in the *Engineering News-Record*, 18 in *Safety + Health*, and 18 in *ISHN*.
- CPWR research, products and activities were featured in 2 editions of the *OSHA QuickTakes* e-newsletter, 4 editions of the OSHA's *Quarterly Compliance Assistance Resources*, 6 times in the NIOSH *e-News* or *Research Rounds*, and 16 times in the NIEHS e-news brief. These publications, which reach hundreds of thousands of stakeholders (e.g., the *OSHA QuickTakes* has a circulation of more than 200,000), included articles on, for example, the Best Built Plans program, the Foundations for Safety Leadership, our noise and PPE for women resources, safety climate resources, and the Safe Construction Network.
- The coordinated digital and social media outreach program conducted through the r2p initiative increased stakeholders' engagement with CPWR content. Compared to year 4, Twitter "retweets" were up 21%, "click-throughs" were up 32%, and impressions were up about 0.7%. Facebook "Likes" were up 2%, and the number of LinkedIn followers increased by 486, bringing the total to more than 1,000. Thirteen CPWR educational webinars allowed more than 1,846 workers, contractors, and other industry stakeholders to hear directly from researchers about CPWR research topics and r2p priorities in real-time. In addition, stakeholders viewed *recorded* CPWR webinars on demand 2,655 times.
- Overall, through participation at industry events, targeted outreach mailings, and allowing those registering for a webinar to sign up for the CPWR Update, the number of contacts in CONDOR increased to 10,898. Roughly 15% only provided mailing addresses, 20% only provided email, and 65% provided both. Overall, 85% have given us permission to include them in blast emails (e.g., Update e-newsletter, surveys).

Specific Aim 1: Maintain and expand the electronic Library of Construction Occupational Safety and Health (eLCOSH), the National Construction Center’s central repository for collecting and disseminating hazard information, research findings and industry best practices to construction industry owners-users, employers, workers, trainers, government, and others.

Content on the eLCOSH website (www.elcosh.org) continued to grow, including information and products developed by CPWR internal and external researchers, and construction safety and health reports and research from external groups. We added 684 pages of content to eLCOSH, exceeding our five-year goals for pages added and learning objects (see Table 3). During the program year, 497,915 users visited eLCOSH.org, an increase of 15% over the previous program year. In addition, 30 nano-enabled construction materials and products were identified and added to the eLCOSH Nano inventory, bringing the total to 617 (see Nanomaterials in Construction project).

Specific Aim 2: Develop publications, and promote and market research findings, from the National Construction Center’s Applied Research, Translation/R2P, New Emerging Research, and Support Services for Construction Industry Data and Statistics Programs.

CPWR’s YouTube channel (<https://www.youtube.com/channel/UCAC28BCIEBdALIJ8A--MhWw>), main website (www.cpwr.com), and electronic newsletter, the CPWR UPDATE, were used to promote research findings and new CPWR products during the year. The UPDATE was sent monthly to a growing number of subscribers – 7,920 as of August 2019, with an “open rate” of 27.5%. During the year, we posted 36 new videos. This brought the total number of videos on CPWR’s YouTube channel to 99. During the year, the videos were viewed 53,444, including 2,655 views of CPWR webinars on-demand. Use of CPWR’s main website, cpwr.com, continued to grow, ending the year significantly higher than at the start of the grant cycle. During the year there were 231,741 sessions, or roughly 15% more than in Year 4, and more than 519,456 page views. Popular products on cpwr.com included Toolbox Talks (more than 230,000 downloads); *Foundations of Safety Leadership* course materials (more than 26,000 downloads); Hazard Alert Cards (more than 18,000 downloads), infographics (more than 18,000 downloads), and the 6th Edition of the Construction Chart Book (more than 13,000 downloads). Efforts through social media and the Construction Safety and Health Network increased CPWR’s reach significantly, as shown in Table 1 (see r2p Coordinating and Prevention Partnerships projects). In addition, the number of LinkedIn followers increased by 486 to 1,062. Since the current version of the website was launched in 2013, the site’s content has grown significantly, and web technology and designs have improved. To help users navigate the site an A to Z index function was added.

Table 1: Social & Digital Media

Metric	12 mo. ending 8/31/2014	12 mo. ending 8/31/2018	12 mo. ending 8/31/2019	Change 2014-2019
elcosh.org users	300,457	430,287	497,915	+197,458; +65.7%
elcosh.org sessions	380,506	541,014	615,211	+234,705; +61.7
elcosh.org page views	658,506	724,554	791,410	+132,904; +20.2%
cpwr.com users	59,029	120,580	160,507	+101,478 +171.9%
cpwr.com sessions	81,439	176,062	231,741	+150,302 +184.5%
cpwr.com page views	229,071	423,563	519,546	+290,475; +126.8%
CPWR UPDATE subscribers	2,555	6,941	7,920	+5,365 +210.0%

Number of @CPWR Tweets	62	647	811	+749; +1,208.1%
@CPWR impressions	33,313	914,243	920,462	+887,149; +2,663.1%
@CPWR retweets	104	2,647	2,085	+1,981; +1,904.8%
@CPWR click-throughs	157	2,892	1,954	+1,797; +1,144.6%
CPWR and eLCOSH Facebook Likes	16,570	32,912	33,729	+17,159; +103.6%

In addition, we had exceeded our five-year goals for targeted outreach in all 11 categories: ENR 400/600, safety consultants/trainers, apprenticeship training staff, and academics actively publishing in the field, and we continued to make gains this year.

From September 1, 2018 to August 31, 2019, we distributed 792,911 printed products and topic-specific flyers in response to orders from stakeholders and at academic conferences, meetings, trade shows, and through targeted mailings. CPWR’s annual report *Highlights: Research. Training. Service.* was published and mailed to 7,905 industry opinion leaders drawn from CONDOR. An additional 122 print copies were distributed following the mailing, and the report was downloaded 171 times from the CPWR website. Working in cooperation with researchers, trainers and staff subject matter experts, CPWR has already met or exceed its five-year safety and health publications and products goals (see Table 2).

Table 2: Products

Product	Years 1& 2	Year 3	Year 4	Year 5	Total	5 Year Goal
Hazard Alert Cards	8 New & 3 Updated	2 New & 3 Updated	4 New	13 Updated	33 - 14 New & 19 Updated	20
Key Findings	39	18	13	16	86	24
Research Publications	15	6	24	16	62	45
Pages posted to eLCOSH	2,448	1,161	659	684	4,952	4000
Learning objects posted to eLCOSH	16	1	0	0	17	10

Specific Aim 3: Evaluate and enhance communication strategies/products to reach multiple targeted audiences, including exploration of innovative dissemination methods, such as social media.

The construction workforce includes a large segment of workers with limited education and/or English-language fluency. Health communications researchers have identified a number of writing, organization, and layout techniques that can make written materials more accessible to low-literacy audiences, and designed instruments to assess whether written materials comply with these techniques. In year 4, the *American Journal of Industrial Medicine* published the results of our study assessing the readability and suitability of construction safety and health materials in use today (Sinyai et al., 2018).

In addition, we revised an older CPWR Hazard Alert using the CDC Clear Communication Index (CCI), and conducted an experiment with 425 construction apprentices and journey-level workers to determine whether use of the CCI improved reading comprehension, and whether readers preferred the revised format. In year 5 we analyzed the data and found that the revised Hazard Alert did modestly outperform the original. Workers who received the revised document were less likely to indicate a problem with unfamiliar or confusing words and were less likely to cite factors making the document difficult to understand compared to those who

received the original document. Workers who received the revised Hazard Alert were also more likely to identify key action messages in the text. The results of our study have been published in the *Journal of Occupational and Environmental Medicine*.

In addition, we promoted the 16 annotated bibliographies we had developed in Year 4 on critical construction safety and health topics -- including falls, musculoskeletal disorders, noise and hearing loss, safety culture and climate and prevention through design (PtD) -- with research audiences. We also established a media section on our main website and developed 10 Media Fact Sheets for use by journalists and as the basis for articles in trade publications. The fact sheets provide a brief overview of 10 hazards facing construction workers, OSHA requirements and recommendations for mitigating the hazards and protecting workers, and access to additional research and resources. Topics include trenches, silica, nail guns, portable generators, confined spaces, electrocution, aerial lifts, and falls from ladders, scaffolds, and roofs. In year 5 we analyzed trends and patterns in the entries covering 15 years of construction occupational safety and health research. The results of this analysis was published in *Safety Science*.

We also conducted a market survey of key target audiences as a follow up to a baseline survey conducted in 2015 to identify any changes in user preferences for types of materials and sources for safety and health information. The 2015 survey was sent to 1,407 contacts in the CONDOR database and 22% (or 314) responded. It was distributed in a paper copy as part of an annual mailing and by email as an online survey to others in the target audiences sample. The link to the most recent survey was distributed to 3,444 contacts in CONDOR. The larger sample reflected growth in the CONDOR outreach database since the original survey was conducted. This survey was only distributed by email as an online survey. Although the sample was much larger, the response rate was much lower – 5% or 179 responses. Some factors that may have contributed to the lower response include 1) using only an online format instead of both paper and online options and not tying the survey to an annual mailing; and 2) the level of construction activity at the time of the surveys. If construction activity was strong, then potential participants may not have felt they could spare the time to participate. Despite a lower response rate, the survey results yielded some interesting findings that will inform future dissemination efforts. Notably, the topics of greatest interest, such as safety culture, falls, chemical exposures, and airborne silica, and the key sources of information remained the same. However, with the most recent survey we noted greater use of social media and increased communications in Spanish to workers most comfortable in that language. These findings correspond with the growth experienced in our social media followers and demand for materials translated into Spanish. Finally, we conducted an annual mailing to 3900 individuals in the following target audiences: firm safety and health staff; safety consultants; union safety and health staff; union trainers; and academics working on construction topics. This mailing highlighted new and popular materials and products.

Specific Aim 4: Explore how journalists in the mass media and the trade press understand safety and health issues and increase coverage of the National Construction Center’s research and materials in the media.

CPWR research, products, and staff were featured in at least 89 stories published in trade, professional and union publications during the program year, including, for example, *Engineering News-Record* (4), *Safety + Health* (18) and *ISHN* (18).

Studies and Results:

- Results from our study on use of CCI to improve reading comprehension has been published in the *Journal of Occupational and Environmental Medicine*.
- An analysis of trends and patterns in 15 years of construction occupational safety and health research has been published in *Safety Science*.

Significance:

The most promising occupational safety and health research findings cannot impact worker safety and health if they are not delivered to an audience with the capacity to use that information. CPWR continues to publish research and products through its web-based outlets, and increasingly supplements this with active dissemination efforts through direct mail, social media, and the e-newsletter, leading to substantial increases in demand for CPWR’s construction safety and health offerings. Research initiatives targeting construction safety

and health personnel (the market survey), trade workers (readability and suitability testing), and academics (the interdisciplinary bibliography project), will inform future tailored outreach for each segment of the CPWR audience.

