

# Risk Factors for Injury Among Construction Workers at Denver International Airport

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**Background** *The Denver International Airport construction project provided a rare opportunity to identify risk factors for injury on a large construction project for which 769 contractors were hired to complete 2,843 construction contracts. Workers' compensation claims and payroll data for individual contracts were recorded in an administrative database developed by the project's Owner-Controlled Insurance Program.*

**Methods** *From claims and payroll data linked with employee demographic information, we calculated injury rates per 200,000 person-hours by contract and over contract characteristics of interest. We used Poisson regression models to examine contract-specific risk factors in relation to total injuries, lost-work-time (LWT), and non-LWT injuries. We included contract-specific expected loss rates (ELRs) in the model to control for prevailing risk of work and used logistic regression methods to determine the association between LWT and non-LWT injuries on contracts.*

**Results** *Injury rates were highest during the first year of construction, at the beginning of contracts, and among older workers. Risk for total and non-LWT injuries was elevated for building construction contracts, contracts for special trades companies (SIC 17), contracts with payrolls over \$1 million, and those with overtime payrolls greater than 20%. Risk for LWT injuries only was increased for site development contracts and contracts starting in the first year of construction. Contracts experiencing one or more minor injuries were four times as likely to have at least one major injury (OR = 4.0, 95% CI (2.9, 5.5)).*

**Conclusions** *Enhancement of DIA's safety infrastructure during the second year of construction appears to have been effective in reducing serious (LWT) injuries. The absence of correlation between injury rates among contracts belonging to the same company suggests that targeting of safety resources at the level of the contract may be an effective approach to injury prevention. Interventions focused on high-risk contracts, including those with considerable overtime work, contracts held by special trades contractors (SIC 17), and contracts belonging to small and mid-sized companies, and on high-risk workers, such as those new to a construction site or new to a contract may reduce injury burden on large construction sites. The joint occurrence of minor and major injuries on a contract level suggests that surveillance of minor injuries may be useful in identifying opportunities for prevention of major injuries. Am. J. Ind. Med. 34:113-120, 1998.*

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## INTRODUCTION

Little information exists on risk factors for injury in construction workers, although they suffer a disproportionate number of injuries relative to workers in other industries. A major obstacle in research has been a lack of complete incidence and denominator data for calculating injury rates that are also linked with descriptive data with which to characterize risk. In addition, the short-term, episodic nature of construction work, the existence of multiple employers on

construction sites, and constantly changing physical work environments have made construction workers difficult to study.

Access to the administrative claims database established for the Denver International Airport (DIA) construction project enabled us to examine risk factors for injury among a large cohort of workers at a single construction site. The DIA administrative database contained information on all workers' compensation claims submitted under the Owner Controlled Insurance Program as well as worker demographic data, information on individual companies and contracts, and payroll by contract and job classification. With these data we were able to calculate injury rates over contract variables of interest and to model injury rates while controlling for prevailing risk of work. We report here our analysis of risk factors for injury among construction workers at DIA and make suggestions for future use of such administrative databases for surveillance and research.

## MATERIALS AND METHODS

### Study Cohort and Claims

We estimated worker age for the 32,081 individual workers (95% male) badged for on-site work at DIA from December 1990 through August 1994 by subtracting birth date from January 1992, the approximate midpoint of DIA construction. Payroll data and dates of termination were not available for individual employees, so we were unable to calculate duration of work for individuals.

From the administrative database, we identified 4,634 claims with payment, including 963 claims (21%) for lost-work-time (LWT). Three fatalities on the project were counted as lost-time claims. We included claims arising from work-related illnesses (less than 10% of claims) as injuries in this report. All claims were linked with the claimant's company and the specific contract on which the employee was working at the time of injury.

