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Worker and Worksite Factors in DIA Construction Injury

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List of Abbreviations

AIR: Accident Investigation Report

ANSI: American National Standards Institute

BLS: Bureau of Labor Statistics

FRI: First Report of Injury

MOIE: Mechanism of Injury Event

WC: Workers' Compensation

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ABSTRACT

Objectives. To develop a method to capture factors contributing to injury from the text of injury reports. To link injury report text with a corresponding workers' compensation administrative database. To analyze the linked data to determine factors contributing to specific types of injury and types of work. To estimate injury and payment rates for each contributing factor. To analyze injury report text for specific injury mechanisms with particularly high rates of occurrence or particularly high payment rates.

Importance to occupational safety and health. Detailed information about factors contributing to construction injury is important to support the design of safety programs directed at particular risks. Understanding the factors contributing to construction injury can help employers and workers approach prevention and intervention with knowledge necessary to targeting high risk workers and common mechanisms of injury. Knowing the rates at which each factor is involved in injury can also help the safety community focus on factors with the highest injury and payment rates, thereby attempting to ameliorate the most frequent and severe injuries in this arguably most dangerous industry.

Approach. We analyzed text describing injury events in over 4,000 injury reports, entered it in a text database, preserving original text, and linked it with an administrative workers' compensation (WC) database. Using Haddon's matrix as a framework, we classified factors contributing to injury during construction of Denver International Airport. This allowed for the calculation of injury and payment rates for factors contributing to construction injury.

Findings. Patterns of contributing factors varied according to injury mechanism and type of work: environmental factors contributed more than any other factor to slip/trip injuries, and building materials contributed to more than 40% of injuries to workers in carpentry, concrete construction, glass installation, and roofing. *Rates* at which factors contributed to injury also varied among types of work: environmental factors contributed at relatively high rates to injuries in glass installation, metal/steel installation and iron/steel erection ≥ 2 stories, and victim factors contributed at high rates to conduit construction and metal/steel installation injuries. WC payment rates for different factors varied widely, ranging from $0.53/$100 payroll to $3.08/$100.
Conclusion. This approach allows systematic analysis of classes of injuries, contributing factors, types of work and other variables to assist in setting prevention priorities.

Significant Findings and Their Usefulness: Worker and Worksite Factors in DIA Construction Injury

The significant findings of this study were:

1. The method of abstracting, coding, storing and retrieving data from injury reports was different from other commonly used methods. It was more flexible and captured more contributing factors than other methods (ANSI, BLS, Lincoln et al., 2004). On the other hand, it did not weigh factors according to their importance in the injury event, nor did it establish a sequence of events.

2. Our examination of factors contributing to construction injury, accomplished by linking our abstracted data from injury reports with administrative workers' compensation data revealed different patterns of factors both for different types of work and for different types of injuries. We were able to calculate injury rates and payment rates for each factor contributing to injury for types of work. For example, glass installation workers are at very high risk of injuries to which environmental conditions and materials contributed. This could lead a safety manager to determine how to modify materials handling practices, which may involve carrying and placing large glass panels or to investigate whether environmental conditions surrounding these workers can be ameliorated in order to reduce risk. Examination of *payment rates* for specific factors might lead one to explore equipment-related safety interventions for workers in metal/steel installation, since the payment rates for equipment factors for this type of work were especially high. The calculation of rates of occurrence as well as payment rates for factors contributing to injury for types of work provided an assessment of risk associated with contributing factors within each type of work. Knowing that workers in certain types of work are at greater risk of encountering specific contributing factors than are other workers can be helpful in focusing prevention interventions where they can be most useful

These findings are described in detail in a forthcoming article (Glazner et al., in press). The scientific report also presents a number of these findings.

3. Our ability to search for injury report text in the linked database we created allowed us to explore in detail the factors contributing to certain injury mechanisms. In particular, we have published a detailed analysis of factors contributing to falls from height (Lipscomb et al., 2004). Another paper, in preparation, examines slip/trip injuries. The database allows us to search for keywords and examine injury text for all injuries with that particular keyword. One can search for types of injury (example: falls from height) or for factors, e.g., equipment, in order to examine them for patterns that can suggest prevention possibilities.

We were prompted by some findings to reflect on the information our detailed factor data provided. For instance, we found that victim factors (i.e., the victim contributed to the injury event) were present in more than half of the injuries. Very few of these, however, were safety infractions. In general, these factors included being in a hurry, inexperience, and 'not being careful.' By examining victim actions in detail, we found that many of them were unlikely to be readily modifiable, simply because it is difficult to completely control worker behavior. There will be times when the worker is distracted or when (s)he is in a hurry or tired, and these conditions may be difficult to avoid. Given the nature of construction, with its often tight time schedules and the physical nature of the work, it may also be difficult either to ensure that workers always use appropriate materials-handling practices and devices or that they avoid some difficult tasks such as holding or lifting heavy materials in a tight space in an awkward position. Moreover, victim actions may be indicators of organizational factors, such as time pressure or lack of training, not mentioned in injury reports. In 96% of injuries with 'victim' as a contributing factor, other factors were also mentioned. Behavioral interventions have been widely used in occupational injury prevention. Our data suggest that it may also be productive to focus on other factors and their contributions to injury.

In sum, we developed a method that can be used by others to capture a complete list of factors contributing to construction injury. It does not require knowledgeable abstractors, and it can be applied to injury reports with relatively sparse information. The method we used elicited much information about each injury. While it did not capture a sequence of events and therefore could not establish injury etiology, it did provide a fairly comprehensive picture of the factors involved in these construction injuries. Linkage of abstracted data with administrative workers' compensation data allowed for calculation of injury and payment rates for each contributing factor identified, a result that, to our knowledge, has not been accomplished until now. The findings of our analyses can provide much information useful in ameliorating the conditions incident to construction injury.