Presentations:

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Safety Voice for Ergonomics
Eastern Washington University, PI: Dan Anton
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

Outputs – Year 5

- Completed modifications to SAVE videos, instructor manual, and apprentice workbook based on feedback from participants and instructors, fall 2018 through spring 2019
- Analyzed data from evaluation and interpreted results, summer 2018 through winter 2019
- Developed SAVE narrated Instructor Orientation Power Point for distribution to the International Masonry Institute (IMI) and CPWR
- Provided final materials (7 videos, instructor manual, apprentice workbook, Instructor Orientation) to IMI and CPWR
- Administered online survey to IMI instructors who received SAVE instructor training to gather feedback and adoption estimates
- Submitted three articles for publication in scientific journals (text messaging, prevalence, findings from the evaluation), and one for a trade newsletter
- Taught final two (of five) 3-hour SAVE Train the Trainer trainings at the International Masonry Institute (IMI) Instructor Certification Program, 9/10/18-9/11/18, Bowie, MD
- Presented SAVE at:
 - The National Occupational Injury Research Symposium, 10/18/18, Morgantown, WV
 - International Union of Bricklayers and Allied Craft workers (BAC) Labor-Management Committee meeting, 3/06/19, San Diego, CA
 - CPWR webinar, 5/21/19
 - CPWR 2019 r2p Seminar and Partnership Workshop, 6/18/19, Silver Springs, MD
 - International Council of Employers of Bricklayers and Allied Craft workers Annual Meeting, 10/30/19, Washington, DC

Outcomes – Year 5

- SAVE materials (videos, instructor and apprentice manuals) available to IMI instructors on IMI portal.
- SAVE is being incorporated into IMI apprentice training program materials, nationally
- SAVE training broadly available (to contractors, safety officers, supervisors, ergonomic practitioners, etc.) through the CPWR website. Between May 15 and August 31, 2019 there were 125 SAVE webpage sessions; the SAVE instructor manual was downloaded 31 times; the apprentice workbook 35 times; and individual units viewed between 11 times (communication unit) and 74 times (Intro unit).
- In Year 5, approximately 42 IMI instructors received SAVE train-the-train 3-hour instruction in Bowie MD, totaling over 100 instructors trained in Years 4 and 5
- SAVE is being broadly adopted by IMI instructors who received SAVE training. Seventy seven instructors who received SAVE instructor training provided email addresses and consent for our team to follow up. An online survey of those 77 IMI instructors conducted in summer of 2019 produced 26 completed responses. Of those, 65% (17 instructors) had taught SAVE during the previous 10 months.

Specific Aims – Year 5

We have met all of our study aims for Year 5. However, three manuscripts are still awaiting acceptance for publication. There were no changes in key personnel.

Specific Aim 1: Develop the SAVE Program

Development the SAVE program materials was completed early in Year 3.

Specific Aim 2: Measure the effectiveness of the SAVE Program

Evaluation of the effectiveness of the SAVE training program tailored to hazards faced by brick and block apprentices was initiated in December 2016 and was completed in July 2018, Year 4. In the first half of Year 5, we analyzed and interpreted the data in preparation for publication and dissemination. Data included self-administered surveys (knowledge, adoption, reaction), and text message information from three study

participants' groups: Ergonomics + Safety Voice, Ergonomics Only and Control groups. At the close of data collection, we had met our goal of recruiting 93 masonry apprentices to participate in the study.

Table 1 below shows the number of apprentices enrolled at each data collection time point in the evaluation RCT (baseline, 2 weeks following primary training, and 3 and 6 months following training). Based on previous studies with construction trades, attrition was expected so baseline recruitment was over-sampled. We initially assessed 128 apprentices at baseline. This number decreased at each data collection point such that at 6-months following the SAVE training 93 participants had completed all follow-up surveys. Data from one apprentice assigned to the control condition was removed as he was the single apprentice who completed post-training measures at his site, which would have resulted in zero within-cluster variance. At 3 and 6 months, participants lost to follow-up simply chose not return follow-up surveys after multiple attempts to encourage response.

Table 1: Total participants enrolled for the primary study evaluation at each data collection time

Group	Baseline	2 weeks	3 months	6 months
	Number of Apprentices in each group			
Ergonomic + Safety Voice	52	52	44	38
Ergonomics	48	48	38	32
Control	28	27	20	23
Totals	128	127	102	93

Specific Aim 3: Finalize and disseminate the SAVE program

Following data analysis, dissemination was a primary focus for Year 5. The final modifications to SAVE videos, instructor manual, and apprentice workbook began early in Year 5 based on feedback from apprentices and instructors. Once complete, SAVE was disseminated through several mechanisms to key stakeholders and beyond, details are provided in “SAVE Dissemination” section below.

Studies and Results

To assess the effectiveness of SAVE broadly we evaluated the data from the three study groups (ergo only, ergo + safety voice and control) and investigated 1) musculoskeletal symptom prevalence, 2) the effect of using text messages to reinforce training and for communicating with participants, and 3) the primary assessment metrics (knowledge, adoption of ergonomic and safety voice practices and reactions to the training). Final analyses were completed in Year 5 as anticipated. Our results have been submitted to four publications: musculoskeletal symptom prevalence findings titled ‘Prevalence of work-related musculoskeletal pain in masonry apprentices’ have been submitted to Ergonomics, text message findings titled “Efficacy of text messaging apprentices to reinforce ergonomics and safety voice training” have been submitted to the Journal of Safety Research, primary outcomes from the evaluation titled ‘Safety Voice for Ergonomics (SAVE): Evaluation of a masonry apprenticeship training program’ has been submitted to Applied Ergonomics, and an article intended for masonry contractors titled “If I just stay strong, I won’t get injured. True or False?” has been accepted for print and online publication to the Construction Contractors Association of the Hudson Valley, in January 2020: <https://www.ccahv.com/>.

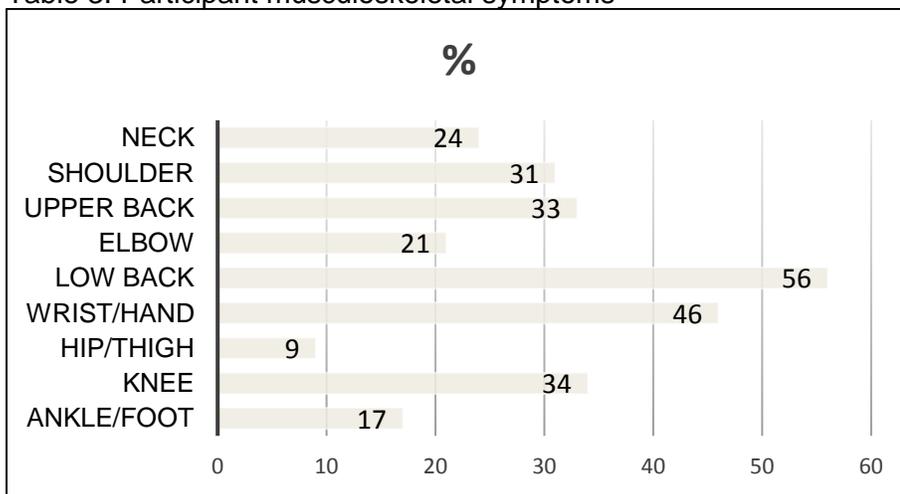
Musculoskeletal Symptom Prevalence: The prevalence of musculoskeletal symptoms among apprentices was calculated from baseline data on 140 apprentices, i.e., before the primary SAVE intervention was initiated. This included baseline data from 12 apprentices who were consented, but then did not continue and receive SAVE training. We collected demographic information and responses to the Modified Nordic questionnaire (MNQ), an assessment of musculoskeletal symptoms. The MNQ asked apprentices about current work-related musculoskeletal symptoms in specific body regions, whether they saw a physician for the symptoms, and if they missed work in the last week due to the symptoms. Demographic information and participant prior training are presented in Table 2. Participant musculoskeletal symptoms are presented in Table 3. The mean number of regions (out of 9 regions surveyed) with reported work-related symptoms across all apprentices was 2.7 (SD = 2.1). Although many apprentices reported musculoskeletal symptoms, none missed work and few consulted a healthcare practitioner. Consistent with previous studies of journey-level masons, low back pain was most

prevalent, yet only 4% of apprentices accessed healthcare in this study compared to 34% in previous research of journey-level masons. These findings suggest that musculoskeletal symptoms occur early in a mason’s career, and that the frequency of symptoms and seeking healthcare, increases with time. These apprentice symptom responses indicate that effective ergonomic interventions have the potential to reduce musculoskeletal symptoms and the risk of MSDs as they progress through their careers.

Table 2. SAVE participant demographic information and prior training

Apprentices at baseline (n=140)		Training	
Age (mean (SD))	29 years (7.2)	OSHA 10 training	68%
1 st year apprentice	45%	Ergonomics training	16%
Male	97%	Stretch & Flex	27%
Caucasian	57%		

Table 3. Participant musculoskeletal symptoms



Text Message Training Reinforcement: To reinforce the primary classroom training, refresher training was implemented by sending weekly text messages for six-months after the classroom training to the 2 intervention groups but not the control group. 119 participants from 8 centers, 61% (n=72) responded to at least one text message. A multivariable logistic regression model that included age, race/ethnicity, previous education, and masonry work performed most often revealed a few predictors that significantly increased the odds of responding to text messages: education and masonry work performed. At the end of the six months of text messaging, 69% of apprentices agreed that text messages reinforced SAVE content. Even though there was no training center requirement to respond, the high response rate suggests that text messaging can be effectively used to reinforce ergonomics and safety voice training for both knowledge and behavior.

SAVE Evaluation Results: Effectiveness of the SAVE intervention was evaluated using a RCT study design that compared study outcomes across the 3 groups (ergonomics + safety voice training, ergonomics training, and control) at baseline, 2-weeks, 3-months and 6-months following the SAVE training intervention. Outcomes consisted of adoption of ergonomic practices, safety voice use, safety participation, safety compliance, and ergonomics knowledge. In the 2 groups that received training, we asked for their reaction to it at the 3-month and final follow-up. The findings demonstrated that, compared to controls, SAVE trained apprentices used their safety voice more ($P = .049$) and had greater safety participation ($P = .028$). They adopted more ergonomic practices such as adjusting scaffolding ($P = .016$) and used better body postures ($P = .042$). Apprentices felt the SAVE intervention was effective and indicated that SAVE prompted them to change workplace safety behaviors. The SAVE evaluation study was registered on ClinicalTrials.gov (NCT02676635).

SAVE Dissemination: To continue disseminating the SAVE Program in Year 5, we conducted two additional IMI instructor trainings in September 2018 in Bowie MD to over 100 IMI instructors who train all around the

country. During the training, we presented a SAVE orientation Power Point designed to ensure a common understanding of ergonomics principles among IMI instructors, and provide an overview of the entire SAVE Program. Instructors watched key segments of SAVE units, and researchers led them through all SAVE activities and discussions. Instructors were familiarized with the instructor manual and how it coincided with the apprentice workbook. Every instructor was provided printed instructor and apprentice workbooks, information on how to access SAVE online, and a SAVE mug. Seventy-seven instructors who agreed to be contacted and provided email addresses were sent an online survey in July 2019 to determine their use of the SAVE training program. In total, 26 instructors (34%) completed the survey. Sixty-five percent (n=17) of the responders taught SAVE in the past year at their training center, with 55% saying they taught it to brick and block apprentices, and 52% to other crafts besides brick and block. When asked how many apprentices were taught SAVE, 37% answered, between 1-10 apprentices, followed by 11-20 apprentices (26%), and 21-30 apprentices (26%). For those that did not teach SAVE, several mentioned that they had not had time to teach it or still needed to get approval to get it into their curriculum. Eighty-eight percent (n=21) said they intended to teach SAVE in the next year. Nearly all instructors agreed or strongly agreed that they would recommend SAVE to other IMI instructors and continue to teach SAVE to apprentices at their training center.

To further disseminate, we presented SAVE to key stakeholders in three BAC meeting committees (brick and block, stone and restoration & retrofit) at the February 2019 (BAC) Labor-Management Committee meeting in San Diego, CA. These meeting committees consisted of IMI administrators, instructors, labor representatives, contractors, and masonry workers from across the US. In May 2019, members of the SAVE team presented the program nationally in a CPWR webinar. There were 194 registered participants, 82 attendees, and the webinar has been posted on the CPWR website as well as on YouTube for others to view. Response to the SAVE webinar was very positive. Following completion of the SAVE 5-year grant funding, SAVE was presented to approximately 24 masonry contractors (with funding directly from CPWR) in October 2019 at the International Council of Employers Annual meeting in Washington, DC.

