Optimum Injury and Illness Prevention Cost for U.S. Construction Projects

Sathyanarayanan Rajendran
Central Washington University, sathyanarayanan.rajendran@cwu.edu

Morgan Bliss
Central Washington University, morgan.bliss@cwu.edu

Dominic Klyve
Central Washington University, klyved@cwu.edu

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Sathyanarayanan Rajendran\textsuperscript{1}, Morgan Bliss\textsuperscript{2}, and Dominic Klyve\textsuperscript{3}

\textsuperscript{1}Associate Professor, Engineering Technologies, Safety, and Construction Department, Central Washington University, Ellensburg, WA, USA (E-mail: sathyanarayanan.rajendran@cwu.edu)

\textsuperscript{2}Assistant Professor, Engineering Technologies, Safety, and Construction Department, Central Washington University, Ellensburg, WA, USA (E-mail: morgan.bliss@cwu.edu)

\textsuperscript{3}Associate Professor, Mathematics, Central Washington University, Ellensburg, WA, USA (E-mail: dominic.klyve@cwu.edu)

ABSTRACT

Worker injuries and illnesses can affect the profitability of an organization. Regardless of the regulatory requirements for safety and health, many organizations prefer to see positive returns (i.e., better safety metric performance) on their safety investments (i.e., project costs associated with injury and illness prevention programs). Understanding the relationship between costs associated with a construction project’s injury and illness prevention program and its safety performance is critical to the future success of construction organizations in the U.S. In evaluating this relationship, the authors’ goal was to identify an equilibrium point of injury and illness prevention program investment at which the relationship can be beneficial to contractors. Data collected from 93 U.S. construction projects were analyzed for the presence of a relationship between project spending and safety performance. Per the analysis, an injury and illness prevention program cost of 5% to 6% of total budget may be adequate to maintain injury rates at low levels. This information can be used in developing or revising a contractor’s project-specific injury and illness prevention budget.
INTRODUCTION

Occupational safety and health continues to be a significant concern for the U.S. construction industry. Per the U.S. Bureau of Labor Statistics, the number of fatal work injuries in the U.S. construction industry in 2014 was 899, representing approximately 19% of all work fatalities (BLS 2016a). The U.S. Occupational Safety and Health Administration (OSHA) has noted that 1 in every 5 worker fatalities in private industry occurs in construction (OSHA 2016). The construction industry had the sixth-highest nonfatal occupational injury and illness rate among all U.S. industries in 2015 (BLS 2016b). A multitude of construction industry safety-related research studies have been published, each proposing recommendations to improve worker safety and health. Despite the available research and an enhanced focus from regulatory agencies such as OSHA, the construction industry continues to be one of the most hazardous industries for worker safety and health in the U.S.

As fiscal, environmental, and cultural stewards, U.S. construction organizations may be interested in methods and information to continuously improve their safety performance. Worker injuries and illnesses can affect the profitability of an organization. Regardless of the regulatory requirements for safety and health, many organizations would prefer to see positive returns (i.e., better safety metric performance) on their safety investments (i.e., project costs associated with injury and illness prevention programs). Anecdotal evidence from construction industry safety practitioners frequently affirms that more money invested in injury and illness prevention leads to improved project safety performance. However, there is not much evidence or published research to support this claim. Developing an understanding of the relationship between the costs of a construction project’s injury and illness prevention program and its safety performance is critical to the future success of construction organizations in the U.S.
BACKGROUND

A thorough literature review was conducted to identify relevant research regarding an absolute relationship between injury and illness prevention program costs and documented safety performance metrics of U.S. construction projects. A secondary goal of the literature review was to establish the design of this study and its parameters. Injury and illness prevention program costs can include administration of the program, direct costs associated with injuries and illnesses, and indirect costs associated with injuries and illnesses (i.e., lost productivity, employee retraining, and administrative time). The benefits of implementing an injury and illness prevention program are touted by the Occupational Safety and Health Administration (OSHA), National Safety Council (NSC), and various state safety and health agencies. In the literature, as well as in industry, terms such as “injury and illness prevention,” “accident prevention,” and “safety investment,” are often used interchangeably. Safety performance metrics that are frequently analyzed by researchers include lagging indicators such as the number of fatalities and number of injuries or illnesses, but may also use leading indicators of safety such as the number of inspections or job hazard analyses completed (Hinze 2005 and Rajendran 2013).

