AMERICAN JOURNAL OF INDUSTRIAL MEDICINE 34:105–112 (1998)

Construction Injury Rates May Exceed National Estimates: Evidence From the Construction of Denver International Airport

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Background *Construction of Denver International Airport (DIA) provided a unique opportunity to describe the magnitude of injury on a major construction project for which complete data on injury and hours at risk were available for over 32,000 employees working 31 million hours.*

Methods *Comprehensive payroll data for all workers, who were paid standard Davis-Bacon wages, allowed calculation of person-hours at risk by job classification. Complete reporting, facilitated by a single workers' compensation plan covering all contracts and by an on-site medical clinic and designated provider system, allowed us to determine both total and lost-work-time (LWT) injury rates per 200,000 hours at risk by industrial sector, company size, and year of construction. Workers' compensation payment rates were calculated and compared with expected loss rates, derived by the National Council on Compensation Insurance, by sector, company size, and year.*

Results *DIA's overall total injury rates were over twice those published by the Bureau of Labor Statistics (BLS) for the construction industry for each year of DIA construction. Differences in LWT injury rates were more modest. Total injury rates were also at least twice BLS's rates for all contractor sizes. The injury rate pattern by company size at DIA differed from BLS's in that small firms had injury rates that were higher than or comparable to most other size categories; BLS's rates for small firms were lower than those for all but the very largest (250 or more employees) contractors. DIA's total workers' compensation (WC) payment rate of $7.06 per $100 payroll was only 11% higher than Colorado-specific expected loss rates reported by the National Council on Compensation Insurance.*

Discussion *Complete reporting, facilitated by the existence of a single WC plan, an on-site medical clinic, and designated medical providers, yielded injury rates significantly higher than previously reported. The relatively small difference between DIA payment rates and expected loss rates suggests that the discrepancy between DIA's injury rates and national estimates is due to underreporting of non-LWT injuries to the BLS. The burden of on-site work-related construction injury may be higher and more costly than has been evident from national data.* Am. J. Ind. Med. 34:105–112, 1998.

KEY WORDS: occupational injury; construction injury; BLS data; workers' compensation; workers' compensation payments; injury severity

INTRODUCTION

Incidence of work-related injury by industry is difficult to ascertain in the United States. We had a unique opportunity to describe the nature and magnitude of work-related injury and illness among workers who built Denver International Airport (DIA), a public works project for the City and County of Denver, which made its insurance data available to our research team. Despite a multitude of employers at DIA, all workers' compensation claims were recorded in a

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All work was performed at the National Jewish Center for Immunology and Respiratory Medicine and the University of Colorado School of Medicine

Contract grant sponsor: the National Institute for Occupational Safety and Health; Contract grant number: 5 R01 OH03254

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Accepted 25 February 1998

centralized database, along with denominator data in the form of payroll according to job classification, as is typically obtained by insurance companies. The existence of a project-wide workers' compensation insurance plan, coupled with an on-site clinic and designated medical provider system for all contractors, addressed the problems of underreporting work-related injury and illness.

Since 1972, the Annual Survey of Occupational Injuries and Illnesses of the Bureau of Labor Statistics (BLS) has generated rates of occupational injury and illness by Standard Industrial Classification (SIC) Code. The numerators for these rates are taken from Occupational Safety and Health Act (OSHA) logs, which record occupational illnesses and injuries, and from workers' compensation claim reports; denominators are based on employee hours reported to BLS by employers surveyed. Persuasive evidence exists that firms with fewer than 50 employees underreport occupational injuries to this national database [Oleinick et al., 1995]. For the construction industry in particular, BLS rates likely underestimate risk for workers on construction sites by including off-site workers, such as office staff.