### Contract Characteristics

We categorized the 2,843 contracts completed by 769 contractors at DIA by contract status, i.e., prime contract, subcontract, and sub-subcontract, and assigned them to one of seven construction domains: site development, airfield construction and paving, roadway construction, terminal/concourse building construction, site utilities, construction management, and "other." We further classified contracts by size of total payroll (adjusted for overtime and to 1994 dollars), which ranged from less than \$100 to over \$16 million, by percent overtime payroll, by contract start year, and by length of contract payroll. We linked individual contracts with their corresponding company's Standard Industrial Classification (SIC) code, size (average number of

employees in the year prior to DIA work), and Colorado business residence status.

We created a measure of prevailing risk for DIA contracts using Colorado-specific expected loss rates (ELRs) derived by the National Council on Compensation Insurance [NCCI, 1995] according to job classification. We calculated DIA-specific ELRs over contracts as the weighted average of ELRs across job classifications [Glazner et al., 1998].

### Injury Rates

We estimated person-hours from contract payroll [Glazner et al., 1998] and calculated injury rates as the number of workers' compensation claims per 200,000 person-hours for the following contract strata: contract status, construction domain, payroll size, percent overtime payroll, start year, contract length, company SIC code, company size, and company Colorado residence status. We determined rates for total injuries, LWT injuries, and non-LWT injuries. To investigate whether injury incidence varied over contract duration, we divided contracts into quartiles of time, and calculated LWT and non-LWT aggregate injury rates for each quartile. Since contract payroll, and thus person-hours at risk, were not evenly distributed over contract length, we also calculated injury rates over quartiles of contract payroll. Ninety-five percent confidence intervals around quartile rates were calculated assuming a Poisson distribution for the number of injuries [Haenszel et al., 1962].

### Statistical Analysis

To determine whether an association existed between the occurrence of minor (non-LWT) and major (LWT) injuries on the same contracts, we performed a logistic regression. The binary response, whether or not a contract had at least one major injury, was modeled as a function of covariates. Specifically, the independent variables were 1) the occurrence of one or more minor injuries on a contract, 2) risk, represented by the log of the contract's ELR, and 3) contract person-hours, which, in order to meet the assumption of linearity on the logit scale, was included in the model as a categorical variable, indicating the quartile of contract person-hours to which a contract belonged.

Using generalized linear model techniques [McCullagh and Nelder, 1989], we examined contract-specific risk factors for all injuries, LWT injuries, and non-LWT injuries while controlling for covariates. We assumed that the total number of injuries per contract, ranging from 0–146 injuries, followed a Poisson distribution. We included the logarithm of contract person-hours in the log-linear model for injury count as an offset variable in order to model the rate of injuries. We included a dispersion parameter to adjust standard errors of the parameter estimates, since the scaled

deviance was less than one. We limited our analysis to those contracts belonging to the subset of Colorado companies for which we had size information (n = 2,140).

For all significant variables (entered at  $P < 0.10$ ), we calculated adjusted rate ratios, which signify the relative risk of injury for each level of the variable as compared with the reference group (denoted by rate ratio = 1.00) while controlling for all other variables in the model. Confidence intervals excluding 1.00 indicate significant differences in risk ( $P < 0.05$ ) between the specific level and the reference level for that variable.

Since many companies held multiple contracts at DIA, we investigated the possible correlation of injury rates among contracts held by the same company. For each injury type (total, LWT, and non-LWT), we developed two Poisson regression models: 1) specifying an independent error structure which assumes independence of injury rates across all contracts, and 2) specifying a compound symmetric error structure which assumes correlation of injury rates within companies. Generalized estimating equations [Liang and Zeger, 1986] were employed in the case involving correlated errors. We compared the 95% confidence intervals around the respective adjusted rate ratios for the two model types (independent vs. correlated) for each injury type model. We found that for all injury type models, the identification of statistically significant risk factors was identical regardless of the type of error structure assumed, suggesting that the more complex models (assuming correlation within companies) offered no meaningful improvement over the simpler models (independence across contracts). We concluded, therefore, that injury rates among contracts belonging to the same company were not correlated. All regression models were fit using the GENMOD procedure in SAS [1985].