Hallowell (2010) was the first researcher to quantify the cost of implementing individual construction safety program elements based on U.S. construction projects. Using interview-based safety investment data from 26 U.S. construction firms, Hallowell quantified the cost-effectiveness of 13 safety program elements that are commonly used in the construction industry. Hallowell concluded the most cost-effective elements of a construction safety program were: (1) subcontractor selection and management, and (2) upper management support and commitment; the least cost-effective elements were concluded to be employment of a full-time safety manager.
and record-keeping. Hallowell (2010) also reported that, on average, the 26 firms self-reported an investment of 2.2% of the tender price of a project in injury and illness prevention efforts.

No other study that focused on U.S. construction projects was revealed during the literature review. However, a few international studies have attempted to investigate the specific effects of safety program investments on safety performance in countries including Hong Kong and Singapore (Lu et al. 2016; Feng et al. 2014; Feng, Y. 2013; and Tang et al. 1997). Using data from 18 building projects in Hong Kong, Tang et al. (1997) concluded that the optimal safety investment needed on a building project is approximately 0.6% of the contract sum.

Feng (2013) investigated the effect of construction contractor safety investments on safety performance and identified the factors influencing these effects using data from Singapore building projects. Feng defined “basic safety investments” to include accident prevention activities by construction contractors and subcontractors, as required by governmental or industry regulations, which establish a minimum safety standard for a building project. Feng concluded that the effect of these basic safety investments on safety performance was not constant when applied under different project conditions (i.e., safety culture of the project and hazard level of the project). Basic safety investments were shown to have a positive effect on accident prevention when applied on a building project with a higher safety culture level and project hazard level. However, the effect of basic safety investments on accident prevention was variable when the hazard level and safety culture level of the project were low.

Feng et al. (2014) further explored the interactive effects of safety investments, safety culture, and project hazard on construction safety performance. This research was based on data from 47 completed building projects in Singapore. Feng et al. suggested that safety performance
of building projects is synergized by the combined effect of safety investments, safety culture and project hazard.

Lu et al. (2016) used agent-based modeling to develop a framework of studying safety performance on a construction site. Rather than attempting to calculate an absolute relationship between safety investments and safety performance, the researchers evaluated the interplay between use of a proactive construction management system, employment of safety supervisors, and other human and environmental factors on a construction project’s safety performance. The agent-based modeling was used to identify which safety investments were most cost effective; the researchers concluded that proactive construction management systems and holding coworkers responsible for each other’s safety were the most cost-effective measures.

Two major studies have specifically attempted to perform a cost-benefit analysis of accident prevention programs in the construction industry (Ikpe, et al. 2012 and Hallowell 2011). Hallowell (2011) developed a risk-based framework to evaluate the potential return on investment for a series of injury and illness prevention investments. This framework uses foundational risk quantification and analysis techniques. Hallowell concluded that the optimal injury and illness prevention investment strategy for each construction organization is identifiable with a formal analysis of the construction organization’s frequency and cost of injuries, specific sequences in which injury and illness prevention techniques are implemented, and how the construction organization manages risk throughout its operations.

Ikpe et al. (2012) investigated the costs and benefits of accident prevention in the United Kingdom (UK), hoping to draw attention to potential economic effects when a UK contractor’s management of health and safety concerns is deemed either effective or ineffective. The researchers concluded that the benefits of accident prevention outweighed the costs, identifying a
ratio of approximately 3:1; this was extrapolated to show that for every £1 spent on accident prevention, UK contractors gained £3 in benefits of accident prevention. This study was limited to the UK construction industry and was focused on contracting firms, not individual projects.

Although the available construction industry studies have tried to evaluate the effect of injury and illness prevention program costs on safety performance, many conclusions are limited to building projects and to projects outside the U.S. In this paper, the authors deviate from the current construction industry body of knowledge by reporting the total injury and illness prevention program cost of U.S. construction projects and their impact on safety performance. In evaluating this relationship, the authors propose to identify an equilibrium point of injury and illness prevention program investment at which the relationship can be beneficial to contractors. This information can be used in developing or revising a contractor’s environmental health and safety (EHS) program budget, a project-specific EHS budget, or contractual requirements for EHS elements.