Another approach to ascertaining the incidence of work-related injury and illness is to analyze workers' compensation claims. Underreporting is a problem here as well, since many work-related injuries do not result in workers' compensation claims [Klein et al., 1984; Hunting et al., 1994; Waller et al., 1989; Kisner and Fosbroke, 1994; Belville et al., 1993; Silverstein et al., 1997]. When workers' compensation claims and emergency department occupational injury surveillance data for the same population have been compared, neither dataset has been found to fully capture occupational injuries [Fingar et al., 1992]. For some conditions, such as cumulative trauma disorders, medical insurance claims have been useful in surveillance [Park et al., 1992], but a comprehensive picture of incidence would require linking both workers' compensation and medical insurance claims to the working populations at risk. Most studies examining workers' compensation claims either have relatively crude estimates of the numbers of workers at risk [Kisner and Fosbroke, 1994] or have used industry-specific employment figures from state unemployment insurance records [Culver et al., 1993; Waller et al., 1989; Fingar et al., 1992]. The health insurance industry collects employment data that may be linked with claims from their insured firms, but these data are often considered proprietary and, with rare exceptions [Tsai et al., 1989], are not used in published surveillance reports.

Historically, construction has been the most hazardous industry, as measured by total injury rate, and was only recently surpassed by manufacturing [BLS, 1995]. Recent efforts to characterize morbidity and mortality in construction workers have relied on proportionate mortality studies [Robinson et al., 1995], data from BLS's Supplementary Data System [Kisner and Fosbroke, 1994; Culver et al., 1993], workers' compensation claims linked to trade union employment records [Lipscomb et al., 1996], and emergency room surveillance of injuries among construction workers [Hunting et al., 1994; Waller et al., 1989; Zwerling et al., 1996]. The last approach is limited by difficulties in defining the populations at risk, with some studies presenting numerator data only and others attempting a population-based approach using U.S. Department of Labor employment data for the catchment area [Zwerling et al., 1996]. Emergency room data give a valuable picture of more serious injuries to construction workers but are less useful for cumulative trauma disorders, minor conditions and illnesses, and fatalities.

We report here the experience of construction workers building DIA, emphasizing injury rates and workers' compensation payment rates, with particular attention to differences according to company size, company SIC, and year of construction. We also compare the experience of these on-site construction workers at DIA with national average construction injury rates and average payment rates for Colorado.

BACKGROUND

The Denver International Airport was built between September 1989 and August 1994 with a construction budget of over $2.7 billion. In total, 2,843 individual contracts were awarded to 769 contractors (number of contracts and contractors consists of unduplicated counts, not including contracts for nominal amounts) without prequalification on the basis of prior health and safety experience. Of these, 74 contractors held 128 general construction or prime contracts and hired subcontractors when necessary. The project employed firms from all three construction industry sectors (SIC codes 15–17), representing virtually all construction trades, to complete contracts for site development, roadway and parking construction, airfield construction and paving, building of concourses and terminals, utility development, and project management.

Beginning in December 1990, the city implemented an Owner Controlled Insurance Program (OCIP) which 1) provided all workers' compensation and general liability insurance for the entire project; 2) established an on-site medical clinic and physician referral system as designated provider for all work-related injury and illness; and 3) created a project-wide safety infrastructure as part of the project's management team. At the time of identification badging, all on-site employees provided demographic information, which was entered in a project-wide database. Contractors reported monthly regular and overtime payroll by job classification, as defined by the National Council on Compensation Insurance (NCCI); these contract-specific reports were subsequently audited. These data were stored in a centralized database, as were workers' compensation

claims, generated for treatment rendered at and coordinated by the on-site clinic. If a first report of injury was not supplied for a claim, the insurance carrier requested one from the injured worker's employer before paying the claim. For some claims, no first report was submitted; therefore, no payment was made. No financial incentive or disincentive existed for medical staff to classify conditions as work-related, and the clinic provided walk-in medical care on-site for nonoccupational conditions for a modest fee.

MATERIALS AND METHODS

Cohort, Claims, and Payments

We retrospectively examined work-related injury and illness in a cohort consisting of 32,081 individual employees badged for on-site work during the construction of DIA between December 1990 and August 1994. For this group, we identified 4,634 workers' compensation claims with payment. We obtained information on the subset of 963 claims with lost-work-time (LWT) from the Colorado Division of Workers' Compensation, which records only those claims for injuries causing an employee to miss more than three scheduled work shifts or resulting in death or permanent disability.