The organization of contributing factors into a matrix encompassing a range of influences on injury occurrence allows for contextual placement of the various factors contributing to injury, thereby prompting consideration of multiple factors in developing prevention programs. Also, by analyzing the contributing factors from several points of view, such as the type of work being performed or the types of injuries sustained, multiple points of intervention most relevant to particular subsets of injuries can be identified.

Scientific Report

Background

Earlier work describing the injury experience of workers building the Denver International Airport (DIA) provided much information on construction injury rates, groups of workers at especially high risk of injury, workers' compensation payment rates, and contract-level risk factors (Glazner et al., 1998; Lowery et al., 1998; Lowery et al., 2000). But such information, while useful in targeting injury prevention resources to, for instance, smaller firms or those working in site development, is not detailed enough or proximate enough to the injury event to support the design of safety programs directed at particular human and environmental risks occurring in construction. For this purpose, more must be known about factors leading to injury.

Studies of factors contributing to fatal construction injuries at the national level have been performed using the National Traumatic Occupational Fatalities surveillance system, which is based on death certificates, and national census data on employment (Ore and Stout, 1997) or on the Census of Fatal Occupational Injuries (CFOI) (McCann et al., 2003). These studies have examined text data to understand circumstances surrounding and factors contributing to each type of fatal injury. They have provided valuable information about factors contributing to occupational and construction deaths, which may differ from those contributing to injuries not resulting in death.

Studies based on medical record review have described injury circumstances for various mechanisms of injury for workers treated in a single emergency department (Hunting et al., 1999; McCann et al., 2003). This approach, too, examines factors that contribute to particular types of injury and provides useful information for directing safety programs at both specific types of injury and circumstances leading to injury, but it does not capture injuries not treated in hospital emergency departments.

Several studies described injury causes or circumstances contributing to injury for particular construction trades or types of work (Welch et al., 2000; Chiou et al., 2000; Lipscomb et al., 2003), while others have described causes or contributors to particular types of injury (Welch et al., 2001; McCann et al., 2003). These types of studies are most valuable for developing specific safety interventions for a few particular types of work or work exposures.

We investigated factors contributing to injury for a wide range of construction work and a wide range of injury mechanisms for a defined population of construction workers. We obtained injury reports for more than 4000 injuries sustained in the building of the Denver International Airport (DIA) and coded these reports to identify factors contributing to the injury. This approach allowed us to examine injuries from the perspective of their contributing factors; it also allowed for examination of the relationship of contributing factors to variables such as type of injury, workers' compensation payments, and others.

The current analysis relies upon a database created by the City and County of Denver's Owner-controlled Insurance Program, which provided all liability and workers' compensation insurance for all workers involved in the construction of DIA. To this administrative database we added text data from the several thousand injury reports describing the injuries occurring during

DIA construction. This linked database provides a wealth of information about the circumstances surrounding injuries occurring on the site of the largest construction project in the world during the period 1990-1994.

Specific Aims

1. Develop methods to code, index, search, and analyze data, including free text, appearing in injury incident descriptions found in First Reports of Injury (FRI) and Accident Investigation Reports (AIR). This process will be performed using Haddon's matrix of injury occurrence as a conceptual framework.

2. Link these data to existing contract-level administrative data available on construction injuries and time at risk during the construction of the Denver International Airport.

3. Describe the circumstances surrounding different types of injuries (falls, motor vehicles, etc.) as well as the circumstances surrounding injuries to sub-populations of construction workers at increased risk (e.g., older workers, new workers, workers for small companies) and for certain, particularly hazardous types of work (e.g., concrete construction, street/road construction).

4. Determine the direct costs, as defined by workers' compensation payments, of injuries with specific contributing factors to help focus intervention recommendations.

Procedures and Methods

Two of the specific aims addressed methods of capturing narrative text and linking it to coded workers' compensation data to more fully analyze the events leading to injury:

(1) Develop methods to code, index, search, and analyze data, including free text, appearing in injury incident descriptions found in First Reports of Injury (FRI) and Accident Investigation Reports (AIR). This process will be performed using Haddon's matrix of injury occurrence as a conceptual framework.

(2) Link these data to existing contract-level administrative data available on construction injuries and time at risk during the construction of the Denver International Airport.

Specific aims 1 and 2 have been accomplished, and a manuscript describing the development of our methods and the linkage with administrative data is in preparation.

These are methodologic aims and as such, their accomplishment did not result in findings as they are usually defined, but did result in a method to code, search and analyze data from injury report text linked with Workers' Compensation (WC) administrative data.

The method we used involved developing coding rules, adapting Haddon's matrix to construction injury, and having two research assistants work independently to code all factors mentioned in injury reports that contributed to injury. The reviewers did not have specific expertise in construction injury. Each reviewer coded all injury reports. A two-step adjudication process was invoked when the reviewers didn't agree; this involved judgments by the other investigators and, when consensus could not be reached because of lack of understanding of the construction process or terms, the safety manager for DIA construction was consulted. All contributing factors were entered into Haddon's matrix, which helped the researchers to consider all factors that could have contributed to injury and, we believe, elicited more complete and more structured information from injury reports than would otherwise have occurred. The often brief nature of the injury reports' narrative text and the complexity of the factors being inferred required a mental model of construction work, making it unlikely that automated coding would be adequate to accurately determine factors contributing to injury. Once coding was complete, it was stored in a qualitative software package (N5). This allowed us to integrate the coded data with data from the administrative claims database by transferring N5 coding into a SAS dataset and vice versa.