To make SAVE widely available, during the summer of 2019, all SAVE materials (7 videos, instructor manual, apprentice workbook and updated, narrated instructor Orientation PowerPoint) were made available to IMI instructors through the IMI portal and for national distribution on the CPWR website. Finally, the study results of the SAVE program have been summarized and submitted for publication to academic journals as noted above.

Significance

As we noted, 56% of apprentices are already experiencing lower back pain, as well as pain in other body regions. These symptoms likely denote the early stages of cumulative trauma disorders. The SAVE Program addresses work-related musculoskeletal disorders and fills a training gap by providing an interactive, innovative training with both ergonomics and safety voice components. To our knowledge, this is the first evidence based ergonomic and safety voice training that has been integrated into construction apprenticeship curricula. The relevance of these materials was ensured with the assistance and extensive feedback by the Masonry r2p partnership, participating apprentices, and IMI instructors. The training was rigorously evaluated using a RCT study design. Our reach was broad; we trained over 105 IMI instructors from across the US.

SAVE is being integrated into IMI apprenticeship training curriculum nationwide by Bob Arnold, the National Training Director at IMI in Bowie, MD. This will enhance engagement in ergonomics and safety voice by apprentices as they mature in their careers. SAVE integration is an important step in the process of empowering new masons to be safety leaders who speak up about safety. SAVE training is an important part of the process of reducing musculoskeletal injuries rates in the masonry trade and beyond. SAVE materials have a national masonry reach by being available online to all IMI instructors via the IMI instructor portal. Further, materials will reach others, such as masonry contractors, safety officers, construction supervisors, and ergonomics practitioners, through the CPWR website and YouTube searches.

Presentations/Publications

Journal Articles

Kincl, L. D., Hess, J. A., Weeks, D. L., Vaughan, A., Anton, D. (2020) Efficacy of text messaging apprentices to reinforce ergonomics and safety voice training, *Journal of Safety Research*, <https://doi.org/10.1016/j.jsr.2020.04.007>

Hess, J. A., Kincl, L. D., Weeks, D. L., Vaughan, A., Anton, D. Safety Voice for Ergonomics (SAVE): Evaluation of a masonry apprenticeship training program. *Appl Ergon.* 2020;86:103083. doi:10.1016/j.apergo.2020.103083

Anton, D., Bray, M., Hess, J. A., Weeks, D. L., Kincl, L. D., Vaughan, A. (2020) Prevalence of work-related musculoskeletal pain in masonry apprentices [published online ahead of print, 2020 Jun 11]. *Ergonomics.* 2020;1-9. doi:10.1080/00140139.2020.1772380

Trade Publications

Vaughan, A., Kincl, L. D., Hess, J. A., Weeks, D. L., & Anton, D. (2020, January). If I just stay strong, I won't get injured. True or False? On the Level – Construction Contractors Association Newsletter.

Presentations

Hess, J. A., Kincl, L. D., Weeks, D. L. & Anton, D. (2018, September). SAVE Program: Train the Trainer. Talk presented at the International Masonry Institute Instructor Certification Program, Bowie, MD.

Kincl, L. D., Anton, D., Bray, M., Hess, J. A., & Weeks, D. L. (2018, October). Safety Voice for Ergonomics. Talk presented at the National Occupational Injury Research Symposium, Morgantown, WV.

Hess, J. Kincl, L. D., Weeks, D. L., & Anton, D. (2019, March). Safety Voice for Ergonomics. Talk presented at the International Union of Bricklayers and Allied Craft workers Labor-Management Craft Committee Meeting, San Diego, CA.

Anton, D., Hess, J. A., Wysocki, D., Kincl, L. D., Vaughan, A., & Weeks, D. L. (2019, May). Safety Voice for Ergonomics [Video webinar]. Retrieved from CPWR's Informational Webinar Series: <https://www.cpwr.com/news-events/cpwrs-informational-webinar-series>

Anton, D., Hess, J. A., Kincl, L. D., Vaughan, A., & Weeks, D. L. (2019, June). Safety Voice for Ergonomics. Talk presented at Continuing the Work: Moving Completed Research into Practice, CPWR 2019 r2p Seminar and Partnership Workshop, Silver Springs, MD.

Hess, J. A., Kincl, L. D., Weeks, D. L., & Anton, D. (2019, October). Safety Voice for Ergonomics. International Council of Employers of Bricklayers and Allied Craftworkers Annual Meeting, Washington, DC.

Test Bench for Evaluating Concrete Drilling Methods
University of California, San Francisco, PI: David Rempel
Final Yr 5 Progress Report
September 1, 2018 – March 1, 2020
(NCE Awarded)

Outputs:

- A paper describing differences in respirable silica dust between the new through bit localized exhaust ventilation (LEV) and the OSHA approved shroud LEV was published in the *Journal of Occupational and Environmental Hygiene*.
- A paper describing the effects of push force during concrete drilling on handle vibration and productivity was accepted for publication in the *International Journal of Industrial Ergonomics*.
- A paper describing differences in respirable silica dust, handle vibration, noise levels and productivity between pneumatic and electric rotary hammer drill was published in *Applied Ergonomics*.
- The findings from several specific aims were highlighted in NIOSH Research Rounds, Vol 4, Number 4 (October 2018). “Outside NIOSH: Research Shows How to Reduce Hazards of Concrete Drilling”.
- The findings from several specific aims were presented in a webinar to ASSP (American Society of Safety Professionals) members on February 15, 2019 “Complying with the Silica Standard – New Resources and Research”.
- The findings from several specific aims were presented to tool manufacturers and contractors at the January 2019 and February 2020 World of Concrete meetings in Las Vegas.
- The findings from several specific aims were presented to contractors and safety professionals at the Oregon Governor’s Occupational Safety and Health Conference, March 5, 2019.
- The findings from several specific aims were presented to contractors and safety professionals at the Ohio Safety Congress and Expo, March 6, 2019 “Respirable Silica Dust Exposure During Drilling into Concrete”.
- YouTube video: “A Controlled Comparison of 2 Concrete Drilling Methods: Concrete Dust, Vibration & Noise” was produced in English and Spanish.
- Detailed respirable silica dust data from our studies were shared with the CPWR Exposure Control Technologies Research team [September 19, 2019].
- Assisted CPWR with development and dissemination of “Best Built Plans” Program.
- The findings on the effects of force applied during drilling on drill handle vibration and productivity were presented at the PREMUS International Congress, September 2, 2019.

Outcomes:

- The State of Alaska “Governor’s Innovation in Safety Award” was presented to Alyeska Pipeline Service Company for using the drill support system developed as part of the overall research project. The company used the support system to reduce worker hazards when drilling 3500 large diameter holes at the Valdez Marine Terminal [April 2019]
- OSHA will consider adding through bit dust extraction to Table 1 for concrete drilling based on our paper: Rempel D, Barr A, Cooper M. Effect of Hollow Bit Local Exhaust Ventilation on Respirable Quartz Dust Concentrations during Concrete Drilling. *Journal of Occupational and Environmental Hygiene* 2019; 16(5):336-340. [April 29, 2019]
- Our publications demonstrating control of respirable silica dust during drilling were used by the American Thoracic Society in their comments to MSHA on silica exposure during mining [October 10, 2019].
- **The Spanish version of the YouTube video was posted:** “A Controlled Comparison of 2 Concrete Drilling Methods: Concrete Dust, Vibration & Noise”. <https://www.youtube.com/watch?v=0CH-eIMaG8Q&feature=youtu.be>
- CPWR Key Findings [October 2019] *Silica dust reduction through hollow bit drill ventilation*.
- CPWR Update: Research News [September 2018] *In concrete drilling, new electric rotary drills protect worker health without reducing productivity*.
- CPWR Highlights, *Buy Smart: Sharp Drill Bits and Electric Rotary Drills Improve Safety* [December 2018]

Specific Aims:

1. Measure productivity, handle vibration, handle torque and respirable silica dust during drilling with 3 types of dust capture methods for an electric hammer drill and 2 dust capture methods for a pneumatic rock drill. Hammer drill and pneumatic rock drill will be of similar mass and similar force on tip (linear drive force). Test with ½, ⅝, and ¾” bits (15 test conditions: 9 for hammer drill and 6 for rock drill).
STATUS: Completed and manuscript published in 2019.
2. Measure productivity, handle vibration, handle torque, and respirable silica dust for 6 different drills during drilling with ½, ¾, and 1” concrete bits at 4 levels of feed force (72 test conditions). The test will include 4 electric hammer drills and 2 pneumatic rock drills. No dust capture will be used.
STATUS: Completed and manuscript accepted for publication. The findings were also presented at an International Conference (PREMUS) in 2019.
3. Measure productivity, handle vibration, handle torque, and respirable silica dust with 2- and 4-blade carbide tip concrete bits (½, ¾ and 1” diameter), at 2 levels of feed force (24 test conditions).
STATUS: Completed and manuscript in preparation. Findings presented at International Conference (PREMUS) in 2019.
4. Measure productivity, handle vibration, handle torque and respirable silica dust with sharp and dull carbide tip concrete bits (½, ¾ and 1” diameter), at 2 levels of feed force (24 test conditions).
STATUS: Completed and two manuscript published in 2017.
5. Share findings with tool manufacturing partners (e.g., HILTI, DeWALT, Bosch, DustControls). Discuss implications for the health of construction workers and how the study findings can be used in design of new, safer products and how best to disseminate the findings to contractors and construction workers.
STATUS: Tool manufacturers are incorporating findings into their training literature.
6. Disseminate study findings to construction workers and contractors using the R2P Roadmap through CPWR websites, union newsletters, California Department of Public Health distributions to California contractors, construction safety conferences, union meetings, presentations at scientific meetings and publications in peer-reviewed scientific journals.
STATUS: Findings from all Specific Aims widely disseminated.
7. Add a hardware and software module to the test bench system so that the system can measure the same outcome measures for concrete grinders. Test reliability of new design.
STATUS: System built, calibrated, and validated with test subjects.

Studies and Results:

The study comparing different localized exhaust ventilation (LEV) systems during concrete drilling found that through bit localized exhaust ventilation (LEV) was as effective as a shroud LEV in controlling respirable silica dust levels. The levels with both systems were well below the OSHA PEL. Without LEV the levels were 22 times the PEL.

The study evaluating the effect of push force during concrete drilling found that Increasing push force on a rotary hammer drill increased drill handle vibration and productivity up to an inflection point of 170 N. Above 170 N there was no change in vibration or productivity. Productivity was modelled based on the maximum allowable duration of exposure to hand vibration as per ISO and ACGIH Action Limits; drilling productivity (in m drilled per day) was achieved with the lowest tested push force.

The newly constructed test-bench system for concrete grinding included a new room with dust containment, an adjustable height structure for supporting vertical and overhead concrete slabs for doing wall or overhead concrete grinding, and systems for monitoring the applied force during drilling, handle vibration, and shoulder muscle activity. The system was calibrated, validated and tested with subjects.

Significance:

The comparison of different LEV systems revealed that the new through bit LEV was as effective as the OSHA Table 1 approved shroud LEV system. Furthermore, the through bit system will be more effective when the concrete surface is uneven. In addition, the through bit system does not require the hole to be brushed out and separately vacuumed prior to inserting epoxy. By adopting the through bit LEV, contractors will protect workers from respirable silica and improve productivity and the holding power of anchor bolts. OSHA was petitioned to add the through bit LEV system to Table 1.