Claims payment data were updated through March 1997, at which time 1.7% of all claims remained open. We estimated total payments for open claims by incorporating the total reserves set aside for these claims by the insurance carrier for the OCIP. We organized claim payments into three categories: medical, indemnity (wage loss, permanent disability, disfigurement, and death), and other (transportation, vocational rehabilitation, and litigation services) and adjusted them for inflation, as appropriate. For the proportion of indemnity payment determined by claimant wage, we used the annual percent change in the Colorado state average weekly wage, since this was the basis for payment for the majority of claimants receiving wage benefits. Scheduled payments for injuries resulting in permanent partial disability remained unchanged over the construction period, as did the fee schedule for medical services. We adjusted medical payments by year to account for changes in intensity of medical services using national estimates from the national health accounts (Office of the Actuary, U.S. Department of Health and Human Services, personal communication, November 9, 1995). For other workers' compensation payments, we adjusted by year using the Urban Consumer Price Index for all items in the Denver-Boulder area [BLS, 1991–1994].

Company Size and Industrial Classification

The insurance database linked contract payroll and employees with their associated companies. By linking company tax identification numbers with state unemployment insurance records, we obtained company SIC codes for 83% of DIA contractors, as well as size (average annual number of employees) for the year prior to starting work at DIA for 65% of contractors. Company size was available only for Colorado companies. The companies that could not be linked with unemployment insurance records (17% of all DIA contractors) were likely to be out-of-state companies and did not differ in terms of contract payroll size at DIA.

TABLE I. Number of Companies Working at DIA, Payroll, and Person-Hour Percentages by Standard Industrial Classification

Standard industrial classification	Number of companies	Payroll (%)	Person-hours (%)
General building (SIC 15)	35	12.9	13.8
Heavy construction (SIC 16)	72	17.3	18.2
Special trades (SIC 17)	326	49.2	45.8
Nonconstruction	207	13.5	14.9
Unknown industry	129	7.1	7.3
Total	769	100.0	100.0

Payroll and Person-Hours at Risk

We used payroll data to estimate person-hours at risk for all contracts, adjusting for overtime pay by dividing the overtime amounts by 1.5. From adjusted payroll, we estimated person-hours by dividing payroll for each trade by the prevailing Davis-Bacon wage of that trade, adopted by the City and County of Denver for paying workers on the DIA project. Using information from the Colorado Building and Construction Trades Council [1994], we defined trades as combinations of similar NCCI job classifications. Our definitions are not strictly synonymous with trade union definitions, however, because we classified laborers by type of work and could not distinguish them from other trades. We assumed that fringe benefits, specified by Davis-Bacon rates, were not included in trade wage rates, since companies with 20 or more employees accounted for 84% of the project's person-hours and were likely to offer a benefit package in lieu of paying benefits in wages (personal communication, Mary Jayne Villalobos, Denver Auditor's Office, January 2, 1997).

Not all workers at DIA were employed by construction contractors. Approximately 27% of all companies were nonconstruction firms, providing services such as engineering, architecture, product supply, and general business services; these firms, along with 129 (17%) companies with unknown SIC codes, accounted for 21% of payroll (Table I). Unless otherwise noted, the results described refer to companies and contracts with construction SIC codes (15–17) only. SIC 15, general construction, refers to general

contractors engaged in construction of buildings; SIC 16, heavy construction, refers to general contractors engaged in highway and street construction; and SIC 17, special trades, refers to contractors engaged in construction trades, e.g., electrical contractors, plumbing and heating contractors, and carpenters.

Rates

From claims and person-hours, we calculated injury rates per 200,000 hours at risk. Each claim represented one injury incident or medical condition, not an individual medical visit. One hundred full-time employees is equal to 200,000 person-hours per year. With claims as the numerator and hours at risk as the denominator, the injury rates we describe are a measure of incidence. We calculated both total and LWT injury rates by industrial sector, company size, and year of construction. The term, ''injury,'' refers to both injury and illness, since less than 10% of all workers' compensation claims were for illnesses. Confidence intervals for all injury rates were calculated assuming a Poisson distribution for number of claims [Haenszel et al., 1962]. The denominator we used for calculating rates is comparable to that used by the BLS, which surveys employers, who report the number of hours their employees work. From the reported hours, BLS calculates the number of full-time employees, which becomes the denominator for its published injury rates (personal communication, Robert Walker, statistician, Bureau of Labor Statistics, June, 1996).