We have compared the results of our method with other methods of analyzing text and found that each method has strengths and weaknesses. In particular, our method is more flexible than were the Bureau of Labor Statistics (BLS), the American National Standards Institute (ANSI), and Lincoln et al. (2004) methods and captures more contributing factors (when they are present in the injury report), but it does not discriminate between more important and less important contributors to injury. Moreover, unlike the Lincoln system, a complete sequence of events is not captured. A manuscript describing our methods and comparing them with others is in preparation.

Results and Discussion

Results of our efforts are described below according to the specific aims to which they are related.

(3) Describe the circumstances surrounding different types of injuries (falls, motor vehicles, etc.) as well as the circumstances surrounding injuries to sub-populations of construction workers at increased risk (e.g., older workers, new workers, workers for small companies) and for certain, particularly hazardous types of work (e.g., concrete construction, street/road construction).

(4) Determine the direct costs, as defined by workers' compensation payments, of injuries with specific contributing factors to help focus intervention recommendations.

Specific aims 3 and 4 have been accomplished. An article describing most of these items (circumstances surrounding different types of injury, as well as circumstances of injury among different types of work) is in press.

Table 1 shows rates per 200,000 person hours of work of factors contributing to injury for different types of work. Objects were involved in the great majority of injuries and this overall injury rate is not very revealing. Specific objects are therefore included in the table. Victim factors contributed to a majority of injuries and the rate per 200,000 hours reflects that. The most common victim factor was "not paying attention/being careless;" there were very few safety infractions. Environmental factors were also important in explaining injuries. These included weather, slippery conditions, mud or ice, and others. Among all objects, building materials, equipment and tools accounted for the highest rates of injury among all types of work.

Perhaps more important than overall injury rates for various factors are the patterns of factors involved in injuries for different types of work. For instance, the highest rate of environmental factors' contribution to injury was for glass installation (17.9 per 200,000 work hours); moreover, environmental conditions were more important in these workers' injuries than every other factor except victim action. Not surprisingly, building materials were involved at a very high rate as well. The types of work for which tools contributed to injury at high rates were iron/steel erection < 2 stories, metal/steel installation, and conduit construction.

Table 2 shows workers' compensation payment rates for the contributing factors we identified. Payment rates are useful in that they are a rough proxy for severity of injury. Payment rates were highest for injuries in which victim factors played a role; second highest were those with environmental factors. Payment rates for building materials and motor vehicle/heavy equipment were also high. Again, the pattern of payment rates among types of work is perhaps of more interest than total payment rates for each factor. For instance, in iron/steel erection< 2 stories, while the injury rate in which victim factors played a part was high (22.9 per 200,000 person hours), the payment rate for this factor was low ($0.28 per $100 payroll). The same holds true for tools (injury rate of 13.1 per 200,000 and $0.20 per $100). Clearly the injuries involving these factors, while fairly common, are not very serious. On the other hand, while the injury rate for driving in which environmental factors were involved was fairly low, the payment rate for these injuries was among the highest, suggesting that these injuries were quite serious.
The information summarized above is described in more detail in the article "Factors contributing to construction injury at Denver International Airport" (Glazner et al., in press).

Another paper, published in the November issue of the Journal of Occupational and Environmental Medicine (Lipscomb et al., 2004), explores in detail the factors contributing to falls from height. This article is attached.

A manuscript in preparation describes the factors contributing to slip/trip injuries. These injuries accounted for over $10 million in WC payments for the construction of DIA, 25% of all payments. Injury and payment rates for these injuries are presented in Table 3 by type of work. Overall, injuries preceded by slipping or tripping occurred at a rate of 5.0 per 200,000 hours worked and incurred payments at the rate of $4.26 per $100 payroll. Types of work with the highest slip/trip injury rates were roofing, iron/steel erection ≥ 2 stories, glass installation, and metal/steel installation. Roofing and glass installation accounted for the highest WC payment rates for slip/trip injuries. Payment rates for street/road construction and concrete construction were also high. Figure 1 shows the principal factors contributing to slip/trip injuries. Clearly, environmental factors were the most important of these. Among environmental factors contributing to slip/trip injuries, walking surface (terrain or other surfaces, uneven or cluttered surfaces, etc.) and slippery surfaces were the most frequently occurring. Next was steps (the worker going up or down steps).

Table 4 shows the major factors contributing to injuries for 6 age groups. Significant differences (chi square analysis) among age groups were found for 5 factors: victim action, structure, size and weight of object, environmental factors and organizational factors. In general, younger workers were more often involved in injuries in which victim action and size and weight of an object were factors than were older workers. Older workers, on the other hand, were more often involved in injuries with contributing factors of structure, environment, and organization.

In Table 5, the results of an analysis of injuries by company size are presented. There were a few statistically significant findings. For instance, there were differences among companies of different sizes with respect to the proportion of injuries in which equipment, motor vehicle/heavy equipment, and environment were factors. No pattern was apparent for any company size range. For instance, in two categories, equipment and motor vehicle/heavy equipment, very large and very small companies were similar, while those in the middle size ranges were not only different from the very large and very small companies, but from each other.

These latter two analyses have not been included in any of our papers, whether published, in press, or in preparation. One of the problematic issues with these analyses is that we have no way of calculating rates, since we don't know hours worked for either age groups or company size. Moreover, the results are not very illuminating, although the age analysis suggests that older workers may make fewer mistakes, since victim factors were less often involved in their injuries. But without the ability to calculate rates, we cannot be sure.

5. *Demonstrate the use of these combined data in testing specific hypotheses about circumstances surrounding specific types of injury among high risk workers (e.g., older workers, new workers, workers for small companies, workers with severe injuries)*

The analytic products of this project are (1) one already published article, "Analysis of text from injury reports improves understanding of construction falls," published in the Journal of Occupational and Environmental Medicine, (2) one article in press, "Factors contributing to construction injury at Denver International Airport,' in press, American Journal of Industrial Medicine, and (3) two manuscripts in preparation: (a) one describing the methods we used for abstracting, coding and using injury reports to analyze contributing factors, as well as comparing four current methods for determining injury etiology from text; and (b) another analyzing the factors involved in slip/trip injuries. Our rationale for pursuing these particular analyses is described in the following paragraphs.