## RESULTS

### Univariate Analysis

The total injury rate at DIA was 29.8 injuries per 200,000 person-hours, reflecting LWT and non-LWT injury rates of 6.2 and 23.4 injuries per 200,000 person-hours, respectively. Over 12% (3,869) of the workers at DIA suffered injuries resulting in claims, 16% of whom (603) sustained more than one injury. The majority of claimants were male (95%), and though the largest proportion of injuries was sustained by younger workers, the rate of both LWT and non-LWT injury increased with age (Table I).

At least one injury occurred on 695 (25%) of the 2,843 contracts completed at DIA. Contracts starting before 1992, contracts for site development, and short-term contracts lasting 1 month or less experienced considerably higher LWT injury rates than did other contracts in the correspond-

**TABLE I.** Distribution of DIA Workers and Injury Rates (Total, Lost-Work-Time and Non-Lost-Work-Time Injuries per 100 Workers) by Age Group

Age group <sup>a</sup>	Number of workers <sup>b</sup>	(%)	Number of injuries	Total injury rate <sup>c</sup>	LWT rate	Non-LWT rate
15-19	1,384	(4%)	92	6.6	0.9	5.7
20-29	8,975	(29%)	1,159	12.9	2.5	10.3
30-39	10,936	(35%)	1,528	14.0	2.8	11.0
40-49	6,429	(21%)	1,002	15.6	3.3	12.2
50-59	3,100	(10%)	580	18.7	3.9	14.7
60+	474	(2%)	97	20.5	3.8	16.7

<sup>a</sup>Age information was missing for 783 (2%) workers and 176 injuries.  
<sup>b</sup>The denominator for the injury rates in this table is number of employees working any amount of time on this project in each age group, not full-time-equivalents (FTE). The rates shown here are therefore lower than those calculated using FTE.  
<sup>c</sup>Differences between total injury rate and (LWT rate + non-LWT rate) reflect either rounding or omission of 44 claims with unknown lost-time status from either the LWT or the non-LWT rate category.

ing strata (Table II). Sub-subcontracts, contracts with no overtime payroll, nonconstruction contracts (SIC Other) and contracts for large companies ( $\geq 250$  employees) experienced lower LWT injury rates than others within these strata. The rate of non-LWT injuries increased with contract payroll size and contract percent overtime payroll, and was higher among contracts for building construction, special trades (SIC 17) contracts, and sub-subcontracts.

Consistent with the finding of higher risk for short-term contracts, we found that LWT injury rates were significantly higher in the first quartile of contract duration compared with all other quartiles (Table III). LWT injury rates fell by over 50% from the first quartile to the last, with the largest reduction (25%) occurring between the first and second quartiles. Non-LWT injury rates remained unchanged over contract duration until the last quartile. The prevailing risk of work performed, as defined by the expected loss rate, decreased by 22% over contract duration (Table III). Examination of injury rates over quartiles of contract payroll revealed that LWT and non-LWT rates were significantly lower in the last quartile compared with the first quartile (data not shown).

### Minor and Major Injuries

We found a positive association between the occurrence of minor (non-LWT) and major (LWT) injuries on contracts. Contracts experiencing one or more minor injuries were four times as likely as those without minor injuries to have at least one major injury (OR = 4.0, 95% CI: (2.9, 5.5)), after controlling for contract person-hours and prevailing risk of work.