We calculated workers' compensation payment rates per $100 of payroll according to three strata: industrial sector, company size, and construction year. To compare actual stratum-specific payment rates with statewide expected rates, we used Colorado-specific expected loss rates (ELR) derived by NCCI for 1992 [1995]. ELRs represent average workers' compensation claim payments per $100 of payroll among workers with the same job classification across industries. We were able to calculate a weighted average of ELRs for each stratum of interest, weighting by the proportion of payroll accounted for by each job classification. To make payment rates and calculated ELRs comparable, we adjusted payments and payroll to 1992 dollars, capped individual payments at $126,000 (the limit used by NCCI) and included only medical and indemnity payments (the payments included by NCCI). Expected loss rates are a useful standard against which to measure payment, since they approximate prevailing risk for each job.

RESULTS

Injury Rates for All Industries

The total injury rate for the DIA project, including both construction and nonconstruction SIC codes, was 29.8 injuries per 200,000 person-hours at risk. Total injury rates declined over the project period, from 36.1 injuries per 200,000 person-hours in 1991 to 22.4 in 1994. We identified 963 LWT claims through the Colorado Division of Workers' Compensation, resulting in an LWT rate of 6.2 injuries per 200,000 person-hours for all DIA workers. The LWT rate declined from 11.4 injuries per 200,000 in 1991 to 3.7 in 1994.

Injury Rates for the Construction Industry

The total injury rate for DIA construction companies (SIC 15–17) *alone* was higher than for all industries combined: 32.7 per 200,000 person-hours, declining from 37.3 in 1991 to 27.7 in 1994. For contracts with construction SIC codes, there were 826 LWT claims, resulting in an LWT injury rate of 6.8 for all years, declining from 11.6 in 1991 to 4.4 in 1994. The following narrative and Tables II and III focus only on these construction contractors.

Total injury rates for DIA workers in the construction industry were significantly higher than those reported by the BLS for the construction industry during the same years. While rates decreased over time in both cases, DIA's total injury rates were at least 2.3 times those published by the BLS throughout the period. There were also significant differences between DIA's LWT rates and BLS's, although these differences were more modest; in the case of 1994 injury rates, no significant difference was found (Table II).

Differences between the DIA and BLS datasets persist when injury rates by SIC code are examined, but the order of rates by industrial classification was the same for the DIA as for the BLS data, with special trades contractors (SIC 17) showing the highest total and LWT injury rates in both databases (Table II).

DIA's injury rates by company size revealed a pattern different from that published by the BLS. While DIA's total injury rates for every company size class were at least double BLS's rates, the greatest rate difference was observed for very small companies (1–19 employees): DIA's rate for this category was over three times BLS's rate. BLS's injury rate for the smallest firms was considerably lower than its rates for larger companies (20–249 employees), while DIA's total injury rate for small firms was higher than its rates for firms with 100 or more employees, about the same as its rate for firms with 50–99 employees and lower than only one other category—firms with 20–49 employees. DIA's LWT injury rates were significantly higher than BLS's, except in the case of companies with 50–99 employees.

Payment Rates

Of the total 4,634 DIA workers' compensation claims, 3,955 were made by workers in companies classified in SIC 15–17. Of these, indemnity payments were made for 974: 826 for lost work time; 420 for permanent disabilities,

TABLE II. Injury Rates per 200,000 Person-Hours for the Construction Industry, DIA, and BLS,[a] According to Year, Standard Industrial Classification, and Company Size

	Number of injuries	DIA total injury rate	95% CI	BLS total injury rate	DIA LWT injury rate	95% CI	BLS LWT injury rate
Year of construction							
1991	575	37.3[b]	34.4, 40.5	13.0	11.6[b]	9.9, 13.4	6.1
1992	1,135	32.9[b]	31.1, 34.9	13.1	7.2[b]	6.4, 8.2	5.3
1993	1,997	32.2[b]	30.8, 33.7	12.2	5.8[b]	5.2, 6.4	4.9
1994	244	27.7[b]	24.4, 31.5	11.8	4.4	3.2, 6.1	4.9
SIC code							
15—General construction	628	29.2[b]	27.0, 31.6	11.3	6.7[b]	5.6, 7.9	4.5
16—Heavy construction	723	25.6[b]	23.8, 27.5	10.9	6.6[b]	5.7, 7.7	4.3
17—Special trades	2,604	36.6[b]	35.2, 38.0	12.6	7.0[b]	6.4, 7.6	5.1
Company size							
1–19 Employees	430	32.7[b]	29.7, 36.0	9.7	5.8[b]	4.6, 7.3	4.4
20–49	727	35.7[b]	33.2, 38.4	14.4	8.0[b]	6.8, 9.4	5.6
50–99	493	33.8[b]	30.9, 36.9	15.0	6.5	5.3, 8.0	5.6
100–249	1,192	30.0[b]	28.3, 31.7	13.6	6.6[b]	5.9, 7.5	5.0
250–499	343	27.1	24.4, 30.2	NA	3.2	2.4, 4.4	NA

