which includes the cost of units of PPE, fitting, education, and training. The production function should portray the ways in which EC and PPE interact to prevent injuries. Different functional forms depict the complex relationships between PPE and EC in different settings.

Results: We found that as the cost of EC and PPE change, so does the firm's optimal quantity of EC and PPE, as the firm is responding to a change in relative costs. The firm is highly responsive to the EC lifetime, which then affects the cost of the PPE. An EC with a relatively long life implicitly raises the cost of PPE, resulting in a relative increase in the optimal amount of EC and decrease in the optimal amount of PPE. Additionally, there were settings where it was optimal for the firm to invest either solely in EC or solely in PPE, a result driven by the form of the production function. To illustrate the method and present numerical results, we used a simple optimization example that involves a series of strong assumptions: the firm produces a hazard at a fixed and known quantity and is acting only in the short-run. In this example, the short-run is implicitly modeled and reflects the time necessary to achieve the hazard reduction. We assumed that PPE cost $50 per unit; EC cost $300 per unit; the production function was Cobb-Douglas; and EC was 9 times more effective than PPE to prevent injuries. Then if a firm aimed to decrease expected injuries by 5, it would minimize its intervention cost by purchasing roughly 25 units of PPE and 4 units of EC, totaling around $2,500.

Discussion: Firms can use our model to understand how to evaluate both the effectiveness and the cost of EC and PPE over time and respond to changes following the passage of new regulation or the development of new standards and technology. This may encourage increased adoption of EC and optimal mix of EC and PPE, thereby improving worker protection. Our model contributes to the OSH literature by providing a new economic perspective to hazard control decision-making.

Session E1
Title: Fatal Injuries in the U.S. Construction Industry
Moderator: Christine Branche

This session is composed of four presentations, providing updated injury data and information on database development from the CPWR safety and health surveillance research.

E1.1
Title: Trends and Patterns of the Construction Focus Four 1992-2016

Authors: Xiuwen Sue Dong, Xuanwen Wang, Rebecca Katz

Background: Fall, struck-by, electrocution, and caught-in/ between are the Focus Four hazards identified by the U.S. Occupational Safety and Health Administration as the leading causes of fatalities in the construction industry. This study examines fatal injuries among construction workers caused by these four hazards.

Methods: Three large national datasets (Census of Fatal Occupational Injuries, Current Population Survey, and Current Employment Statistics), covering 1992 to 2016, were analyzed. Stratified and time series analyses were conducted using SAS 9.4 to identify high-risk subgroups in construction over time.

Results: From 1992 through 2015, the Focus Four claimed the lives of 745 construction workers annually, accounting for 70% of all construction fatalities. Specifically, 8,211 deaths were from falls to a lower level, 4,648 deaths were due to being struck by an object or a vehicle, 2,807 deaths were caused by contact with electric current, and 2,207 deaths were from caught-in/ between injuries over this period. Each of these causes of death hit their lowest point between 2010 and 2012 during the latest recession and increased since then, though at different paces. Risks of the Focus Four vary by demographics and occupation. Deaths from falls to a lower level reached 353 in 2015, a 36% increase since 2011 and more rapid growth than the other three causes. Increases in fall fatalities were disproportionately high in residential construction and among Hispanic and foreign-born workers. The risk of struck-by was higher among highway maintenance workers and power-line installers, while the risk of caught-in/ between injuries was highest among ironworkers. In addition, excavating or loading machine operators had a higher risk of fatality from being struck-by as well as caught-in/ between injuries. Although electrocutions remained the third leading cause of death in construction, such deaths decreased by 39% between 2003 and 2015, suggesting effective interventions. Overall, older construction workers had an elevated risk for fatal injuries caused by the Focus Four. (Results will be updated to cover the 2016 data).

Discussion: This study identifies worker groups and occupations with high risk of the fatal four hazards in construction. Enhanced hazard controls and interventions are needed to improve construction safety and health overall.

E1.2

Title: Fatal Occupational Injuries at Road Construction Sites from 2003–2016

Authors: Xuanwen Wang, Xiuwen Sue Dong, Rebecca Katz

Background: Working at road construction sites is dangerous. This study examines the trends and patterns of fatal occupational injuries among construction workers at road construction sites over time, especially after the recent economic downturn.

Methods: Two large national datasets from 2003 to 2016 were analyzed, including the Census of Fatal Occupational Injuries and the Current Population Survey. Stratified and time series analyses were conducted to identify differences among subgroups in construction over time. Linear regression and odds ratios with 95% confidence intervals were utilized to measure whether changes or differences are statistically significant.

Results: From 2003 to 2015, 1,166 construction workers died at road construction sites, comprising more than 70% of such deaths in all industries. Coinciding with the employment trend, the number of fatalities at road construction sites climbed from a low of 73 in 2010 to 87 in 2015, a nearly 20% increase over five years. In terms of event or exposure, more than half of road construction deaths between 2011 and 2015 were pedestrian vehicular incidents where a worker was struck by a vehicle or mobile equipment. Another 12.6% were roadway incidents that occurred while a worker was operating a vehicle. Trucks were the top source of deaths at road construction sites, involved in nearly one-quarter of road construction site fatalities. Passenger vehicles (including automobiles, buses, and passenger vans) were the second most common source, causing 17.5% of construction fatalities at those sites. By industry subsector, 309 workers in the Highway, Street, and Bridge subsector (NAICS 2373) were killed at road construction sites, accounting for 72% of all road construction fatalities during these years. By occupation, construction laborers had the highest number of fatalities at road construction sites, while highway maintenance workers had the highest risk of such deaths (14.2 deaths per 100,000 full-time equivalent workers). Workers 55 years and older as well as African American workers also experienced an elevated risk of such fatalities.

Discussion: Compared to other major industries, the construction industry experiences a large burden of deaths at road construction sites. Interventions should be enhanced for high-risk occupations and worker groups. Note: The numbers will be updated to 2016 when the 2016 CFOI micro data are available.

E1.3

Title: Mapping and Dissemination of Data on Fatal Construction Injuries in the United States, 2011-2018

Author: Gavin West

Background: Falls from elevation are the leading cause of fatal and non-fatal injuries in construction. Approximately one-third of work-related deaths in construction are due to falls. Hundreds of construction workers in the U.S. are killed every year due to on-the-job falls, and over 10,000 are seriously injured. In 2012, a national campaign was launched to raise awareness and prevent fatal falls in construction. One aspect of supporting the campaign's objectives was to provide construction industry stakeholders and campaign partners with readily accessible, current, and detailed information about fatal falls in their geographic areas.

Methods: Incident-specific information on work-related construction fatalities was collected for calendar years 2011 to 2017. OSHA records of construction fatality investigations, including open investigations, were obtained on a quarterly basis. Daily reviews of Google Alerts results using the search term "worker killed" were used to identify news reports of construction fatalities. Incident-specific fatality data were extracted from news reports, combined with OSHA data, and disseminated to stakeholders and the general public on a quarterly basis via CPWR's campaign website (www.stopconstructionfalls.com). Information collected included age, occupation, industry, address and location of death, major cause of death, etc. The data were made readily accessible via interactive online maps and downloadable spreadsheets. Descriptive statistics were calculated to summarize the data contained in the maps and usage.

Results: The mapping project has facilitated access to

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