Once we had coded and entered the data from injury reports and begun to examine it, we found that it supported a number of analyses, ranging from an analysis of the injury and payment rates associated with each factor contributing to injury to detailed analyses of specific mechanisms of injury. As we realized the breadth of the analysis the data could support, we decided that testing the relatively narrow hypotheses we had included in our proposal was not as valuable as an overall analysis of the factors contributing to injury and some sub-analyses of important mechanisms of injury. Moreover, as we became more familiar with the construction safety community, we decided that a broad, easily interpretable analysis of contributing factors would be more readily accepted and more relevant to the safety community than would detailed analyses of narrow hypotheses. We therefore calculated injury and payment rates for each contributing factor to assess their importance in injury etiology and severity. An article describing the findings of this analysis is in press.

It also became apparent to us that the methods we used to determine the factors contributing to injuries would be of interest to the injury research community, because text analysis has become an important way of discovering what actually happened during injury events. The results of this type of analysis are potentially more revealing and useful for designing prevention strategies than are analysis of injury rates. We therefore decided to put our energy toward a detailed description of our methods, including comparison of our methods with 3 other methods, either used by public agencies (BLS, 1992, ANSI, 1963) or described in the research literature (Lincoln et al., 2004). A manuscript that describes our methods and compares them with others is in preparation.

The hypotheses contained in specific aim 5, while seeming reasonable at the time of the proposal, are very narrow and do not address the broad range of issues we were able to explore with the dataset we created. We therefore devoted little time to testing them. A brief description of our efforts in this regard is presented below.

a. *Hypothesis 1*: Worker action, supervisor action, and failure to use PPE (personal protective equipment) are more frequent contributing factors in injuries occurring at small companies than in injuries occurring at large companies.

We found that supervisor action and failure to use PPE contributed so rarely to injury that hypothesis testing of these factors would not have been worthwhile. Table 5 shows that, among injured workers, approximately the same percentages of injured workers contributed to their own injuries, regardless of firm size. Chi square analysis was used to determine significance, but no pattern with respect to company size was apparent.

b. *Hypothesis 2.* Worker action and failure to use PPE are more frequent contributing factors in injuries occurring to younger workers than in those occurring to older workers.

Failure to use PPE was a rare contributor to injury and was therefore not susceptible to analysis. Table 4 shows that, indeed, victim action was a significantly more common contributor (using chi square analysis) to injury for young injured workers than for older injured workers.

c. Hypothesis 3. Worker action and failure to use PPE are more frequent contributing factors in injuries occurring during the first quartile of contract payroll than in injuries occurring in the last three quartiles of contract duration.

As mentioned above, failure to use PPE was a rare occurrence among injured workers. We did not test this hypothesis with respect to worker action because we found that the overall analysis of factors and their contribution to injury was more deserving of analysis and description than was this particular hypothesis.

Hypothesis 4. Specific risk factors for increased payments for injuries included equipment, machines, heavy building materials and working above ground level, and contributed to increased payment independent of known, contract-level risk factors.

Working above ground level did not appear as a specific factor contributing to injury. Payment rates for the other risk factors, equipment, machines, and heavy building materials, were not among the top three payment rates. They were 5^{th}, 4^{th}, and 7^{th}, respectively (Table 2). The top three contributing factors, in terms of payment rates, were victim factors, environmental factors, and building materials (of all sizes and weights).

Hypothesis 5. Specific risk factors for injuries to concrete construction workers included equipment and heavy building materials and contributed to increased payments independent of known, contract-level risk factors.

Workers in concrete construction were at higher risk for injuries involving equipment than were workers in all other types of work (Table 1), but two other factors (victim factors and building materials) were more likely to have contributed to injury than was equipment. Heavy building materials, captured in our coding scheme as "object size/weight," were also more likely to contribute to injury in concrete construction than for most other types of work; this category was 5^{th} most likely among all factors to contribute to concrete construction injuries. With respect to payment rates for concrete construction, both equipment and heavy objects accounted for the second highest rates among all workers. A paper describing these findings in more detail is in press.

f. Hypothesis 6. Risk factors for different types of injuries—specifically falls and overexertion injuries involving the back—are different.

Table 6 shows the frequency with which each major factor contributed to injury. This is not adequate to support or refute the hypothesis above. We decided to explore injury types individually, as demonstrated in the published article about falls from height and the manuscript in preparation regarding slip/trip injuries, in order to understand in depth the contributors to these injuries.

The organization of contributing factors into a matrix encompassing a range of influences on injury occurrence allows for contextual placement of the various factors contributing to injury, thereby prompting consideration of multiple factors in developing prevention programs. Also, by analyzing the contributing factors from several points of view, such as the type of work being performed or the types of injuries sustained, multiple points of intervention most relevant to particular subsets of injuries can be identified.

Sometimes a contributing factor is important across types of work and types of injury. An example of this is the contributing factor, "motor vehicles/heavy equipment," for which WC payment rates were high. The types of injuries this factor was involved in were numerous and varied (caught and jumped injuries, slips/trips, as well as motor vehicle injuries). Taken together, this evidence could prompt attention, not just to the operator of the motor vehicle, but also to more regular inspection of such equipment, stringent replacement schedules, redesign of steps for mounting and dismounting, and perhaps others.