**RESEARCH QUESTION**

The authors developed a testable null hypothesis that there is no correlation between a construction project’s injury and illness prevention program cost and the project’s safety performance. If the null hypothesis were false, the resulting research question became: why is there a negative relationship between a construction project’s injury and illness prevention program cost and the project’s safety performance? If the null hypothesis were true, the resulting research question became: why is there a positive relationship between a construction project’s injury and illness prevention program cost and the project’s safety performance? To answer these questions, the authors obtained quantitative data on completed and in-progress construction projects in the U.S., as well as qualitative data from the safety director or safety manager of
construction organizations represented in the quantitative data. The qualitative data was collected to supplement the findings and provide clear reasons for statistical inferences made as part of this research.

RESEARCH METHODS

The premise of the research was that a correlation exists between a construction project’s injury and illness prevention program cost and the project’s safety performance. The research design used for the study consisted of two phases, one quantitative and the other qualitative: (1) the collection and analysis of project injury and illness costs and safety performance data of multiple projects, and (2) informal interviews of construction organization safety directors and safety managers regarding a relationship between a project’s environmental health and safety budget and its effect on the injury and illness rates. This approach allowed for an exploration of the relationship between the construction project’s injury and illness prevention program costs and the project’s safety performance via statistical testing of empirical project data, to explain the presence of a correlation (positive or negative), if one was observed, via interviews with experienced construction safety professionals.

The quantitative phase involved the development, distribution, and analysis of a short project-specific questionnaire. The questionnaire was developed based on the authors’ combined professional and research experience in the construction safety discipline. The questionnaire was piloted to multiple occupational safety and health professionals in the construction industry. This pilot study helped determine the clarity of the questionnaire and its accompanying instructions, as well as the feasibility of obtaining the data requested in the questionnaire. Suggested revisions from the pilot study were considered and incorporated when feasible. The questionnaire
consisted of three sections requesting information on project demographics, safety performance, and project injury and illness prevention program cost.

The first section of the questionnaire was used to gather information about the project demographics, such as project type, size (in square feet), location, cost (in U.S. dollars), delivery method, contract method, percent complete, year completed, and number of subcontracts awarded. The second section of the questionnaire was used to obtain information related to the safety performance of the project, including the following metrics: total project work hours, total number of OSHA recordable injuries, and OSHA’s days away, restricted, or transferred injuries. The third and final section of the questionnaire focused on project injury and illness prevention program cost information, specifically: the total project injury and illness prevention program cost in U.S. dollars, and the total program costs as a percentage of total project cost. In asking for the injury and illness prevention program costs as a percentage of total project cost, the authors believe this accounts for marginal costs and should be relatively consistent among geographical regions, whereas actual costs tend to be more variable (Hallowell 2010). Questionnaire respondents were asked to estimate how much money each project spent on injury and illness prevention program measures.

The participants targeted for the study were primarily construction organizations in the Western U.S., many of whom also perform work in other parts of the country. The data requested were understood to be sensitive and confidential; therefore, the participants were selected based on convenience. Questionnaire respondents represented 13 contractors with whom the authors had personal contact that were willing to participate in the research study. Similar research suggests that the use of a “purposeful sample” can be ideal for enhancing validity when a large sample size is unrealistic (Patton 1990 as cited in Hallowell, 2010). All the quantitative and
Qualitative data were collected in person, over the phone or via email from the project manager or project safety professionals. The duration of the data collection was from August 2015 to December 2016. The Human Subjects Review Program of Central Washington University reviewed and approved the research study.

The qualitative phase of data collection consisted of open-ended interviews with four safety directors or safety managers. Responses to the open-ended questions were collected over the phone or via email. An important aspect of this process was that all interviews were performed with safety directors or managers from the same construction firms from which the empirical data from the quantitative component were collected. These qualitative responses were used to explain phenomena observed with the quantitative data.

All but two of the 13 construction firms that provided project data for this study were ranked within the top 100 of the Engineering News Record (ENR) Top 400 Contractors list (ENR 2016). A total of 112 projects were represented in the questionnaire’s raw data. These projects were constructed (both completed and in progress) from 2011 to 2016. The authors reviewed the data for completeness and conformance with study definitions, and identified 93 individual projects with adequate cost and safety performance data for the statistical analysis.