The finding that the greatest daily productivity in concrete drilling was achieved at the lowest push force, that still achieved stable cutting, is counter intuitive. Contractors, construction workers and drill manufacturers will be informed of the finding.

The new test bench system for overhead and wall concrete grinding will be used to evaluate the effect of upper extremity exoskeleton support on shoulder fatigue, productivity and grinding quality in the new exoskeleton grant.

Publications:

Botti L, Martin B, Barr A, Kapellusch J, Mora C, Rempel D. Drilling into concrete: [2020] Effect of feed force on handle vibration and productivity. *International Journal of Industrial Ergonomics*. (accepted for publication)

Rempel D, Antonucci A, Barr A, Cooper M, Martin B, Neitzel R. [2019] Pneumatic rock drill vs. electric rotary hammer drill: Productivity, vibration, dust, and noise when drilling into concrete. *Applied Ergonomics* 74:31-36. PMID: 30487106

Rempel D, Barr A, Cooper M. [2019] Effect of Hollow Bit Local Exhaust Ventilation on Respirable Quartz Dust Concentrations during Concrete Drilling. *Journal of Occupational and Environmental Hygiene*, 16(5):336-340. PMID: 3103200.

NIOSH Research Rounds [October 2018], Vol 4, Number 4, *Outside NIOSH: Research Shows How to Reduce Hazards of Concrete Drilling*. <https://www.cdc.gov/niosh/research-rounds/resroundsv4n4.html>.

The Synergist Newswire (AIHA) [October 19, 2018] *Outside NIOSH: Research Shows How to Reduce Hazards of Concrete Drilling*.

Occupational Health & Safety, OH&S [October 19, 2018]. *NIOSH-Funded Studies Show Ways to Reduce Silica Exposure in Concrete Cutting*. (oshonline.com)

Electrical Construction & Maintenance (EC&M) Magazine [June 18, 2019] *How Proactive Ergonomics Programs Protect Electricians*. by Amy Fischbach. <https://www.ecmweb.com/construction/how-proactive-ergonomic-programs-protect-electricians#close-olyticsmodal>

Presentations:

Barr A [January 21-25, 2019] *New Research on Silica, Vibration, and Productivity During Concrete Drilling*. World of Concrete, Las Vegas, NV

Betit E (CPWR) & Rempel D. [February 15, 2019] *Complying with the Silica Standard – New Resources and Research*. Webinar for Am Soc of Safety Professionals (ASSP).

Rempel D. [March 5, 2019] *Silica: What You Need to Know About Equipment, Research, and Resources*. Presentation with CPWR and FedOSHA at the Oregon Governor's Occupational Safety and Health Conference, Portland, OR.

Barr A. [March 6, 2019] *Respirable Silica Dust Exposure During Drilling into Concrete*. A talk within the CPWR Research: Improving Health and Safety in Construction Session. Ohio Safety Congress & Expo., OH.

Barr A [May 1, 2019] *Respirable Silica Dust Exposure During Drilling into Concrete*. Webinar. UC Berkeley Center for Occupational and Environmental Health. https://youtu.be/Yal3yMnmN_c

Barr A. [June 18-19, 2019] *Technology Transfer – from Research to Technology*, at CPWR r2p and Partnership Workshop. Silver Spring, MD.

Rempel D, Antonucci A, Barr A, Martin B. [September 1, 2018] *Drilling into Concrete: Effects of Bit Wear on Drill Handle Vibration*. International Ergonomics Association Congress 2018, Florence, Italy

Rempel D, Antonucci A, Barr A, Martin B. [October 1-5, 2018] *Handle Vibration on a Pneumatic Rock Drill and Electric Rotary Drill While Drilling into Concrete*. Human Factors and Ergonomics Society Annual Meeting, Philadelphia, PA,

Rempel D, Betit E, Antonucci A, Barr A, Cooper M, Martin B. Neitzel R. [October 16-18, 2018] *Drilling into Concrete: Effects of Bit Wear on Drill Handle Vibration. Comparison of productivity, vibration, dust, and noise between pneumatic rock drill and an electric rotary drill*. National Occupational Injury Research Symposium, Morgantown, WV.

Rempel D, Antonucci A, Barr A, Martin B. [September 2, 2019] *Controlling vibration exposure when drilling into concrete findings from two studies*. PREMUS 2019 (Prevention of Musculoskeletal Disorders), Bologna, Italy.

Rempel D [October 18, 2019] *Construction Ergonomics*. AIHA Hawaii Local Section, Marine Corps Base Hawaii, HI.

Barr A [February 5, 2020] *Respirable Silica Dust Exposure During Drilling into Concrete*. World of Concrete, Las Vegas, NV.

Nanomaterials in Construction: Tracking Product Diffusion and Measuring Exposures
CPWR – The Center for Construction Research and Training, PI: Lippy
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

Outputs

- Enlarged the web-based inventory of construction-related materials that appear to be nano-enabled or nanostructured. As of August 31, 2019, there were 617 products and 354 articles at <http://www.nano.elcosh.org>. The site received 8,478 views in Year 5.
- Presented on nanomaterials in construction to diverse audiences including researchers, industrial hygienists, safety professionals, health and safety trainers, and contractors (see list of presentations and publications attached separately for more detail).
- Four toolbox talks focused on working safely with nanomaterials were downloaded 7,542 times from cpwr.com during Year 5.
- Developed six additional toolbox talks in Year 5; three were posted to cpwr.com since August 31, 2019, and three are going through the review and publishing process.
- Published a paper in the *Journal of Occupational and Environmental Health* on potential for exposure to nanoscale TiO₂ during spraying and sanding of paint. The publication was recognized with the first inaugural award for *Best Paper* by the AIHA Nanotechnology Working Group at AIHce 2019 “for excellence in the use of nanotechnology research.” A shorter summary of the study, written for a wider audience, was posted as a *Key Findings* document on cpwr.com.
- Provided dust samples, paint samples, and exposure measurements to Dr. Jenny Roberts and Dr. Emily Lee of the NIOSH Health Effects Laboratory Division. The first set of data and samples were gathered in April 2019, by request, as part of a follow-up study that used paint without added nanoscale TiO₂ to inform Dr. Robert’s and Dr. Lee’s ongoing research into potential health hazards associated with exposure to engineered nanomaterials. The second set of data and samples was collected during a second test, conducted in August and described below, of a paint containing silver nanomaterials.
- Linked additional potential hazards of nanomaterials to various control technologies in CPWR’s Construction Solutions website, (<http://www.cpwrconstructionsolutions.org/search.php?q=nanomaterials>).
- Distributed 2,219 paper copies of our nanomaterials hazard alert cards, which also had 235 downloads during Year 5.

Outcomes

- Increased knowledge of the types and uses of nanomaterials in construction products, as indicated by thousands of visits to the elcosh nano website, has helped the industry, safety professionals, and researchers to identify and assess risks to workers by providing basic yet critical information that is difficult to find elsewhere.
- Greater understanding of potential nanomaterial hazards and safe work practices by the construction workforce has been achieved through the distribution of nanomaterial hazard alert cards, which can be used as handouts when training workers.
- Downloads of more than 7,000 nano toolbox talks indicate a greater likelihood that workers are using engineering controls and respirators to prevent exposure to dusts and mists that contain engineered nanomaterials and possibly other harmful substances, such as crystalline silica. Toolbox talks are often delivered to a work crew by a foreman at the start of a shift, although they can also be used during classroom training.
- Provided two train-the-trainer sessions for International Union of Operating Engineers health and safety trainers at their training facility in Crosby, TX. The sessions were integrated into the following 2018 courses:
 - OSHA 2225 Respiratory Protection, September 18-21
 - OSHA 521 Industrial Hygiene, September 24-28
- Peer-reviewed publications resulting from this project have received 29 citations, according to Google Scholar.

- We were contacted directly by the Supervising Lab Scientist at the Bureau of Materials & Research for the NH Department of Transportation, who was concerned about potential employee exposure associated with the use of a nano-enabled asphalt additive being imported from India for use on DOT projects in the northeast region. Through follow-up calls and emails, we provided a summary of our research and guidance from NIOSH to assist the department with their efforts to assess and control occupational exposures.
- Dr. Lippy's continued participation, informed by CPWR research, in ISO Technical Committee 229, Working Group 3 on health, safety and environmental concerns about nanomaterials has contributed to the process of setting relevant standards.

Specific Aims

Aim 1: Using data from the CPWR National Construction Center's database of nano-enabled products and input from the affected trades, we will select products for testing that pose the greatest risk to construction workers and measure exposure to free ENPs during tasks routinely performed by construction trades.

Aim 2: Identify and evaluate commercially available control technologies to determine effectiveness in reducing exposures to ENPs among the construction trades while performing common tasks.

The proposed activities and corresponding outputs for Year 5 were closely linked under Aim 1 and Aim 2. For Aim 1, we proposed conducting two exposure studies in Year 5. In addition to measuring exposures, we proposed evaluating exposure control technologies during these studies as part of Aim 2. We conducted the first study in April and the second study in August of 2019. Details of both tests are provided below in the Studies and Results section.

A third proposed activity for Year 5, listed under both Aim 1 and Aim 2, was to provide summaries of findings on exposures and controls. A central finding corroborated by all of our studies thus far, including those conducted in Year 5, is that different types of local exhaust ventilation can easily be attached to different types of power tools used in construction and effectively reduce airborne nanoparticle emissions and exposures. The project's findings on effectiveness of control technologies have been widely disseminated under Aim 4.

Aim 3: Maintain a database of nano-enabled construction products and prioritize potential exposures for sampling using a focus group of tradespersons and safety experts, informed by a risk matrix tool. Disseminate this database to relevant stakeholders.

We proposed establishing the elcosh nano database in Year 1 and to continue updating it throughout the remainder of the project, including Year 5, and have followed through on both fronts. To our knowledge, the database continues to be the most comprehensive collection of publicly available information on reported applications of nanotechnology in frequently used construction materials. At the end of Year 5, the database contained over 600 products and over 350 articles covering a range of relevant topics focused on nanomaterials and construction, including health and safety news, or updates on policy and regulation. Sustained visits to the site, year after year, indicate a useful resource with an engaged group of users.

<i>Contract Year</i>	<i>Calendar Year</i>	<i>eLCOSH Nano Number of Views</i>
Year 1	2014 – 2015	4,688
Year 2	2015 – 2016	11,062
Year 3	2016 – 2017	8,456
Year 4	2017 – 2018	9,570
Year 5	2018 – 2019	8,478

Aim 4: Raise awareness among construction industry stakeholders about the use of nano-enabled construction materials, potential exposures and effective control strategies by broadly disseminating project findings.

Proposed project deliverables under Aim 4 for Year 5 were three new toolbox talks, one peer-reviewed journal article, one presentation at a local or national conference, and three new Construction Solutions. All of these dissemination goals for Year 5 were either met or exceeded. The same holds true for all Aim 4 outputs proposed for the entire 5-year duration of the project, with one exception. Our only unmet goal was to host two conference roundtables (see Table below). In place of these roundtables, we have instead delivered train-the-trainer sessions, including two in Year 5, that have enabled us to share information with construction industry stakeholders more directly. Members of the research team have also participated in, or led sessions at workshops akin to conference roundtables. For example, Dr. Lippy took part in the EU-US Bridging Nano EHS Gaps Workshop in October of the current reporting period and participated in or led sessions at prior workshops hosted by the National Nanotechnology Initiative. Moreover, the team far exceeded the proposed goal of five presentations at local and national conferences over the entire five years, delivering ten presentations in Years 4 and 5 alone in addition to prior presentations. In Year 5, the team also delivered a third peer-reviewed publication and webinar, compared to two of each proposed initially.