Because victim actions played a role in a majority of injuries and were prominent in most MOIEs, it may seem logical to focus safety interventions on workers. Most victim actions that contributed to injury were inappropriate acts, including not paying attention and not being "careful," and motions such as carrying, lifting, pushing, and pulling, usually involved in materials handling. Less than 10 percent were safety infractions. By examining victim actions in detail, we found that many of them were unlikely to be readily modifiable, simply because it is difficult to completely control worker behavior. There will be times when the worker is distracted or when (s)he is in a hurry or tired, and these conditions may be difficult to avoid. Given the nature of construction, with its often tight time schedules and the physical nature of the work, it may also be difficult either to ensure that workers always use appropriate materials-handling practices and devices or that they avoid some difficult tasks such as holding or lifting heavy materials in a tight space in an awkward position. Moreover, victim actions may be indicators of organizational factors, such as time pressure or lack of training, not mentioned in injury reports. In 96% of injuries with 'victim' as a contributing factor, other factors were also mentioned. It may be as productive, from the point of view of prevention, to focus on other factors and their contributions to injury.

Assessing the possible modification of environmental factors also has potential to improve construction safety. These factors contributed to a majority of slips/trips, falls (no slip), and motor vehicle injuries; these injury mechanisms together accounted for $17 million in WC payments at DIA and were among the five MOIEs with the highest average payments. While environmental factors contributed to nearly 85 percent of slip/trip injuries, victim actions were rarely involved. Trying to change worker behavior would therefore not be likely to have an important safety effect on slip/trip injuries. But actions such as ensuring that there are always adequate outdoor walkways that are kept clear of debris and avoid rough terrain, that there is always adequate lighting and that slippery conditions are ameliorated, perhaps by employees dedicated to these tasks, could yield improvements in slip/trip injury rates. Because slips and trips are such frequent injury mechanisms and because they often result in severe injuries, avoiding even a fraction of them could significantly reduce both human and workers' compensation costs.

The calculation of rates of occurrence of factors contributing to injury for types of work provided an assessment of risk associated with contributing factors within each type of work. Knowing that workers in certain types of work are at greater risk of encountering specific contributing factors than are other workers can be helpful in focusing prevention interventions where they can be most useful. For example, glass installation workers are at very high risk of injuries to which environmental conditions and materials contributed. This could lead a safety manager to determine how to modify materials handling practices, which may involve carrying and placing large glass panels or to investigate whether environmental conditions surrounding these workers can be ameliorated in order to reduce risk.

While these results have the potential to be useful in setting prevention priorities, they essentially serve as pointers to the more detailed information contained in injury report text residing in a text database. The examination of injury report text for injuries involving particular objects or particular mechanisms of injury can help to identify modifiable factors that contributed to injury. For example, there were numerous cases of faulty equipment or equipment breakage leading to injuries. In many of these cases, it appeared that the equipment in question was old.

This suggested that effective prevention could focus on development of stringent equipment replacement schedules or regularly scheduled equipment inspections by employees given this specific responsibility.

The merging of text explaining the circumstances surrounding injury with data in an administrative database can facilitate multiple approaches to characterizing injuries and their contributing factors as well as development of specific interventions that can either avoid or ameliorate injuries. Moreover, the administrative database provided to us allowed the calculation of the rates at which multiple factors contributed to injury by type of work, about which little has been published in the research literature.

Using Haddon's Matrix to systematically examine injury reports forced the coders and investigators to consider multiple elements involved in the injury. This is not the only conceptual model that could have been used, but we believe that having such a framework elicited much more complete descriptions of the circumstances surrounding injury than would otherwise have occurred in this review of over 3,500 text reports.

Conclusions

We developed a method that can be used by others to capture a complete list of factors contributing to construction injury. It does not require knowledgeable abstractors, and it can be applied to injury reports with relatively sparse information. The method we used elicited much information about each injury. While it did not capture a sequence of events and therefore could not establish injury etiology, it did provide a fairly comprehensive picture of the factors involved in these construction injuries. Linkage of text data with administrative workers' compensation data provided a way to systematically analyze classes of injuries, contributing factors, types of work and other variables and for calculation of injury and payment rates for each contributing factor identified, a result that, to our knowledge, has not been accomplished until now. The findings of our analyses can provide much information useful in ameliorating the conditions incident to construction injury.

Table 1: Rates per 200,000 Person Hours of Occurrence of Major Factors and Specific Objects Contributing to Injury for Various Types of Work, Denver International Airport. 1990-1994