Of the 93 sample projects from 13 states, most projects (67%) occurred in California and Washington. Responding organizations were assured that the information provided would be kept confidential, including the respondents’ name and the individual project identities. The 93 projects consisted of projects from diverse facility types, including: housing, hotels, mixed use, condominium, hospital or medical building, office buildings, K-12 education, higher education university buildings, and others. For the purposes of statistical evaluation, these facilities were grouped under four major construction industry divisions: Residential (30%), Commercial
Heavy Civil (18%), and Industrial (11%). The cost of the 93 sample projects ranged from $70,000 to $1.5 billion (mean = $115 million; median = $60 million) and the size ranged from 3,000 square feet (SF) to 10,000,000 SF (mean = 435,446 SF; median = 125,000 SF). 67% of the individual projects were at least 80% complete, and 47% of the projects were fully complete.

The projects used multiple delivery methods and contract types, with most projects using the design-bid-build (DBB) method and lump-sum contract types.

All 93 construction projects provided information on the number of days away, restricted, or transferred (DART) injuries. 88 projects provided the number of OSHA recordable injuries; these were calculated into an OSHA total recordable injury rate (TRIR) using the total work hours expended on the project. For the construction projects, the TRIR ranged from 0 to 25 (mean = 2.42; median = 1.42), with 32 projects reporting zero injuries. The DART rates ranged from 0 to 25 (mean = 1.57; median = 0), with 47 projects reporting zero injuries.

For comparison, the national average DART rate in the construction industry in 2015 was 2.0 and the national average TRIR rate in 2015 was 3.5 (BLS 2016c). Hence, compared to the national construction industry statistics, the sample projects had relatively low illness and injury rates. The average injury and illness prevention program cost budgeted for the sample projects ranged from 0.001% to 20% of project cost (mean = 4%; median = 3%). This average injury and illness prevention program percentage equates to an average spending of $5.5 million.

**Safety and Cost Metrics**

The primary metrics used for the statistical analysis included:

1. **OSHA Total Recordable Injury Rate (TRIR):** Total recordable injuries are those incidents that resulted from an exposure or event in the workplace and that required some type of medical treatment beyond first aid, including any loss of consciousness. The recordable
injuries reported by questionnaire respondents were normalized to TRIR using a standard calculation established by OSHA. The calculation takes the total number of injuries and illnesses recorded for the project, multiplying this total number of injuries and illnesses by 200,000 and then dividing the injuries by the worker-hours accumulated on the project to obtain the standard OSHA TRIR (i.e., total injuries per 200,000 worker-hours).

2. Days Away, Restricted, or Transfer Rate (DART): Injuries that resulted from an exposure or event in the workplace which required employees to miss work, perform restricted work activities (i.e., light or modified duty) or transfer to another job. The DART recorded injuries were normalized to DART rates by using a calculation similar to TRIR to obtain the standard OSHA DART rate (i.e., DART injuries per 200,000 worker-hours).

3. Construction Project Injury and Illness Cost: Project costs associated with any worker injury and illness prevention program measures. These project costs include costs associated with various site-specific safety program elements such as pre-task planning, safety training, safety personnel, personal protective equipment (PPE), signage, etc. These costs do not include the direct cost of incidents/accidents or insurance costs. These costs were normalized by defining them as a percentage of project cost.

RESULTS AND ANALYSIS

The main objective of the quantitative data analysis was to empirically test the study hypothesis, and answer the associated questions based on results of the test. As mentioned earlier, to answer these questions, the authors obtained quantitative data on completed and in-progress construction projects in the U.S., as well as qualitative data from the safety director or safety manager of construction organizations represented in the quantitative data. The qualitative
data was collected to supplement the findings and provide clear reasons for statistical inferences made as part of this research. Hence, this section is organized by empirical data and qualitative data.

**Empirical Data**

Sufficient data was collected concerning 93 construction projects for analysis. Of these, only one data point was removed for most of the statistical analysis. One small ($2.4 million) commercial project with only 8,000 total worker hours recorded one DART injury, giving a DART rate of 25.0 – an outlier so extreme as to play havoc with the distribution-based statistical methods employed below. For each construction project, several variables (e.g., contract type) were recorded, allowing the authors to control for extraneous factors, if necessary, when looking at the relationship between injury and illness prevention program spending and injuries. In the end, there was little need to include most of these variables in the statistical model.