[a]Sources for BLS rates: U.S. Department of Labor, Bureau of Labor Statistics, 1992, 1993, 1994, and BLS News, December 15, 1995.
[b]Rate significantly different from BLS rate ($P < 0.05$).

TABLE III. Workers' Compensation Adjusted Payment Rates for Construction Contractors at DIA and Expected Loss Rates by Standard Industrial Classification, Year, and Company Size ($1992)

	Total claims	
	DIA payment rate	Expected loss rate
Industry	Per $100 payroll	Per $100 payroll
General building (SIC 15)	$ 8.77	$7.29
Heavy construction (SIC 16)	8.13	6.33
Special trades (SIC 17)	6.22	6.12
All construction (SIC 15–17)	7.06	6.35
Year		
1991	$16.07	$7.90
1992	6.96	7.07
1993	5.26	5.89
1994	5.06	4.99
Total	7.06	6.35
Company size		
1–19 employees	$ 6.14	$7.92
20–49	8.73	6.38
50–99	5.01	6.00
100–249	7.45	6.28
250–499	4.26	4.46
Total	7.06	6.35

including ten for permanent total disabilities; and two for fatalities. (While there were three fatalities on the DIA project, only two were associated with firms with construction SIC codes.) Indemnity payments for both LWT and disabilities could have been made on the same claim. The total number of claims with indemnity payments included 38 that could not be categorized regarding LWT based on information available. The mean payment for all claims made by construction workers (SIC 15–17) was $9,526/claim; the median payment was $317; payments were less than $68 for 10% of all claims. For LWT claims, the mean was $40,359, and the median was $14,127. LWT claims accounted for 88% of all workers' compensation payments for construction workers.

For all construction SIC codes, the payment rates were higher than expected loss rates (Table III). As was the case with injury rates, payment rates declined over time, as did ELRs, reflecting diminished risk of the work being performed. For only two company size categories were payment rates higher than expected loss rates: firms with 20–49 employees and those with 100–249 employees. In the case of 20–49-employee firms, the difference was sizable.

DISCUSSION

The incidence of work-related injury and illness for on-site workers building the DIA far exceeded the BLS's estimates for the construction industry (SIC 15–17). There are several possible explanations for this: 1) the injury rate at the DIA site was much higher than on construction sites nationally; 2) the DIA experience is representative of construction sites nationally, but underreporting of injury rates to the BLS survey results in sizable underestimates of

total construction injuries; or 3) the DIA experience is representative of construction sites nationally, but the inclusion of off-site workers in the BLS survey lowers national injury rates substantially.

We think it unlikely that the injury rate at the DIA site was substantially higher than in construction nationally. While DIA was an exceptionally large project, no component was unusual; the work performed was typical of other projects in the various project domains (e.g., site development, roadway construction, building construction). The overall project was unusual only in the number of contracts involved, and therefore engineering complexities associated with connecting structures built by different companies (personal communication, Stacy Pocrass, Construction Risk Manager for DIA, July, 1997). Moreover, the project's safety management team required written safety plans and job hazard analyses of prime contractors, oversaw contractor compliance with safety rules and regulations, collected attendance logs of required weekly ''tool box'' safety meetings, investigated incidents and accidents, and administered on-site safety programs, such as drug and alcohol testing and incentive awards. Project management's commitment to safety increased substantially in late 1991, resulting in a several-fold increase in safety personnel at the project management level (from 5 to 41 employees) in early 1992. It seems unlikely that this safety infrastructure, often lacking in construction projects, would be accompanied by injury rates more than twice the national average. The decline in both total injury rates and LWT injury rates at DIA after 1991, while payroll more than doubled during 1992 and nearly doubled again in 1993, argues for the effectiveness of this enhanced safety infrastructure.