	Victim	Object Total	Specific Objects							Environmental	Organizational
Type of work			Materials	Equipment	Tools	Motor veh/ Heavy equipment	Structure	Object size/ weight	Ladder/ scaffolding		
Carpentry	18.4	30.8	14.5	6.5	4.7	0.8	5.1	2.3	4.4	10.9	3.1
Concrete Construction	20.1	32.6	14.5	7.1	6.0	1.4	3.4	3.7	2.0	10.7	2.6
Concrete construction—bridges	11.3	13.7	5.6	4.8	3.2	0.8	0.8	0.8	0	4.0	0.8
Conduit construction	25.5	38.0	11.2	5.2	10.8	5.6	1.3	3.9	0	12.9	3.0
Driving	5.5	12.1	0	2.2	0	8.8	0	0	0	7.7	1.1
Electrical wiring	14.6	25.3	9.7	4.5	5.6	2.0	4.4	1.6	2.0	11.1	3.8
Electrical wiring-low voltage	3.0	3.6	1.2	0	1.8	0.6	0.6	0	0.6	0.6	0
Elevator construction	14.8	36.5	11.3	5.2	6.1	1.7	7.0	1.7	2.6	6.1	0
Glass installation	24.3	37.6	17.0	4.6	6.9	2.3	6.0	4.1	3.2	17.9	4.6
Heavy equipment installation	15.6	25.4	9.2	4.0	6.5	3.1	3.4	2.2	1.1	8.3	4.3
Inspection/ analysis	14.3	22.9	7.5	5.5	4.4	2.0	2.7	3.8	0.3	8.5	1.0
Insulation work	6.4	10.2	3.8	3.8	0	1.3	1.3	1.3	2.6	6.4	1.3
Iron/steel erection <2 stories	22.9	29.4	4.9	4.9	13.1	0	0	0	3.3	6.5	0
Iron/steel erection ≥2 stories	23.2	36.1	14.6	6.0	8.8	1.7	6.2	3.1	2.4	14.1	2.9
Masonry	16.2	24.5	8.5	4.8	7.4	2.0	3.4	2.6	0.6	4.3	1.1
Metal/steel installation	25.9	36.8	13.2	4.1	12.7	3.6	4.1	2.7	2.3	15.9	1.4
Painting	10.5	14.6	4.1	4.7	2.3	1.2	0.6	2.3	1.8	5.3	1.8
Pipefitting	8.4	16.4	4.1	4.3	3.9	1.7	1.0	2.2	2.2	7.2	0.7
Plumbing	18.9	28.7	11.0	4.9	6.8	2.8	2.8	2.7	1.2	13.1	2.9
Roofing	16.6	31.5	19.9	5.0	5.0	1.7	6.6	5.0	3.3	13.3	3.3
Sheet metal installation	14.3	20.2	5.9	4.0	4.7	1.6	1.2	0.6	1.6	9.0	1.2
Street/road construction	12.6	21.4	3.5	5.8	3.6	7.9	1.2	1.8	0.4	7.8	0.7
Supervision	2.9	6.5	2.1	1.3	1.0	0.7	0.9	0.4	0.1	3.3	0.7
Mean injury rates-all inj.	13.3	22.0	7.5	4.5	4.5	2.9	2.6	1.9	1.3	8.4	1.9

Table 2: Workers' Compensation Payment Rates per $100 Payroll for Major Factors and Specific Objects Contributing to Injury for Various Types of Work, Denver International Airport. 1990-1994

	Victim	Specific Objects							Environ-mental*	Organiz-ational*
Type of work		Materials*	Equipment*	Tools	Motor vehicle/ heavy equip*	Structure*	Object size/ weight*	Ladder/ scaffold		
Carpentry	$2.49	$2.61	$ 1.24	$ 0.25	$ 0.71	$2.23	$0.64	$1.13	$2.76	$0.53
Concrete Construction	8.14	4.96	2.96	1.20	0.49	1.47	2.80	1.07	4.65	0.40
Concrete construction—bridges	2.36	0.32	2.03	0.29	0.01	0.08	0.01	0	0.09	0.00
Conduit construction	1.51	0.86	0.33	0.32	2.24	1.80	0.25	0	2.64	0.04
Driving	5.99	0	0.04	0	6.36	0	0	0	9.48	0.03
Electrical wiring	1.13	1.31	0.65	0.48	0.22	0.92	0.06	0.15	1.11	0.60
Electrical wiring-low voltage	3.56	3.28	0	0.02	0.01	0.27	0	0.27	0.27	0
Elevator construction	2.05	0.48	0.49	0.07	0.35	0.56	0.10	0.04	1.30	0
Glass installation	5.14	3.82	0.72	1.07	1.33	0.16	2.77	0.04	15.69	13.39
Heavy equipment installation	6.26	2.27	0.31	0.52	2.26	2.59	0.64	0.20	1.01	0.55
Inspection/ analysis	3.12	0.79	1.32	0.16	0.07	0.15	0.55	0.01	1.76	0.01
Insulation work	0.10	0.01	0.79	0	0.00	0.08	0.01	0.09	0.11	0.00
Iron/steel erection <2 stories	0.28	0.10	0.08	0.20	0	0	0	0.05	0.86	0
Iron/steel erection ≥2 stories	4.72	3.68	4.07	0.13	2.29	5.23	1.51	2.70	6.74	3.58
Masonry	6.14	1.78	0.62	0.87	0.51	0.18	1.63	0.18	0.49	0.20
Metal/steel installation	5.52	3.98	4.94	0.18	0.07	2.57	3.22	0.49	4.33	0.80
Painting	6.30	1.37	3.73	0.39	0.06	0.01	0.92	3.93	3.92	3.91
Pipefitting	2.88	1.43	0.13	0.18	0.60	0.03	1.01	3.05	2.03	0.30
Plumbing	2.09	2.01	0.64	0.19	0.18	0.30	0.88	0.02	1.18	0.15
Roofing	21.31	4.47	0.88	0.36	4.27	3.41	0.04	16.32	24.01	0.89
Sheet metal installation	1.80	0.92	0.18	0.15	0.93	0.01	0.01	0.05	1.30	0.02
Street/road construction	5.41	0.81	2.78	0.40	6.69	1.37	1.30	0.97	7.53	0.16
Supervision	0.35	0.07	0.02	0.29	0.03	0.40	0.01	0.00	1.06	0.02
Total Payment Rate	$3.41	$1.63	$1.30	$0.40	$1.62	$1.08	$0.85	$0.63	$3.08	$0.53
Spearman Correlation	0.298	0.711*	0.485*	0.332	0.481*	0.629*	0.540*	0.330	0.698*	0.671*

*Spearman Rank Correlation coefficient between payment rates and injury rates significantly ($p \leq .01$) different from 0.