<i>Project Deliverables Proposed for Aim 4 (Years 1 through 5)</i>	<i>Status</i>
10 Toolbox talks	Goal met
2 peer-reviewed journal articles	Goal exceeded
5 presentations at local and national conferences	Goal exceeded
2 conference roundtables	Unmet goal, but a proposed session for AIHce 2020 was accepted
10 construction solutions	Goal exceeded
2 webinars	Goal exceeded

Studies and Results

The study of exposure to nanoscale titanium dioxide conducted in Year 4 was published in Year 5 in the *Journal of Occupational and Environmental Hygiene* and was recognized with the first inaugural award for *Best Paper* by the AIHA Nanotechnology Working Group at AIHce 2019 “for excellence in the use of nanotechnology research.” The study estimated exposures to nano-size titanium dioxide (TiO₂) while spraying and sanding a commercially available paint.

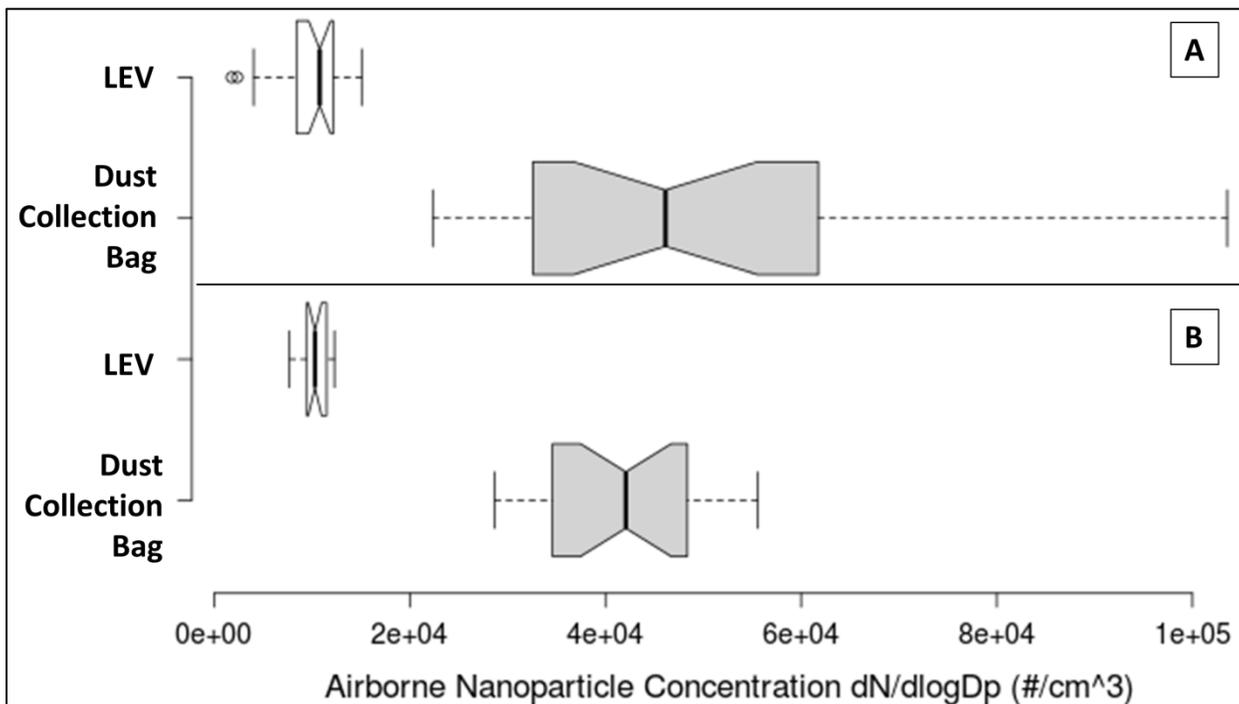
Measurements were compared to the NIOSH recommended exposure limit for ultrafine TiO₂ of 0.3 mg/m³ as a time-weighted average concentration for up to 10 hours per day during a 40 hour workweek. Air samples were collected while a tradesperson performed the tasks in an environmentally controlled chamber. Dust capture during sanding was provided by a dust collection bag or local exhaust ventilation attached to a high efficiency vacuum. Personal and bystander exposures were characterized using particle counts, energy dispersive spectroscopy for metals, airborne mass concentrations, and electron microscopy. Complete and final results and conclusions are provided in the paper, and a briefer summary is provided in CPWR’s Key Findings document:

- Characterization of the paint before testing indicated that most of the TiO₂ primary particles in the paint were nano-size and bound together to form larger structures, called agglomerates.
- Sonication in acetone caused the nanoparticles to separate, raising the question of whether paint thinners and mechanical mixing could mimic this effect observed in the lab.
- Individual nanoparticles were detected by particle counters during spraying and sanding but could not be confirmed by electron microscopy.
- Exposures during sanding were below the NIOSH REL. Dust levels were relatively low, and local exhaust ventilation significantly reduced the number of airborne nanoparticles.

- The researchers concluded that workers could potentially be exposed to levels above the NIOSH REL for ultrafine TiO₂ when applying the paint with an airless sprayer.
- They recommended that employers and industrial hygienists characterize exposures and use the hierarchy of controls to protect the health of employees.
- Future research should consider whether chemicals commonly used in construction, including those found in paint thinners, could impact occupational exposure to nanomaterials in paints.

As described above in the outputs section, a follow-up to this study was conducted in April of 2019 to provide comparison data and measurements for NIOSH collaborators studying the toxicity of the materials we tested in Year 4. In Year 5, the protocol above was replicated using a base paint from the same manufacturer containing titanium dioxide that was larger than nanoscale. A primary interest of Dr. Roberts and her colleagues was to determine if the nano-enabling of the paint changed the distribution of the inhalable and respirable fractions of the airborne particles.

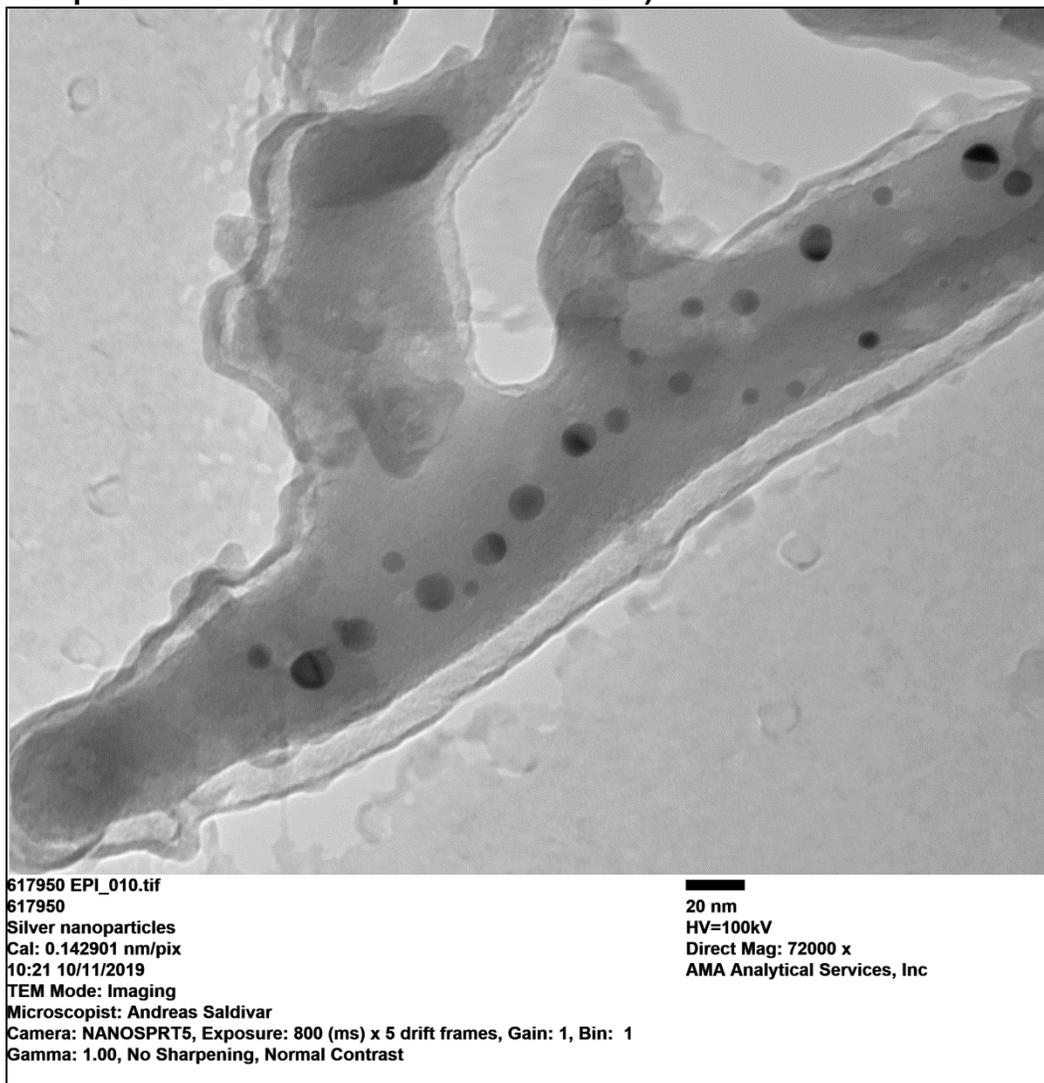
Interestingly, the follow-up study in Year 5 to compare the two types of paint found a difference in nanoparticle emissions between the spray aerosols but not between the sanding dusts. Spraying the comparison paint without nanoscale TiO₂ generated much lower particle number concentrations in the nanoscale size range, with peaks of less than 400 particles per cubic centimeter. In comparison, peaks in the nanoscale size range exceeded 8,000 particles per cubic centimeter in the Year 4 study when spraying the nano-enabled paint. The chart below illustrates nanoparticle emissions during sanding for both studies. The Year 4 results were closely replicated, which suggests that, unlike the differences observed while spraying the two different types of paint, the nanoparticle emissions during sanding were associated with the sanding process itself rather than the paint. Potential explanations for this phenomenon, such as the formation of pyrogenic aerosols, are discussed in our most recent publication. Regardless of the origin of the particles, the Year 5 follow-up study corroborated prior findings showing the effectiveness of local exhaust ventilation (LEV) in reducing airborne nanoparticle concentrations.



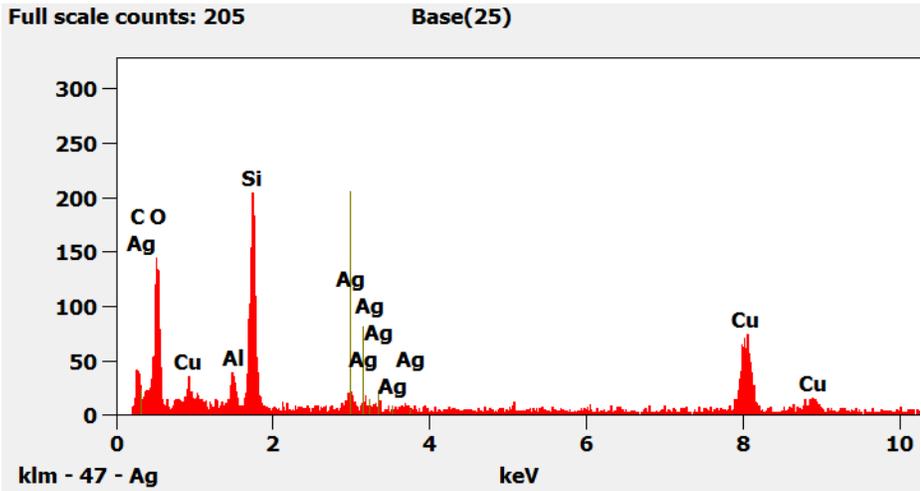
The upper portion of the Figure (A) shows nanoparticle emissions while sanding paint containing larger than nanoscale TiO₂ in Year 5. The lower portion of the Figure (B) shows nanoparticle emissions while sanding paint containing nanoscale TiO₂ in a previous Year 4 study. Center lines show the medians; box limits indicate the 25th and 75th percentiles as determined by R software; whiskers extend 1.5 times the interquartile range from the 25th and 75th percentiles, outliers are represented by dots. n = 22, 22, 24, 28 sample points. LEV = Local Exhaust Ventilation.