A likely explanation for the discrepancy between DIA injury rates and BLS rates is that the latter do not reflect the true incidence of construction work-site injury and illness. We found that DIA's LWT injury rates are more comparable to those reported by the BLS from its annual survey than are total injury rates, suggesting that the apparent excess in injury rates at DIA was largely in the category of injuries without LWT compensation. Moreover, both the overall payment rate and the distribution of payments suggest that many DIA claims were likely related to minor injuries, including first-aid injuries. First-aid injuries are specifically excluded from reporting requirements on OSHA 200 logs, which are one basis of reporting to BLS's Annual Survey [BLS, 1995b]. While they were also not reportable at the DIA, the definition of first-aid injuries at DIA may have been narrower than that of OSHA and the BLS. Other instructions in the BLS survey (''we are providing employers the option of either completing the forms we have provided or of submitting copies of documents that typically exist in establishments'' [BLS, 1986]) imply that minor injuries, the care for which has been paid for by the employer or employee with no workers' compensation claim filed, need not be reported. This could be a common occurrence among both larger, self-insured firms and smaller firms anxious to avoid a compensation claim that could affect future premiums. In contrast, at the DIA, claims were generated whenever medical treatment was rendered, even for minor injuries.

Oleinick et al. [1995] concluded that the BLS report of substantially lower injury rates in small construction firms (<25 employees) than in mid-sized firms (50–499) was likely attributable to underreporting. They presented BLS data for all injuries in the construction industry nationally, which showed that companies with fewer than 25 workers reported less than half the injury rate of companies with 50 or more workers. DIA injury rate data by company size contrast with BLS data in that the injury rates for the smallest firms are not the lowest and the range of injury rates by company size is modest. Furthermore, Colorado construction companies with employment of fewer than 50 prior to DIA experienced significantly higher total injury rates (34.5 per 200,000 person-hours) than did larger companies (30.2), consonant with the increased risk of their work, as reflected in their expected loss rates. Thus, our data support the contention that small firms underreport injuries to the BLS Annual Survey. Also consistent with the conclusions of Oleinick et al. for the construction industry, we found that LWT injury rates showed only a modest employment size effect, with the smallest firms (1–19 employees) having rates that were not significantly different from those of mid-sized firms (50–249 employees).

If the difference between DIA's injury rates and BLS's is largely attributable to underreporting to the BLS survey, as we believe, it is likely that construction firms make fewer workers' compensation claims than are justified. Companies may simply pay for medical treatment and file no claim. Furthermore, medical claims for work-related injuries, which should be paid by workers' compensation insurance, may be made to and paid by health insurance carriers. This could happen for any number of reasons, including physician or worker unfamiliarity with workers' compensation or a wish on the part of the worker or the firm to avoid workers' compensation claims. Workers' compensation premiums are usually calculated individually for each firm, while health insurance premiums, for all but the largest firms, are calculated by pooling the experience of many like-sized firms. Thus, if costs were shifted from workers' compensation to health insurance, a firm's workers' compensation premium could be kept artificially low without an offsetting rise in health insurance premiums, because those premiums would be subsidized by companies sharing the firm's health insurance pool. It may not be feasible to correct underreporting to BLS occurring as a result of cost shifting to health insurance from workers' compensation.

When a company underreports work-related injury, its workers' compensation experience will not reflect its actual injury experience. In such cases, construction project manag-