**TABLE II.** DIA Injury Rates (per 200,000 Person-Hours) by Contract Strata

Contract variable	Number of contracts	Total injury rate <sup>a</sup>	LWT injury rate	Non-LWT injury rate
Construction domain				
Management	34	9.6	1.4	8.2
Site development	179	24.8	9.4	15.1
Roadways	218	21.0	4.9	15.9
Airfields	386	29.9	6.6	23.0
Utilities	432	25.3	5.4	19.5
Other	342	25.5	4.2	21.1
Buildings	1,252	34.7	6.7	27.6
Company size (number of employees)				
1–19	1,104	28.1	5.1	22.8
20–49	575	34.5	7.7	26.4
50–99	240	30.9	6.3	24.3
100–249	199	28.1	6.2	21.7
250+	22	25.7	3.0	22.4
Missing	703			
Contract status				
Subcontract	1,664	31.2	6.5	24.0
Sub-subcontract	1,051	32.7	4.8	27.5
Prime	128	26.8	6.1	20.4
Contract start year				
1994	91	17.6	5.9	11.8
1993	1,419	28.7	5.5	23.1
1992	1,005	28.5	5.7	22.6
1990/91 <sup>b</sup>	328	32.9	7.6	24.9
Company SIC code				
SIC 15	102	29.2	6.7	22.1
SIC 16	303	25.6	6.6	18.7
SIC 17	1,339	36.6	7.0	29.3
Other	782	18.9	4.2	14.5
Missing	317			
Contract payroll size				
>\$1 mi.	117	31.3	6.1	24.9
>\$100K–\$1M	518	28.4	6.5	21.6
≤\$100K	2,208	23.6	5.5	18.1
Percent overtime payroll				
>20%	521	33.2	6.4	26.5
>0–20%	1,621	29.7	6.3	23.2
0%	701	12.7	3.6	9.2
Contract length				
≤1 month	368	36.5	15.7	19.1
>1–6 months	948	26.7	5.1	21.6
>6–12 months	774	28.5	6.0	22.2
>12–24 months	642	31.6	6.8	24.6
>24 months	111	28.6	5.7	22.6

**TABLE II.** DIA Injury Rates (per 200,000 Person-Hours) by Contract Strata (Continued)

Contract variable	Number of contracts	Total injury rate <sup>a</sup>	LWT injury rate	Non-LWT injury rate
Colorado company status				
Colorado	2,507	29.1	5.9	23.0
Non-Colorado	310	33.3	7.8	25.1
Missing	26			

<sup>a</sup>Differences between total injury rate and (LWT rate + non-LWT rate) reflect either rounding or omission of 44 claims with unknown lost-time status from either the LWT or the non-LWT rate category.

<sup>b</sup>This category includes 12 months of 1991 and only 1 month of 1990 data because DIA's insurance program was implemented December 1, 1990.

**TABLE III.** DIA Injury Rates (per 200,000 Person-Hours) and Expected Loss Rate Over Quartile of Contract Duration

Quartile	LWT injury rate	95% CI	Non-LWT injury rate	95% CI	ELR
1st	8.3	(7.5, 9.3)	24.6	(23.1, 26.2)	\$6.31
2nd	6.2*	(5.6, 7.0)	25.5	(24.2, 26.9)	6.01
3rd	5.1*	(4.4, 5.8)	23.3	(21.9, 24.8)	5.17
4th	4.0*	(3.2, 5.0)	15.3*	(13.6, 17.2)	4.92

\*Significantly different from 1st quartile.

## Poisson Regression Models

Predictors of both LWT and non-LWT injury rates in the Poisson regression models included expected loss rate, construction domain, company size, contract status, start year, and SIC code (Table IV). The risk for each injury type (LWT and non-LWT) differed among levels of these variables, however. For example, in the case of construction domain, site-development contracts were at highest risk for LWT injuries, whereas building contracts had higher risk for non-LWT injuries. For contract status, sub-subcontracts experienced significantly lower risk for LWT injury than did prime contracts. While sub-subcontractors' crude rate of non-LWT injury was considerably higher than that of prime contractors, their risk of non-LWT injury did not differ from that of prime contractors after adjusting for prevailing risk and the other factors in the regression model. Special trades contracts (SIC 17) suffered higher non-LWT injury rates compared with nonconstruction contracts (SIC Other), and heavy construction contracts (SIC 16) experienced significantly lower risk of LWT injury.