Given that prior results indicated there was potential to exceed the NIOSH REL for ultrafine TiO₂ while applying paint with an airless sprayer, the team conducted a second study in Year 5 during August of 2019. This most recent study employed a similar protocol to test a commercially available paint containing silver nanomaterials, in comparison to a base paint provided by the US-based manufacturer without the added silver. Laboratory analyses for the silver study are ongoing, but in the meanwhile the team is preparing a scientific manuscript for publication. Preliminary results show free-standing nano-silver in a bulk sample of the nano-enabled paint before spraying, and also in air samples collected during spraying. Similar to prior tests, most silver nanomaterial detected by electron microscopy was encapsulated in larger globs of the paint matrix. Mass concentrations of silver in the paint itself were relatively low, and mass concentrations of silver in air samples analyzed thus far indicate that the spraying and sanding tasks studied would be unlikely to exceed recommended exposure limits that will be established in a forthcoming NIOSH Current Intelligence Bulletin for silver, which is good news for the workers who apply these products.

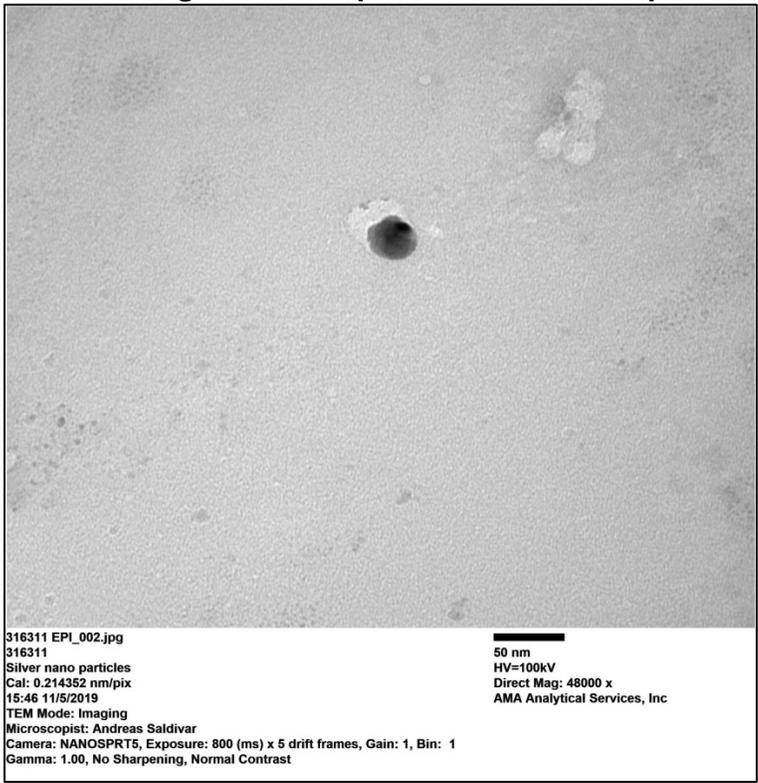
Bulk analysis of the paint showing silver nanoparticles embedded in aluminum silica material (silver nanoparticles are the dark spheres in the fiber)



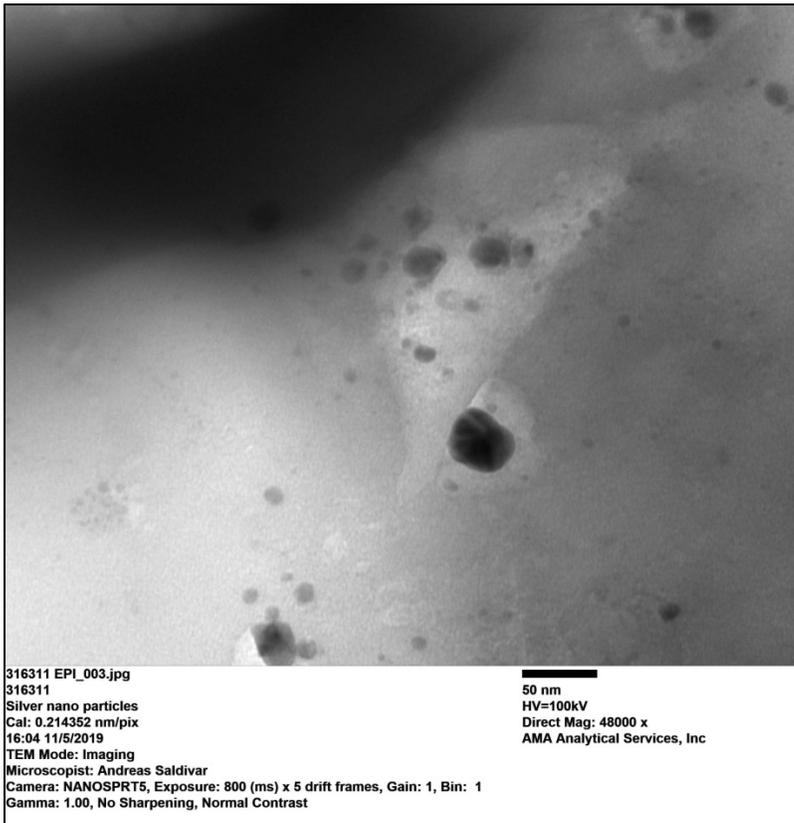
EDXA data from the particles pictured above



Free-standing silver nanoparticle in an air sample collected during spraying



Silver nanoparticles within a larger glob of paint collected in an air sample while spraying



Significance

Our work continues to generate significant interest among construction industry stakeholders, researchers, and health and safety professionals. There are promising societal benefits to be gained through new applications of nanomaterials in the built environment, such as the potential for improved energy and resource conservation. Responsible development of new technologies, however, requires anticipation, assessment, and control of potential workplace hazards, which this 5-year project has helped to achieve for construction workers.

Publications

West, G. H., Cooper, M. R., Burrelli, L. G., Dresser, D., & Lippy, B. E. (2019). Exposure to airborne nano-titanium dioxide during airless spray painting and sanding. *Journal of Occupational and Environmental Hygiene*, 16(3), 218-228. <https://doi.org/10.1080/15459624.2018.1550295>

Lippy, B.E., West, G.H. [TBD]. Industrial Hygiene Issues in Construction: Advanced Materials and Manufacturing section. Patty's Industrial Hygiene and Toxicology, Seventh Edition, accepted, publication pending.

Data Tracking and Support Services
CPWR – The Center for Construction Research and Training, PI: Dong
Final Yr 5 Progress Report
September 1, 2018 – August 31, 2019

Outputs:

- Three peer-reviewed journal articles (two published, one under review)
- Four CPWR Quarterly Data Reports (published)
- Eleven presentations completed (nine conferences; two webinars)
- Five presentations scheduled
- Online Construction Fatality Maps, 2010-2019
- 71 data requests/statistical consultations

Outcomes:

Our data products and research findings are widely used by construction stakeholders.

- **The Construction Chart Book** continues to be a highly valued resource for all construction stakeholders. In Year 5 alone, 15,347 page views and 13,622 downloads of the sixth edition of the Chart Book were recorded through www.cpwr.com from September 1, 2018 to August 31, 2019.

A list of selected users (with links to websites) is below:

- [American Industrial Hygiene Association](#)
- [American Society of Safety Engineers \(ASSE\)](#)
- [Building Product Marketing and Innovations](#)
- [Business and Industry Connection Magazine](#)
- [Cigna](#)
- [Concrete Construction](#)
- [Construction Dive](#)
- [Construction Superintendent](#)
- [Paint Square](#)
- [EHSToday](#)
- [Elevator Industry Jobsite Safety](#)
- [Facility Safety Management](#)
- [General Building Contractors Association](#)
- [Industrial Safety & Hygiene News](#)
- [National Institute of Environmental Health Sciences](#)
- [National Institute of Standards and Technology](#)
- [National Research Council](#)
- [Ohio Bureau of Workers' Compensation](#)
- [Omega Safety Training](#)
- [Partnership for Working Families](#)
- [Safety & Health Magazine](#)
- [Safety Resources](#)
- [Safety Unlimited News-Service](#)
- [United Rentals](#)
- [US Glass News Network](#)

Selected press/ citations highlighting CPWR Data Center products:

- **Deaths and injuries involving elevators or escalators in construction and the general population** (Fourth Quarterly Data Report in 2018)
Total page views = 749; total downloads = 910
 - Bloomberg Environment. 2019. Elevator-Related Construction Deaths Increase, Study Says.
<https://news.bloombergenvironment.com/safety/elevator-related-construction-deaths-increase-study-says>

- Industrial Safety & Hygiene News. 2019. Elevator-related construction fatalities on the rise. <https://www.ishn.com/articles/110211-elevator-related-construction-fatalities-on-the-rise>
- Safety + Health Magazine. 2019. Elevator-related fatalities in construction industry increasing: CPWR. <https://www.safetyandhealthmagazine.com/articles/18054-elevator-related-fatalities-in-construction-industry-increasing-cpwr>
- PR Newswire. 2019. The Elevator Consultants Responds to Startling Elevator Safety Issues with Advice for Building Owners to Instantly Implement. <https://www.prnewswire.com/news-releases/the-elevator-consultants-responds-to-startling-elevator-safety-issues-with-advice-for-building-owners-to-instantly-implement-300835576.html>
- Construction Dive. 2019. Report: Elevator-related construction deaths on the rise. <https://www.constructiondive.com/news/report-elevator-related-construction-deaths-on-the-rise/548008/>
- The Peralta Firm, P.L.L.C.. 2019. Construction Industry Sees Rise in Fatal Elevator Accidents. <https://www.peralta.com/blog/2019/april/construction-industry-sees-rise-in-fatal-elevator/>
- Elevator Radio Show. 2019. Show Notes for episodes 521 & 523. <https://www.elevatordirshow.com/elevator-blog>
- Elevator Schmelevator. 2019. Elevator Injuries on the Rise. <https://schmelevator.wordpress.com/2019/01/28/elevator-injuries-on-the-rise/>
- **Trends of fall injuries and prevention in the construction industry** (Second Quarterly Data Report in 2019):
 - Total page views = 259; total downloads = 388*
 - NIOSH eNews. 2019. The Center for Construction Research and Training Quarterly Report. <https://www.cdc.gov/niosh/enews/enewsv17n5.html>
 - NIOSH eNews. 2019. New Data Report Analyzes Construction Falls. <https://www.cdc.gov/niosh/enews/enewsv17n4.html>
 - Construction Safety & Health Network. 2019. Fatal falls in construction: Total deaths rise, but rate falls, report shows. <https://safeconstructionnetwork.org/collaborations/fatal-falls-in-construction-total-deaths-rise-but-rate-falls-report-shows/>
 - The USGlass Magazine. 2019. Construction Fall Fatality Rates Drop Despite Overall Number Increase. <https://www.usglassmag.com/2019/07/construction-fall-fatality-rates-drop-despite-overall-number-increase/>
 - Gair, Gair, Conason, Rubinowitz, Bloom, Hershenhorn, Steigman & Mackauf. 2019. Fall Fatalities and Deaths in the American Construction Industry. <https://www.newyorkpersonalinjuryattorneysblog.com/fall-fatalities-and-deaths-in-the-american-construction-industry/>
 - Webinar: Total attendees = 171; total views = 109.
- **Heat-related deaths among construction workers in the United States** (published in AJIM)
 - Industrial Safety & Hygiene News. 2019. Construction workers hit hard by heat-related illness. <https://www.ishn.com/articles/111287-construction-workers-hit-hard-by-heat-related-illness>
 - Safety + Health Magazine. 2019. Increase in heat-related construction worker deaths may be tied to global warming: CPWR. <https://www.safetyandhealthmagazine.com/articles/18824-increase-in-heat-related-construction-worker-deaths-may-be-tied-to-global-warming-cpwr>
 - Observer. 2019. US Construction Workers Are Dropping Dead—Here’s Why. <https://observer.com/2019/08/construction-worker-deaths-climate-change-economy/>
 - Kjellstrom T, Lemke B, Lee J. Workplace Heat: An increasing threat to occupational health and productivity. American journal of industrial medicine. 2019 Oct. doi: 10.1002/ajim.23051.
 - Public Citizen disseminated publication to their Heat Stress Network via email in June of 2019.
 - Bloomberg Environment requested copy of publication in August of 2019 to use for a future story.
- **Construction Fatality Maps:** The maps continue to be a frequently used resource and have amassed 168,229 combined views, representing an increase of more than 20,000 views in Year 5. We also received