Various tests were conducted; however, no confounding factors were identified. ANOVA analysis showed no significant difference in DART values among groups based on project type (commercial, heavy civil, industrial, residential); project delivery type (design bid build, design-build, construction management / general contractor, construction manager at risk); or contract type (guaranteed maximum price, lump sum, cost-plus, firm-fixed price). Moreover, regression analysis showed no significant correlation between DART and project cost, the number of subcontracts, the number of total worker hours, or the size of the project as measured in square feet.

This leads to the research question: what is the relationship between spending on injury and illness prevention programs and safety performance, as measured by the TRIR and the DART rate?
Figure 1 shows a scatterplot of TRIR as a function of the total percentage of the cost of a project spent on injury and illness prevention programs for the 86 projects for which sufficient data were available. Note that while it seems there may be a slight negative trend, there is no strong relationship. Simple statistics confirms this; the correlation coefficient between the variables is $R = -0.06$ – a value far from significant. However, upon further examination, the authors noticed an interesting feature of these data. Namely, TRIR rates behave very differently between projects which spent more than 5% of the overall budget on injury and illness prevention program costs than those that spent less than 5%. Of the 31 projects which spent 5% or more on injury and illness prevention program costs, only 2 (6.5%) had a TRIR greater than 4 (a “high” TRIR). Of the 55 projects which spent less than 5% on injury and illness prevention program costs, however, 15 (27.3%) had a TRIR greater than 4. This data can be examined in Error! Reference source not found. A two-sample proportion test shows the difference of these proportions to be significant ($p=0.005$; Fisher’s exact test $p$-value 0.024). The project-based data suggest that, while there is not a continuous reduction in TRIR as injury and illness prevention program spending increases, there is a threshold which spending should reach for a project to avoid having a high TRIR.

When reviewing the DART rate, a similar phenomenon was encountered. Once again, the scatterplot in Figure 2 suggests there may be no strong correlation between the variables, and this is the case; the correlation here is $R = -0.02$, a value not significantly different than 0. However, the authors again note that there is a threshold value which seems to separate projects with a “high” DART rate from those with a “low” rate. In this case, a “high” DART rate was defined as above 2.5, and a “low” rate was defined as 2.5 or less. Once the “high” and “low” DART rate projects were divided, the authors observed the striking fact that no project which spent more
than 6% of costs on injury and illness programs had a high DART rate. Note that the threshold here is slightly higher than that which separated projects with high and low TRIR.

These data can also be looked at another way. The 80 projects which spent 6% or more on injury and illness prevention program costs had a mean DART rate of 0.52, while those spending less than 6% had a mean DART rate of 1.42. A two-sample t-test shows this difference to also be significant (p=0.01). The authors were curious about the injury and illness rate trend, examining the US construction industry’s national TRIR/DART average and the Washington/California state construction industry TRIR/DART averages, since 67% of the sample projects were built in Washington or California. The average TRIR and DART for the U.S. construction industry was 3.7 and 2.1, Washington was 7.45 and 3.85, and California was 4.05 and 2.7 (BLS 2016d). These statistics, in part, helped us define the high and low TRIR/DART rates.

Certainly, additional study is needed, and the authors would like to expand this survey to a larger range of projects. Based on the current data set, however, it seems that there is a spending threshold for injury and illness prevention programs of 5% or 6% of total project costs for which construction projects should budget. Statistical analysis supports that an injury and illness prevention program cost of 5% to 6% of total budgets may be adequate to keep injury rates at low levels.

**Interview Results**

In the qualitative component of this research study, four safety directors or managers from the construction organizations represented in the quantitative component were interviewed. A 16-question survey was administered to participants and results were compiled. The job titles of respondents included District HSE Manager, Safety Director, Corporate Director of Safety
and Health, and Assistant Director of Safety. Survey respondents worked for their respective companies for an average of 12.8 years, ranging from 8.5 to 19 years. With an average of 20.5 years of experience in the construction industry (range: 9 to 39 years) and an average of 22.3 years of experience as a safety and health professional (range: 15 to 39 years), the respondents provided a wealth of expertise.