With respect to company size, contracts belonging to companies with fewer than 100 employees had elevated risk for both LWT and non-LWT injuries relative to large

TABLE IV. Rate Ratios for Risk Factors for LWT and Non-LWT Injuries in the Construction of DIA (n = 2,140 Contracts)

Contract variable	Number of contracts	LWT rate ratio	95% CI	Non-LWT rate ratio	95% CI
Expected loss rate (log)		1.65	(1.48, 1.83)	1.10	(1.02, 1.19)
Construction domain					
Management	21	0.72	(0.46, 1.12)	0.56	(0.42, 0.74)
Site development	152	1.46	(1.18, 1.81)	0.59	(0.48, 0.73)
Roadways	170	0.67	(0.52, 0.86)	0.66	(0.54, 0.81)
Airfields	241	1.09	(0.88, 1.35)	0.87	(0.73, 1.04)
Utilities	347	0.87	(0.71, 1.07)	0.75	(0.64, 0.88)
Other	265	0.37	(0.23, 0.60)	0.84	(0.66, 1.08)
Buildings	944	1.00	—	1.00	—
Company size (number of employees)					
1–19	1,104	1.73	(1.36, 2.20)	1.28	(1.10, 1.49)
20–49	575	2.51	(2.01, 3.15)	1.25	(1.08, 1.44)
50–99	240	2.07	(1.64, 2.62)	1.17	(1.01, 1.36)
100–249	199	1.70	(1.38, 2.11)	1.11	(0.98, 1.26)
250+	2	1.00	—	1.00	—
Contract status					
Subcontract	1,220	0.88	(0.73, 1.06)	0.86	(0.74, 0.99)
Sub-subcontract	827	0.53	(0.41, 0.69)	0.93	(0.77, 1.12)
Prime contract	93	1.00	—	1.00	—
Contract start year					
1994	77	1.37	(0.57, 3.30)	0.44	(0.15, 1.25)
1993	1,065	0.78	(0.67, 0.90)	0.90	(0.81, 1.01)
1992	726	0.84	(0.76, 0.94)	0.93	(0.86, 1.01)
1990/91	272	1.00	—	1.00	—
Company SIC code					
SIC 15	83	0.80	(0.61, 1.05)	0.99	(0.80, 1.24)
SIC 16	234	0.67	(0.51, 0.87)	0.94	(0.75, 1.18)
SIC 17	1,150	0.88	(0.73, 1.07)	1.48	(1.26, 1.74)
Other	673	1.00	—	1.00	—
Contract payroll size		*	*		
>\$1 mi	91			1.30	(1.09, 1.54)
>\$100K–\$1M	349			1.09	(0.92, 1.28)
≤\$100K	1,700			1.00	—
Percent overtime payroll		*	*		
>20%	358			1.57	(1.13, 2.17)
>0–20%	1,248			1.20	(0.88, 1.64)
0%	534			1.00	—

\*Variable nonsignificant at  $P < 0.10$  level.

companies ( $\geq 250$  employees). Contract payroll size and overtime proportion of payroll were associated only with non-LWT injury rates when controlled for other variables in the model, with contracts of over \$1 million and contracts with greater than 20% overtime payroll having increased risk for these injuries. Results of models of risk factors for non-LWT and total injuries were similar (data for total injuries not shown).

## DISCUSSION

Risk of worksite injury is heightened for older workers, workers new to a site, workers on contracts for building construction and site development, workers on contracts with sizable overtime payroll, and on contracts belonging to small and mid-sized companies. Furthermore, the occurrence of minor injuries (non-LWT) increases the risk of

having major (LWT) injuries on the same contracts. These findings extend what is known about risk factors in an industry plagued with high injury rates.