and responded to data requests for fatalities involving heavy equipment, electrocutions, detached excavator buckets, and methylene chloride.

Specific Aims and Study Results in Year Five

Aim 1: Track fatal and nonfatal injuries and illnesses in the construction industry /

Aim 2: Characterize the changing construction industry and its workforce

We have conducted several studies to achieve these two aims in the current reporting period.

1. Deaths and injuries involving elevators or escalators in construction and the general population:

This study was conducted per request from stakeholders. We analyzed elevator- and escalator-related fatal and nonfatal injuries using data from the Census of Fatal Occupational Injuries, Survey of Occupational Injuries and Illnesses, Current Population Survey, National Electronic Injury Surveillance System, and OSHA Integrated Management Information. We found an overall upward trend in elevator-related fatalities in construction, as the number of deaths and rate has doubled from 2003 to 2016. Between 2011 and 2016, 145 construction workers died due to elevator-related injuries, accounting for more than half of such fatalities in all industries. The majority (53.5%) of elevator-related fatalities in construction were caused by falls to a lower level, nearly half (47.9%) of which were falls from 30 feet or more. We also found that about 46% of construction workers with elevator-related nonfatal injuries required 31 days or more off of work to recover. These findings were reported in the fourth Quarterly Data Report in 2018: <https://www.cpwr.com/wp-content/uploads/publications/Quarter4-QDR-2018.pdf>

2. Nonstandard work arrangements in the construction industry: Although nonstandard work arrangements are common in the construction industry, no detailed information was available for this industry. To better understand this important issue, we analyzed the most recent Contingent Worker Supplement to the Current Population Survey. We found significant socioeconomic disparities between standard and nonstandard work arrangements among construction workers. These findings were reported in the first Quarterly Data Report in 2019: https://www.cpwr.com/wp-content/uploads/publications/Quarter1-QDR-2019_0.pdf Selected findings were also included in the progress report for the Disparities project.

3. Trends of fall injuries and prevention in the construction industry In order to provide updated data to intervention programs and continued support to the National Campaign to Prevent Falls in Construction, we analyzed fatal and nonfatal falls in the construction industry from 2003 to 2017. We found fall injuries remain the top cause of construction fatalities, and the number of fatalities has increased as construction employment rebounded with the economic recovery. However, the rate of fatal falls has been relatively stable over the past few years and slightly decreased in 2017. In addition, the rate of fatal falls showed signs of decreasing among roofers, the occupation with the highest risk of falls, and construction laborers, the largest occupation in this industry. We also found that Hispanic construction workers, foreign-born workers, older workers, and roofers still have a higher risk of fatal falls than the average of all construction workers. Moreover, fatal falls at small construction establishments with fewer than 20 employees accounted for 75% of fatal falls, despite making up only 39% of construction payroll employment. These findings were reported in the second Quarterly Data Report in 2019: <https://www.cpwr.com/wp-content/uploads/publications/Quarter2-QDR-2019.pdf>

4. Heat-related deaths among construction workers in the United States: Heat is a severe hazard for construction workers and may be worsening with global warming. We identified heat-related deaths during 1992-2016 from the Census of Fatal Occupational Injuries. Denominators estimated from the Current Population Survey were matched with demographic and occupational categories in rate calculations. We found

that construction workers accounted for 36% of all occupational heat-related deaths in the U.S. during the study period, which was disproportionately high given that construction workers only made up 6% of the overall workforce. We also found that increasing summer temperatures were significantly associated with the increase in heat-related death rates. Compared to all construction workers, the risk nearly doubled for construction workers born in Mexico. By occupation, cement masons, roofers and construction helpers were three occupations with the highest risk in construction. The findings were published by AJIM (Epub 2019 Jul 22).

Aim 3: Track U.S. construction employer programs/policies/practices on safety and health

We collaborated with Dodge Data & Analytics since 2012 to conduct the Construction Safety Management Survey biennially. In addition to regular surveys, two supplemental surveys were conducted, collecting more information on safety leadership at company level. The findings indicate that mentoring is a good practice that can be more widely used in the construction industry. The results also show a significant difference in safety and health needs by company size, suggesting how important it is to hear directly from target audiences about their needs and concerns. The most recent regular survey was completed in October 2019. Initial findings from the survey will be reported by Dodge and CPWR in November 2019.

Aim 4: Provide data and statistical consultations to construction stakeholders

We received various requests for data or statistical support from construction stakeholders across the country on a weekly basis. During this grant year, we have provided **71** internal and external data requests/statistical consultations.

Our research results have been disseminated through regular online publications, online databases, online mappings, national fall prevention campaigns, training classes, conference presentations, webinars, peer-reviewed journal articles, trade magazines, data requests, statistical consultations, Twitter, Facebook, ResearchGate, safety and health blogs, CPWR website, NIOSH website, citations by other researchers, stakeholders, and the media.

Publications:

CPWR Data Reports:

- CPWR. [2019]. Quarterly Data Report, Third Quarter - Trends of Musculoskeletal Disorders and Interventions in the Construction Industry <https://www.cpwr.com/publications/third-quarter-trends-musculoskeletal-disorders-and-interventions-construction-industry>
- CPWR. [2019]. Quarterly Data Report, First Quarter - Nonstandard work arrangements in the construction industry. https://www.cpwr.com/wp-content/uploads/publications/Quarter1-QDR-2019_0.pdf
- CPWR [2019] Quarterly Data Report, Second Quarter - Trends of fall injuries and prevention in the construction industry. <https://www.cpwr.com/wp-content/uploads/publications/Quarter2-QDR-2019.pdf>
- CPWR [2018] Quarterly Data Report, Third Quarter - Fatal injuries among small construction establishments. <https://www.cpwr.com/publications/third-quarter-fatal-injuries-among-small-construction-establishments>

Peer-reviewed journal articles:

- Dong XS, West GH, Holloway-Beth A, Wang X, Sokas RK. [2019] Heat-related deaths among construction workers in the United States. Am J Ind Med. Dec;62(12):1047-1057. doi: 10.1002/ajim.23024. PMID: 31328819

- Ringen K, Dong XS, Goldenhar LM, Cain CT. [2018]. Construction safety and health in the USA: Lessons from a decade of turmoil. *Ann Work Expo Health*. Sep;62(Suppl_1):S25-S33. doi: 10.1093/annweh/wxy069.

Presentations:

- Dong XS, Wang X, Katz R. [2018]. Trends and patterns of the Construction Focus Four, 1992-2016. The 7th National Occupational Injury Research Symposium: Morgantown WV, October 15-18.
- Dong XS, Wang X, Katz R. [2018]. Safety management and safety culture in the construction industry. The 7th National Occupational Injury Research Symposium: Morgantown WV, October 15-18.
- Dong XS. [2018]. Fatal injuries among small construction establishments in the United States. APHA Annual Meeting & Expo 2018, San Diego, CA, November 10-14.
- Dong XS. [2018]. Inequity in health insurance coverage and healthcare among U.S. construction workers. APHA Annual Meeting & Expo 2018, San Diego, CA, November 10-14.
- Katz R, Dong XS, Wang X. [2018]. Recommendations for construction safety and injury prevention: Findings from the Construction FACE database. The 7th National Occupational Injury Research Symposium: Morgantown WV, October 15-18.
- Jackson R. [2019]. Non-standard work arrangement in the construction industry, CPWR Webinar, April 24.
- Jackson R. [2019]. Non-standard work arrangement in the construction industry, Council of State and Territorial Epidemiologists in Raleigh, NC, June 2.
- Wang X, Katz R, Dong XS. [2018]. Fatal occupational injuries at road construction sites from 2003 to 2016. The 7th National Occupational Injury Research Symposium: Morgantown WV, October 15-18.
- West G. [2018]. Mapping and dissemination of data on fatal construction injuries in the United States, 2011-2018. The 7th National Occupational Injury Research Symposium: Morgantown WV, October 15-18.
- Dong XS. [2019]. Construction Industry and Safety and Health of its Workers, at the fifth Research to Practice (r2p) seminar and partnership workshop, "Continuing the Work: Moving Completed Research into Practice", Silver Spring, MD, June 18.
- Dong XS, Bunting J. [2019]. Fall injuries & prevention in construction. CPWR Webinar, July 24.

Impact

Our research findings and data products have been widely used by construction stakeholders. We continuously receive high praise and positive feedback from users (see Outcomes).

Assessing Public Policy Intervention Impacts on Construction Fatality Rates
University of Pittsburgh, PI: John Mendeloff
Final Yr5 (UPitt's Yr 2) Progress Report
August 1, 2018 – August 31, 2020
(NCE Awarded)

Outputs for the projects

- We developed a new method to calculate fatality rates by state/year for the construction of single-family, detached housing. Analysis showed that these rates were considerably higher in New England and the Middle Atlantic states, probably because a much higher share of these homes have more than one story.
- We developed a new data set with information from California about the Permit program that it uses to pre-screen dangerous construction work.
- We compared the number of construction deaths investigated by OSHA and the number in the same categories identified by CFI and found that OSHA data appear to capture the great majority of the deaths that CFI captured. The significance of this is that OSHA data can often be viewed as fairly complete even for years when CFI data are unavailable.
- We expanded our database to include a) maximum workers' compensation (WC) payments in each state; b) state/years in which small construction firms were not required to have WC coverage; c) the number of OSHA-funded consultation visits in construction in each state/year; d) the number of Hispanic construction workers born in the US; e) the number of Hispanic construction workers born abroad; f) the end-use of construction projects where workers died; g) the type of project (e.g., new, repair); h) the size of the project in dollars; i) whether the worker died in the same county where the employing firm was located; j) the amount of spending for the OSH program in state plan states.
- Presentations:
 - Mendeloff, J., and Gray W. "Explaining State-Level Variations in Construction Fatality Rates," presented at NIOSH NOIRS Conference, Oct. 17, 2018.
 - Mendeloff, J., and Gray W. "Explaining State-Level Variations in Construction Fatality Rates," CPWR Webinar, Jan 23, 2019.
 - Mendeloff, J. "Presentation to Board of Occupational Safety and Health State Plan Association (OSHPA)," Nashville, TN, March 2019.
 - Mendeloff, J., Gray, W. "Explaining Variations in Construction Fatality Rates," Presented June 18, 2019 at CPWR R2P Conference.
 - NIOSH blog "Measuring Workplace Risks across States," July 30, 2020.