Table 3. Injury and payment rates [1] by type of work ; slips and trips, building of Denver International Airport, 1989-1994

Trade	Frequency	Injury rate (95% CI)	Payment rate
Insulation	5	6.4 (2.1, 14.9)	$0.04
Masonry	11	3.1 (1.5, 5.5)	$0.47
Carpentry	48	7.8 (5.8, 10.3)	$2.30
Concrete construction	109	6.7 (5.4, 8.2)	$3.96
Street road/construction	109	4.2 (3.4, 5.1)	$4.79
Iron/steel > 2 stories	38	9.1 (6.5, 12.4)	$2.80
Metal/steel installation	19	8.6 (5.2, 13.4)	$2.52
Plumbing	55	6.2 (4.6, 8.2)	$0.90
Pipefitting	14	3.4 (1.9, 5.7)	$0.30
Sheet metal	11	3.4 (1.7, 6.1)	$0.72
Electrical wiring	128	6.7 (5.6, 8.0)	$0.98
Conduit construction	18	7.8 (4.6, 12.3)	$2.36
Roofing	6	9.9 (3.6, 21.5)	$20.56
Elevator construction	6	5.2 (1.9, 11.3)	$1.26
Glass installation	19	8.7 (5.2, 13.5)	$13.20
Superintendent	23	1.6 (1.0, 2.4)	$0.71
Inspectors	13	4.4 (2.3, 7.5)	$1.55
Engineers/ architecture	8	1.4 (0.60, 2.8)	$0.02
Heavy equipment	38	4.6 (3.1, 6.6)	$0.64
Clerical	15	2.1 (1.4, 3.0)	$1.10
Overall [2,3]	751	5.0 (4.6, 5.4)	$4.26

(1) Injury rates are per 200,000 hours; payment rates are per $100 of payroll.

(2) Only types of work with > 5 slip/trip injuries. No slips/trips were identified in boiler making, plastering/finishing, stone crushing, pile driving, drivers, crane hoisting, iron/steel erection under 2 stories, electrical power line work, concrete/bridges, painting, or low voltage specialties.

(3) Remaining slips in 'other' category.

Figure 1. Factors identified in text records as contributing to injuries preceded by slips/trips by mechanism of injury, building of Denver International Airport

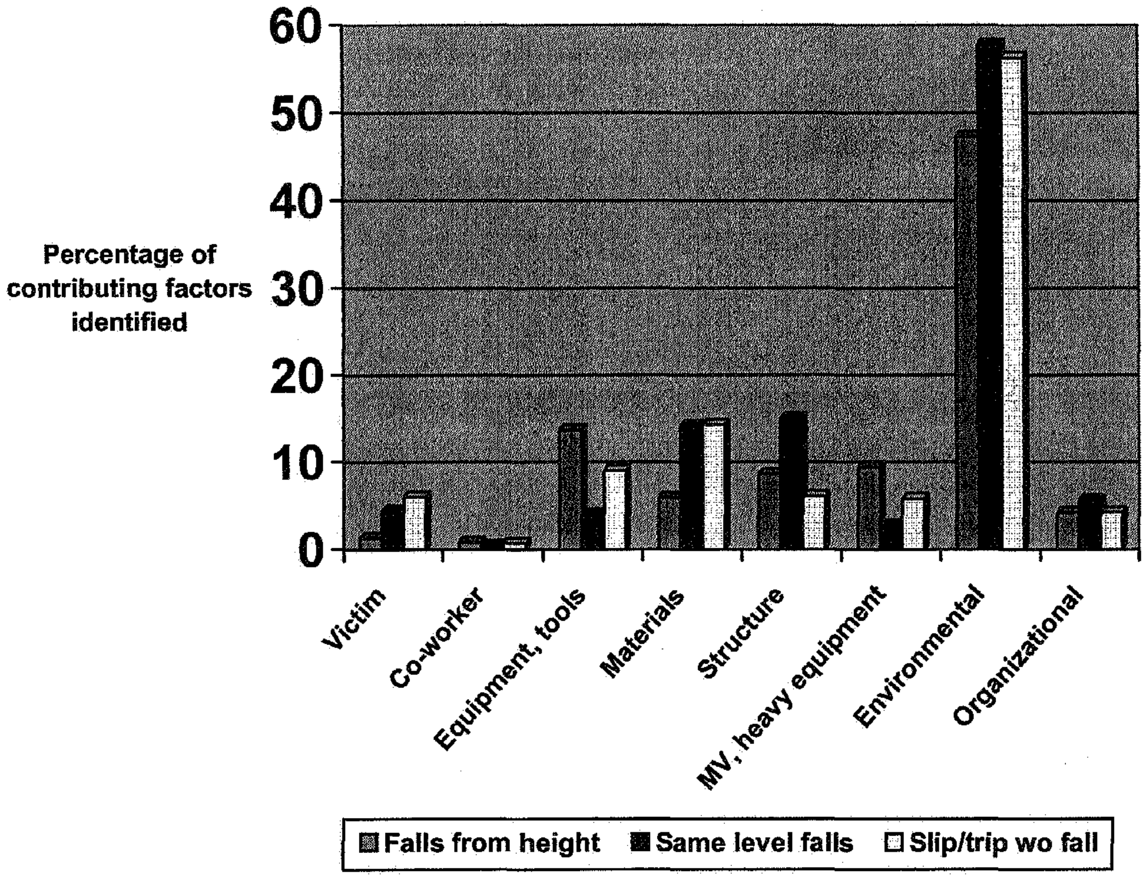

Table 4: Frequency of occurrence of each contributing factor to injuries by age of worker (%)

	Victim Action*	Object							Environment*	Organizational*
Age of Worker (# of injuries)		Materials	Equipment	Tools	Motor vehicle/ heavy equipment	Structure*	Object size/weight*	Ladder/ scaffold		
15-19 (45)	66.7	31.1	15.6	22.2	4.4	6.7	6.7	6.7	17.8	4.4
20-29 (936)	56.4	30.9	21.3	19.2	9.6	9.9	9.4	4.7	32.8	6.9
30-39 (1216)	57.0	30.4	17.0	19.0	12.2	8.5	8.4	4.8	31.7	6.2
40-49 785)	50.8	29.3	17.6	17.2	13.1	12.6	5.5	5.0	36.6	8.9
50-59 (465)	51.8	33.8	16.6	18.7	11.4	13.8	7.7	6.2	40.6	10.5
≥ 60 (84)	50.0	26.2	13.1	14.3	14.3	13.1	4.8	8.3	48.8	14.3

* Statistically significant at the $p<0.05$, based on Chi-Square test of significance.