Older workers at DIA were more likely to suffer work-related injuries, confirming the findings of several reports on construction-worker mortality [Buskin and Paulozzi, 1987; Kisner and Fosbroke, 1994] and morbidity [Fredin et al., 1974]. Other reports, however, have suggested that younger workers are at increased risk for all injuries [Lipscomb et al., 1996; Vézina et al., 1996] and that older construction workers (over 44 years) are underrepresented among LWT injuries [OSHA, 1992]. Older workers have been found to employ better safety practices in the construction industry [Dedobbeleer and German, 1987], but such practices may not predict injury avoidance. We found that the rates of both LWT injuries and non-LWT injuries at DIA increased with age, with no evidence that young, presumably less experienced, workers were at higher risk. Further study of the specific types of injuries and accidents sustained by older workers would be useful in developing appropriate prevention strategies for these workers.

Our findings of higher injury rates at the beginning of contracts and for short-term contracts are consistent with other reports indicating that injuries are more likely to occur during the first month of employment [OSHA, 1992; Culver et al., 1993; Vézina et al., 1996] and with an influx of new workers to a site [Hubbard and Neil, 1985]. There are a number of factors that likely contribute to these early injuries, including worker unfamiliarity with the site and/or unfamiliarity with job tasks specific to the project [Hubbard and Neil, 1985]. Exposure to safety training and safety instruction at initial employment has been shown to positively affect worker safety performance [Dedobbeleer and German, 1987]. At DIA, all new workers, regardless of prior work experience, attended an orientation covering general on-site safety procedures (personal communication, Skip Guarini, Field Safety Manager DIA, January 1997). Job-specific safety training, however, was subject to the policies of individual employers. Our findings suggest that studies to evaluate the efficacy of site-specific and job-specific safety training in reducing injury in workers new to a site would be valuable.

The excess risk of non-LWT injuries for building construction contracts may be attributable to the work environment created by having multiple trades, numerous employers, and diverse operations existing in close proximity to one another. With nearly five times the recorded person-hours of any other domain, building construction was the largest, most concentrated, and most diverse work effort on the DIA site. Inasmuch as these factors affect the safety of the work environment, enhancement of safety efforts in concentrated work areas may prove beneficial. The increased risk of LWT injury among workers in site development suggests that injuries sustained when operating

heavy equipment tend to be more severe. On the other hand, the specialized nature of the work may limit opportunities for modified or light duty work following injury, resulting in more lost work time than would otherwise occur.

Our finding of increased risk for non-LWT injuries on contracts with sizable overtime payrolls (>20% of total payroll) confirms that time constraints and work pressure have adverse effects on safety and work-related morbidity [Salminen et al., 1993; Levitt and Samelson, 1993; Fredin et al., 1974]. We were not able to link overtime payroll to individuals to determine whether injuries were more common among workers paid for overtime. Overtime work, however (which occurred on the vast majority of contracts at DIA), is likely a marker for schedule pressure on contracts and the construction workforce as a whole. We did not find, as others have [Vézina et al., 1996], that risk of LWT injury increases with increasing overtime work. One possible explanation for the lack of association between overtime and LWT injury in the multivariate analysis is that workers earning high overtime wages are reluctant to miss work when injured. The federal wage base adopted at DIA was considerably higher than average wages paid in Colorado for similar occupations [CDLE, 1996]. It is also possible that contracts with and without overtime differed relative to specific tasks performed which may have been only partially controlled for in the models by ELRs.

With respect to company size, our findings confirm several others showing that fatal and nonfatal injuries among construction workers are more likely among employees of small or mid-sized firms [Suruda, 1992; Buskin and Paulozzi, 1987; Hinze and Raboud, 1988; Salminen et al., 1993]. These findings conflict with national injury estimates [BLS, 1994], which indicate that employees of very small construction companies (<20 employees) experience injury rates as low as those of employees of large companies (500+ employees). While lower injury rates among large companies may be attributable to more stable workforces and to the availability of safety resources [Salminen et al., 1993], low injury rates among small companies are probably due to underreporting of injury to the Bureau of Labor Statistics [Oleinick et al., 1995; Glazner et al., 1998]. The reporting procedures established under DIA's Owner Controlled Insurance Program coupled with its on-site medical clinic facilitated the complete reporting of injury, thereby virtually eliminating the potential for reporting bias by company size. Our results indicate that employees of smaller companies are at higher risk of injury than those of large companies when controlling for job risk and other predictors of injury.