Outcomes and r2p for the project

- Our presentation to the OSHPA Board (see above) facilitated their request to members to agree to interviews, which we have carried out with all but 4 of the 21 states. The current chair of OSHPA and another member have asked us if they can distribute some of the presentations we have made to their members.
- We provided one of our presentations to the Executive Director of the International Association of Industrial Accident Boards and Commissions (the association of state WC agencies). She invited us to their annual meeting and John Mendeloff was able to attend.
- We sent some findings to Tom Shanahan, Exec V-P of the National Roofing Contractors Association and followed up with a telephone meeting with him to discuss what issues for roofers he would like us to examine.

Specific Aims

We address the progress that has been made on each Specific Aim. That progress is presented in more detail in the discussion of Studies and Results.

Aim #1: Identify the impact of OSHA inspections on construction fatalities by looking at the inspection rate (inspections per 1000 employees), the average penalties per inspection, and the average experience level of inspectors, as well as differences in impact between federal and state OSHA enforcement programs.

Higher penalties per inspection continue to show associations with higher fatality rates, not lower ones. However, this relation holds only among federal states; in state plan states, penalty size is not related to fatality rates. None of the control variables we have introduced change the finding that most state plan states have the lowest fatality rates. Determining the role of inspection frequency is complicated by the fact that all of the high frequency inspection rates are found in state plan states. That makes it difficult to tell if the mechanism is the high frequency of inspection or some other features of those states. Higher rates of consultations appear to be associated with lower fatality rates.

Aim #2: Identify the effects of variations in workers' compensation (WC) costs to employers and other specific WC provisions on fatalities.

Along with the length of the waiting period (before indemnity benefits can be received), we also examined the size exemptions that some states still apply to requirements for WC coverage. The evidence seems fairly robust that size exemptions in construction are linked to higher state fatality rates. The finding that fatality rates at small firms were especially elevated in those states indicates that the relationship is causal.

We continue to find that longer waiting periods are linked to higher fatality rates and we believe that there is a plausible causal connection.

Aim #3: Identify several non-policy factors that influence the rate of fatalities in the construction sector and estimate their impact—e.g., the mix of sub-industries within construction, wage levels, the extent of work performed in large projects, the extent of unionization, and demographic characteristics such as age, experience and ethnic and language differences.

One notable finding concerned Hispanic and foreign-born Hispanic workers. In the full sample, we found no significant effects on fatality rates of their shares in the construction labor force. However, there was an indication that in federal OSHA states, a higher Hispanic share was linked to higher fatality rates. In the roofing industry, there were strong effects with the share of foreign-born Hispanic workers raising the rate and the share of other Hispanic workers lowering it.

Another insight came from creating a method for estimating fatality rates for workers in single-family home construction. The data on these deaths came from OSHA. For a denominator, we used the Commerce Department's data on the number of single family residences constructed in each state. Interestingly, the highest rates were found in New England and the Middle Atlantic states. We then obtained data on the percentage of these homes that had more than one story and found that the percentages were considerably higher in those two regions. In retrospect, it doesn't seem strange that building homes with more stories would increase the rate of fatal falls, the largest risk in construction; For other types of construction, these regions are relatively safe.

Aim #4: Identify possible interactions between OSHA and WC interventions, on the one hand, and non-policy factors: different sub-industries, different size categories of firms, different unionization rates, and different demographic groups.

The chief interaction that we have examined involves firm size and WC exemptions based on firm size. The effects of the WC policy variables were the same in federal and state plan states.

Aim #5: Identify those states which appear to have unusually low or high fatality rates, after controlling for differences in observable factors, and examine what further factors might account for those findings.

As we observed in an earlier report, Wisconsin and Washington State have much lower fatality rates than other states, although Arizona, California and Oregon are not far behind. All but Wisconsin are state plan states and all of those are in the West. Through document review and interviews with state officials, we attempted to identify practices that seemed like promising candidates for preventing fatalities. Washington and Oregon lead the way in high inspection rates, making their presence more visible than it is in most states. Washington also innovated with a policy (the "Stute" decision) that held general contractors responsible for OSHA violations committed by their subcontractors. However, since a federal court decision in 2017, federal OSHA enforcement now appears to follow similar policies under its multi-employer policy.

California has low fatality rates despite having a below average inspection rate. It does have an interesting policy requiring employers who carry out especially risky work (trenching and construction at heights above 36 feet) to obtain permits by visiting the Cal-OSHA offices and providing information that allows OSHA to monitor them. As noted, we present an analysis of these data in Part 2 of our Report. Wisconsin has had a policy for over 80 years that requires an employer to pay a 15% surcharge on WC payments when an accident was caused by a safety violation. However, that policy has been less frequently relied upon since federal OSHA took over enforcement in that state.

Studies and Results

Aim 1---States where the OSHA program operates under a State Plan have lower fatality rates, on average, than states where federal OSHA operates the program. The gap increased somewhat in the 1980s and early 1990s, but appears to have shrunk somewhat since 2000. In general, state plans inspect more frequently but levy lower penalties than federal OSHA. Higher average penalties are linked to higher, not lower, fatality rates in federal states, but not in state plan states. Higher inspection rates are linked with lower fatality rates; however, when we include state plan status in the model, that effect disappears—i.e., among state plan states and among federal OSHA states, there is not a clear relationship between inspection rates and fatality rates.

It is possible that the relation between higher average penalties per inspection and higher fatality rates that we find in federal states is evidence of worse compliance causing higher penalties; however, higher average penalties per inspection are not due to citing more violations. Instead, they are due to higher penalties per violation, suggesting that the differences may be due to different enforcement styles rather than to underlying differences in the extent of employer compliance.

For general construction and special trades contractors, we found the same protective effect of more inspections and the opposite effect of higher average penalties. In contrast, more frequent inspections had no effect in heavy construction or in the roofing industry. For small firms (under 11 employees), we found no effects of either inspections or penalties. However, except for heavy industry, longer WC waiting periods and exemptions for small firms were linked to higher fatality rates.

Aim 2---Longer waiting periods before indemnity benefits are awarded is consistently found to be linked to higher fatality rates. We believe that there is a strong argument that this relationship is causal, although it is difficult to test because very few states changed their policy in the years we examine. States which exempt small construction firms from the requirement to have workers' compensation coverage have higher fatality rates. The causal impact of this policy is indicated by the finding that the higher rates are much more pronounced for small firms in those states.

Aim 3--- Earlier studies have left researchers puzzled by the finding that the share of construction workers who are Hispanic was linked to lower, not higher, fatality rates. Overall, we do not find an effect; however, in federal OSHA states the coefficient for the Hispanic share was significant and positive at the 0.10 level. Nationally, the death rate of Hispanic construction workers fell sharply as their share of employment rose from about 10% to 30%. In the roofing industry, foreign-born Hispanic workers had much higher death rates than non-Hispanics, while native-born Hispanics had much lower death rates.

We constructed a data set on worker deaths in the construction of new single-family homes and the number of new single-family homes constructed in each state-year. We found that death rates in this sector were highest in New England and the Middle Atlantic states. This finding was surprising because these states have not usually been identified as high-risk states. We tied these findings to data on the percentage of new single-family homes with more than 1 story and found that the percentages were considerably higher in those two regions.

Many studies of fatalities have relied on OSHA data from accident investigations. Those data do provide some information not collected by CFOI. We wanted to study how complete the OSHA data are by comparing the numbers to those reported by CFOI since 1992. We eliminated CFOI deaths that would not generally be investigated by OSHA (involving criminal behavior or highway motor vehicle crashes or air, railroad or maritime transportation). For recent years, we found that the OSHA data appear to capture the great majority of deaths

reported by CFOI, although there are exceptions. These comparisons can be useful for researchers thinking of using the OSHA data and wanting to know how comprehensive its coverage is. For a number of years, the OSHA data provide information that was not included in CFOI.

Aim 4 --- In states that have size exemptions, the rates for small firms are much higher than the rates for those firms in states without the exemptions. .

Aim 5--- As we noted, on average, states with state plans have lower fatality rates than federal OSHA states. Washington, California, Arizona, Maryland and Minnesota are among the 6 states with the lowest rates while Kentucky and Tennessee are exceptions. Wisconsin stands out as a federal state with a very low fatality rate. Mississippi, Arkansas and West Virginia have fatality rate about 3 times higher than the safest states.

We have tried to identify special state policies that might account for good performance and which might be transferable to other states. This has led us to identify the California program to require permits before allowing several types of high risk construction to begin; the Washington state judicial ruling that general contractors are responsible for OSHA violations committed by their sub-contractors; and the Wisconsin practice of adding a 15% surcharge to WC payments when an injury was caused by an OSHA violation. As noted below, we have obtained special data from California and are assessing the Permit program there.

Significance

Given variations in the reporting of non-fatal injuries across states, fatal injuries are the most valid measure of serious workplace risks. To this point, there has been limited interest among Workers' Compensation agencies about how the design of their policies affects fatality risks. Our results on longer waiting periods and numerical size exemptions show that these policies are associated with higher fatality rates. Changing those policies should lead to fewer deaths.

Federal OSHA requires that state plan programs be "as effective as" the federal program. States with more inspections and consultations have lower fatality rates and these are mostly state plan states. It is possible that each federal inspection has more impact, but that the total effect is outweighed by the greater frequency in state plan states. Given the costs of added inspections and consultations, it is also worth exploring further the potentially helpful practices of some state programs, including their better integration with local public and private organizations and the use of permit programs.

Accomplishments

We submitted our final report to CPWR on March 4, 2020. Part 1 provided the main analysis of the impact of public policies on construction fatality rates. Part 2 provided a series of analyses on:

Detailed differences between federal states and state plan states

Fatality rates of union and non-union workers by state

Analysis of the California Permit Program for Construction

Analysis of death rates (per housing start) in single-family residential construction

We continue to work to prepare several articles for publication, including

- The Role of the California Permit Program in Preventing Fatalities
- Variations in Fatalities in the Roofing Industry Across States
- Variations in State Policies in Workers' Compensation and Safety Inspections
- A less scholarly version of major findings for professional journals

Articles Submitted for Publication

Wayne B. Gray, John Mendeloff, "Construction Fatalities across States and over Time: The Role of Public Policies"

Mendeloff, J., Gray, Wayne B., Stasio, Tanya, Afridi, N. "Comparing the Number of Deaths Reported by CFOI and Investigated by OSHA "

Presentations/Abstracts/Publications Archive Inventory

NIOSH blog "Measuring Workplace Risks across States," July 30, 2020.

Mendeloff, J., Gray W. "Explaining State-Level Variations in Construction Fatality Rates," presented at NIOSH NOIRS Conference, Oct. 17, 2018.

Mendeloff, J., Gray W. "Explaining State-Level Variations in Construction Fatality Rates," CPWR Webinar, Jan 23, 2019.

Mendeloff, J. "Presentation to Board of Occupational Safety and Health State Plan Association (OSHPA)," Nashville, TN, March 2019.

Mendeloff, J., Gray, W. "Explaining Variations in Construction Fatality Rates," Presented June 18, 2019 at CPWR R2P Conference.

Mendeloff, J., Gray, Wayne B., Stasio, Tanya, Afridi, N. "Comparing the Number of Deaths Reported by CFOI and Investigated by OSHA," in preparation.