When asked how their company determined the budget for injury and illness prevention costs as part of the total project budget, a variety of responses were received. Two respondents identified historical spending with planned site-specific procedures as a dynamic and ongoing budgeting process, whereas another noted that injury and illness prevention program spending is not identified as a separate line item for each project – the costs are rolled into the costs of doing work. Three of the four respondents were involved in setting a project’s injury and illness prevention budget, but rarely in a direct fashion. All respondents identified that a project’s injury and illness prevention budget was a collaborative effort, shared between the estimators, superintendents, project managers, safety director/manager, and regional or site-based safety professionals.

Major injury and illness prevention expenses on a project were identified by respondents and are combined in Table 3. When asked what the injury and illness prevention expenses were as a percentage of total project costs, the responses were mixed. Two respondents noted that most safety managers in construction do not operate under a fixed budget – first, because they will not cease spending on safety-related items if the initial budget is exceeded, and second, because much of the project safety-related cost is carried by the subcontractors. One respondent noted that the injury and illness prevention expenses were “very low” when compared to the total project cost, and another stated that 2% to 3% of the total project cost could be attributed to the
injury and illness prevention expenses, but that it varied by the type of project and was subjective.

The survey also asked if the injury and illness prevention costs included subcontractors. One respondent identified that the site-specific orientation for each subcontractor would be covered by the general contractor, but that safety materials and personal protective equipment were generally not provided. Two additional respondents noted that the subcontractors were responsible for all their injury and illness prevention costs. One respondent stated that their construction organization’s injury and illness prevention budget did cover subcontractors.

Challenges associated with ensuring an adequate injury and illness prevention budget were also identified in the survey. One respondent stated that the most significant challenge was getting the safety staff position allocated, and this was echoed two other respondents who continued to explain that the competitive bidding process and tight budgets made it difficult to win work when bidding against general contractors that do not allocate money to safety. One respondent said that getting an adequate budget was not a challenge.

When asked how they overcame these challenges to ensure an adequate injury and illness budget, respondents noted the benefit of “selling” safety and getting buy in from their client(s), as well as evaluating the safety staffing based on project complexity, job location, presence of high risk activities, and availability of qualified workers. One respondent explained that injury and illness prevention costs must be part of the estimate and design. Respondents also provided some best practices for budgeting injury and illness prevention: (1) determine up front what to consider as an injury and illness prevention cost, and then set up a tracking system to capture historical costs; (2) ensure subcontractors understand safety requirements prior to onboarding;
and (3) ensure safety requirements at the project site are written/established and contractually
binding.

Near the end of the interview, respondents were asked whether they believed that
spending more money on injury and illness prevention expenses would improve safety
performance – some interesting responses were received. One respondent stated that there was
no correlation; a company could have all the right safety equipment and still have a poor safety
record. The other three respondents stated that they believed that spending more money on injury
and illness expenses would improve safety performance, especially when done strategically and
for excavation safety.

The consensus of the safety director interviews seemed to reflect the findings of the
statistical analysis – that costs associated with injury and illness prevention may have an impact
on safety performance, but that the relationship was complicated. Additionally, respondents to
the interviews identified that the costs associated with injury and illness prevention are not well
tracked in industry, and varied greatly from project to project.

STUDY LIMITATIONS

As with many studies of construction project performance including cost and safety, the
selected research methods and data obtained in the study inhibit the generalization of the
research findings beyond the study sample. Major limitations are presented below:

- A limitation impacting the research study is the data collection process. The selection of
  contractors was based on construction organizations with whom the authors had personal
  contact who were willing to share this sensitive data; therefore, it was not random.

Selection of the projects within each firm was at the discretion of the construction
organization. The authors had no influence on this process. Since the data was not randomly sampled, statistical inferences could not be made to the study population which, in this case, consists of all U.S. construction projects. Inferences can be made only to the data set obtained as part of this research study.

- The TRIR and DART data used for the study is observational data and cannot be used to make cause and effect statements.
- The authors did not consider other safety interventions implemented by the construction organization or the effectiveness of their injury and illness prevention program as a confounding factor.
- A disproportionate number of sample projects (41%) were built in Washington. Interpreting the results may be skewed by the dominance of projects from one state. The authors suggest future research comprising a diversified pool of projects from several states.