Multivariate analysis revealed that sub-subcontracts had significantly lower LWT injury rates than did prime contracts, contradicting a report by Salminen et al. [1993], which suggested that subcontracts are 1.5 times more likely to have serious worksite injuries compared with main

contractors. Our finding is strengthened by our ability to control for prevailing risk of work, which, at DIA, was considerably higher for sub-subcontracts than for prime contracts, as measured by ELRs (\$7.60 vs. \$5.72 per \$100 payroll). Sub-subcontractors generally perform a much narrower scope of work as compared with prime contractors, which may in part explain the lower injury rates for these contracts. The specialized and potentially hazardous nature of the work performed on these contracts likely requires that these workers be well trained.

Expected loss rates, which are typically used within the insurance industry to set workers' compensation insurance premiums, proved to be a significant predictor for all injuries. We validated the use of ELRs as a measure of risk by demonstrating the strong relationship between log ELR and injury occurrence on a contract level. When independent variables were examined univariately in the Poisson regression model, only construction domain accounted for more of the variability in contract total injury rates (as measured by Akaike's [1974] information criteria). Tables of state-specific ELRs are available for those states using the National Council on Compensation Insurance (NCCI) as their rating bureau. These data, linked with numerator and denominator data reported by job classification code, enable a fine distinction in the measurement of expected job risk that can be used in epidemiologic research and by project safety personnel to identify contracts at particularly high risk of injury.

Our findings have several implications for public health resource allocation and safety management. The absence of correlation between injury rates among contracts held by the same company suggests that targeting safety resources at the level of the contract, as opposed to the company, may be an effective approach to injury prevention. The association between minor (non-LWT) and major (LWT) injuries on contracts underlines the importance of monitoring both types of injury. Although major injuries often get the attention of management, minor injuries account for the vast majority of injuries at most construction sites (75% at DIA) and are associated with sizable direct and indirect costs to the employer [Hinze and Applegate, 1991; Levitt and Samelson, 1993]. Occurrence of minor injuries may be a useful trigger for assessment of safety practices and intervention to avert major injuries. Limited safety resources can also be targeted to older workers, workers new to a site, contracts for building construction and site development, contracts with sizable overtime payroll, and contracts belonging to small and mid-sized companies. Project management may consider requiring that employers provide job- and site-specific training to new workers, with consideration given to the fact that some new workers may be inexperienced in construction work. On contracts with substantial overtime or other risk factors (including having had a minor injury), interventions might include increasing requirements

for safety infrastructure, job hazard analyses, and safety training of management and workers.

This retrospective analysis is a model for analyses that could be performed during large construction projects having centralized claims databases, so that surveillance can lead to intervention during the life of the project. We recommend creating administrative databases that can link individual workers to contracts and to payroll, enabling calculation of rates by demographic, overtime, and job categories. Further, we would suggest that the amount of lost work time be included in indemnity claim files, obviating the need to link claims data with state labor department data files [Glazner et al., 1998]. Finally, information about companies, such as employment size and prior experience modification rating (EMR), would be invaluable for such a database. Without EMR data, the question of whether prior company experience predicts injury experience on a large project with owner-managed safety infrastructure will be difficult to answer. The answer to this question has important implications for bid prequalification on projects for which owners hope to minimize preventable work-related injury and its costs.

In summary, ongoing surveillance with administrative databases established for Owner Controlled Insurance Programs could make them an important resource for project prevention activities, as well as for occupational health and safety research.

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