Table 5: Frequency of occurrence of each contributing factor to injuries by size of company (%)

	Victim Action								Environment*	Organizational
Company size: number of employees (# of injuries)		Materials	Equipment*	Tools	Motor vehicle/ heavy equipment*	Structure	Object size/weight	Ladder/ scaffold		
1-19 (449)	57.2	28.5	17.8	17.8	8.5	11.1	9.4	4.0	29.2	8.2
20-49 (607)	57.5	31.1	15.3	20.9	11.5	10.9	9.6	5.6	35.1	8.6
50-99 (495)	53.7	34.1	23.4	16.0	10.1	10.5	7.1	6.5	30.3	5.0
100-249 (978)	54.2	28.8	19.5	18.3	17.7	8.9	7.4	5.2	39.2	8.2
≥ 250 (244)	57.8	34.0	16.0	23.0	6.6	13.5	6.6	6.2	41.0	9.4

* Statistically significant at the $p<0.05$, based on Chi-Square test of significance.

Table 6: Percent of Injury Reports Mentioning Major Factors Contributing to Injury for Various Mechanisms of Injury Event, Denver International Airport Construction, 1990-1994

Mechanism of Injury Event (N)	Victim Action (N=2005)	Objects (N=3317)	Environmental (N=1265)	Organizational (N=286)
Burn (90)	55.6%	76.7%	13.3%	7.8%
Caught (172)	33.1	97.1	8.7	4.1
Cumulative Trauma (57)	54.4	63.2	8.8	1.8
Electrical Shock (17)	70.6	100.0	41.2	29.4
Fall/no slip (194)	31.4	91.8	69.1	11.9
Foreign body in eye (480)	63.1	79.2	35.4	5.6
Jumped (19)	31.6	94.7	0	5.3
Motor vehicle (174)	25.3	94.3	62.6	3.4
Repetitive motion (7)	100.0	85.7	28.6	0
Slips/trips (721)	15.0	83.5	84.5	14.6
Straining/overexertion (616)	98.7	91.4	10.2	1.3
Struck against (260)	79.6	96.9	12.7	6.5
Struck by (808)	56.6	98.6	12.6	9.7
Twisted by/pulled by (68)	79.6	100.0	5.9	1.5
Percent of all injuries	54.4%	90.1%	34.3%	7.8%

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Lincoln AE, Sorock GS, Courtney TK, Wellman, HM, Smith GS, Amoroso PJ. Using narrative text and coded data to develop hazard scenarios for occupational injury interventions. *Injury Prevention* 2004; 10:249-254.

Lipscomb HJ, Glazner J, Bondy J, Lezotte DC, Guarini K. Analysis of text from injury reports improves understanding of construction falls. Journal of Occupational and Environmental Medicine; 46:1177-1184, 2004.

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APPENDIX

Lipscomb HJ, Glazner J, Bondy J, Lezotte DC, Guarini K. Analysis of text from injury reports improves understanding of construction falls. Journal of Occupational and Environmental Medicine; 46:1177-1184, 2004.

Publications:

Current:

Lipscomb HJ, Glazner J, Bondy J, Lezotte DC, Guarini K. Analysis of text from injury reports improves understanding of construction falls. Journal of Occupational and Environmental Medicine; 46:1177-1184, 2004.

Glazner J, Bondy J, Lezotte, DC, Lipscomb H, Guarini K. Factors contributing to construction injury at Denver International Airport. American Journal of Industrial Medicine. In press.

In preparation:

Bondy J, Glazner JE, Guarini K, Lipscomb HJ. Methods to identify factors contributing to injury using narrative text from injury reports. Manuscript in preparation.

Lipscomb HJ, Glazner JE, Bondy J, Lezotte DC, Guarini K. Injury report text analysis of slip/trip injuries at Denver International Airport. Manuscript in preparation.

Abstracts Presented:

Glazner JE, Bondy J, Lezotte DC, Guarini K, Lipscomb HJ. Injury and Payment Rates for Different Injury Mechanisms Among Types of Construction Work, presented at National Occupational Injury Research Symposium, October, 2003.

Glazner JE, Bondy J, Lezotte DC, Guarini K, Lipscomb HJ. Construction Injury: Patterns of Factors Contributing to Different Types of Injury Events, presented at the National Occupational Injury Research Symposium, October, 2003.

Lipscomb HJ, Glazner JE, Bondy J, Lezotte, DC, Guarini K. Use of text data from injury reports/investigations to understand falls from height in construction, presented at the National Occupational Injury Research Symposium, October, 2003.

Bondy J, Glazner JE, Lezotte DC, Guarini, K, Lipscomb HJ. Using narrative reports to identify factors contributing to construction injury. Presented at the National Occupational Injury Research Symposium, October, 2003.

2. Financial Status Report

The financial status report is not yet available. The final invoice from Duke University for one of our investigators arrived last week and has not yet appeared in our accounting system. When that payment is made, we will prepare a financial status report. That report may be sent directly by George Johnston of our Grants and Contracts Office. It should be sent within the next two weeks.

3. Equipment Inventory

We acquired no equipment under this grant.

4. Final Invention Statement

No inventions were conceived under this grant.