Although the authors acknowledge that these limitations must be addressed, this study has laid the foundations for future research to examine the relationship between safety performance and a project’s injury and illness prevention program costs.

CONCLUSIONS AND RECOMMENDATIONS

The major objective of this study was to investigate the relationship between injury and illness prevention program cost and safety performance of U.S. construction projects. A statistical analysis of 93 construction projects tested the presence of a relationship between project safety spending and safety performance metrics (e.g., TRIR and DART). Based on the quantitative and qualitative analyses of the study sample:
• There is not a statistically significant difference between safety performance (defined as TRIR and DART of construction projects) and project injury and illness prevention costs.

• There is not a continuous reduction in TRIR as injury and illness prevention program spending increases; however, there is a threshold, at 5% of project costs, at which spending should reach for a project to avoid experiencing a high TRIR.

• There is not a continuous reduction in TRIR as injury and illness prevention program spending increases; however, no project which spent more than 6% of costs on injury and illness prevention programs had a high DART rate.

• There is a statistically significant project spending threshold for injury and illness prevention programs in construction project budgets. This spending threshold was identified as 5% or 6% of total construction project costs. Statistical analysis supports that an injury and illness prevention program cost of 5% to 6% of total budget may be adequate to maintain low injury rates.

• The costs associated with injury and illness prevention may have an impact on safety performance; however, the relationship is complicated.

• Best practices for budgeting for injury and illness prevention were identified as: (1) determine up front what to consider as an injury and illness prevention cost, and then set up a tracking system to capture historical costs; (2) ensure subcontractors understand safety requirements prior to onboarding; and (3) ensure safety requirements at the project site are written/established and contractually binding.

The project injury and illness prevention information that was available for the study did not include the types of prevention elements and their corresponding itemized costs. Therefore, it
was not possible to evaluate the relationships between individual prevention elements, their synergistic effects, costs of prevention elements, and project safety performance. Relating safety performance to specific prevention program elements and costs could be accomplished in a much larger study that involves significant data gathering and project documentation review for multiple projects. Further research is encouraged to establish such relationships.

ACKNOWLEDGEMENTS

The authors would like to thank the companies that participated in this study and provided project data, and the students who helped with data collection.

REFERENCES


Table 1. Projects which spent at least 5% of costs on injury and illness prevention program (IIPP) elements were significantly more likely to have a TRIR less than 4.

<table>
<thead>
<tr>
<th>IIPP percentage</th>
<th>Total</th>
<th>High TRIR (&gt;4.0)</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% or greater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>55</td>
<td>15</td>
<td>27.30%</td>
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<tr>
<td>Yes</td>
<td>31</td>
<td>2</td>
<td>6.50%</td>
</tr>
</tbody>
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Table 2. All projects which spent at least 6% of costs on IIPP had DART rates less than 2.5. Of the projects which did not reach this threshold of spending on IIPP, 22% had rates above 2.5.

<table>
<thead>
<tr>
<th>IIPP percentage</th>
<th>Total</th>
<th>High DART rate (&gt;2.5)</th>
<th>Proportion</th>
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<tbody>
<tr>
<td>6% or greater</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>80</td>
<td>18</td>
<td>22.5%</td>
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<tr>
<td>Yes</td>
<td>11</td>
<td>0</td>
<td>0%</td>
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</table>

Table 3. Injury and illness prevention expenses prevalent in construction projects in the U.S.

<table>
<thead>
<tr>
<th>Safety Director/Manager Interview</th>
<th>Responses</th>
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<tbody>
<tr>
<td>Major injury and illness</td>
<td>Fall protection gear (personal fall arrest system, horizontal life line, self-</td>
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<tr>
<td>prevention expenses on a</td>
<td>retracting lanyard)</td>
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<td>construction project</td>
<td>Personal protective equipment</td>
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<td>Signage</td>
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<td>Labor for housekeeping</td>
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<td>Training</td>
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<td>Salary for full-time safety professional</td>
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<td>Shoring</td>
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<td>Trench boxes</td>
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<td>Personnel oversight and management</td>
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Fig. 1. Scatterplot of TRIR as a function of project costs spent on IIPP.

Fig. 2. Scatterplot of DART as a function of project costs spent on IIPP.