ers and prime contractors that base subcontracting decisions on experience modification ratings, which in turn are based on workers' compensation claims data, will make decisions using erroneous information. Furthermore, if firms do not identify all work-related injuries, they will not correctly assess the magnitude and cost of work-related injury and may not target internal safety resources appropriately. The payment rates described here include only direct costs of injury. If indirect costs, which include lost productivity, disrupted work schedules, administrative time for investigations and reports, training replacement personnel, cleanup and repair or replacement of equipment or property, adverse publicity, and third-party liability claims against the contractor, were included, total costs would increase dramatically. Ratios of indirect to direct costs in construction range from 1.6:1 [Levitt et al., 1981] for all claims to 4.2:1 for medical-only claims and 20.3:1 for LWT claims [Hinze and Applegate, 1991]. National resources, too, might be misdirected if true construction industry injury rates are closer to DIA's rates than BLS's rates, since construction could once again replace manufacturing as the riskiest industry, assuming that underreporting does not occur equally across industries. This assumption is likely to be correct for several reasons: 1) the construction industry includes many small firms relative to other industries, and most evidence points to small firms as those most likely to underreport [Oleinick et al., 1995]; 2) the construction industry, made up almost entirely of firms that must compete with others to work on projects, has a strong incentive to underreport because of the use of experience modification ratings (based on workers' compensation claims) in the bidding process [Levitt and Samelson, 1993]; and 3) construction is one of the riskiest industries, with concomitantly high workers' compensation premiums and, therefore, an economic disincentive to make claims.

Apart from reporting, we would expect DIA's injury rates to be slightly higher than BLS-reported rates because only on-site workers were enrolled in its OCIP. In contrast, BLS staff survey companies and calculate company-wide rates by SIC codes. Even with identical injury experience of on-site construction workers, DIA rates would be higher than BLS rates on the basis of BLS's inclusion of lower-risk off-site workers in the denominator. For instance, in Colorado in 1993, clerical workers accounted for 9.7% of the construction work force. At DIA, clerical workers accounted for only 5% of the work force, suggesting that about half of the clerks employed by construction firms worked off-site [CDLE, 1994]. The small excess of LWT injury rates at DIA, in comparison with BLS rates, might be expected to be largely attributable to this difference in at-risk populations. Counterbalancing this effect, however, is the BLS survey's definition of LWT time as greater than one day, in contrast to Colorado's workers' compensation definition of four or more lost work shifts. The proportion of LWT injuries reported to BLS with fewer than three lost days in both 1992 and 1993 was 27% [BLS, 1995b,c]. This suggests that the DIA's rates should have been substantially lower than the BLS's.

For DIA construction, the overall workers' compensation adjusted payment rate per $100 of payroll was 11% higher than would have been expected based on the overall ELR, calculated using Colorado-specific ELRs by job classification. Because NCCI's rates (the basis for our calculated ELRs) are based on workers' compensation claims, they are limited by any tendency of companies or employees to not file workers' compensation claims for work-related conditions. We believe that higher overall workers' compensation payment rates per $100 of payroll for DIA construction are largely explained by the more complete reporting of work-related injury and illness among DIA construction workers that resulted from the medical, safety, and reporting infrastructures at this project. The increase in payment rate is roughly comparable to the cost of the excess incidence (over BLS rates) in non-work-loss claims, based on average payments for such claims recorded in the DIA database. It is worth noting, however, that the only year in which the adjusted payment rate exceeded the ELR by more than 1.5% was 1991, when DIA's expanded safety infrastructure was not yet fully in operation. These two pieces of evidence suggest that, in addition to more complete reporting of minor injuries, other factors, such as superior claims management and perhaps less severe than average LWT injuries, may be reflected in the overall payment rate. While the large discrepancy between DIA's total injury rates and BLS's appears to have had a relatively small effect on payment rates, the reader should not underestimate the need for reporting minor injuries, since we found that minor injuries are associated with major injuries on the same contract [Lowery et al., 1998]. We are unaware of publicly available sources of payment data for workers' compensation claims in the construction industry with which to compare the DIA payment experience. Such data would be of interest in substantiating our surmise that DIA medical and indemnity payments were not higher than usual payments for work-loss claims for the construction industry.

In summary, the DIA experience gives the best estimate available to date of the burden of on-site work-related injury and illness in construction workers. This burden is substantially higher and more costly than has been evident from data published by the BLS, from the NCCI data, or from the more limited estimates generated by emergency room surveillance studies [Waller et al., 1989; Fingar et al., 1992; Hunting et al., 1994; Zwerling et al., 1996]. Construction worker morbidity has been difficult to study because of the multiplicity of small employers who are present on construction sites for variable and often short periods of time. Denver's OCIP enabled us to aggregate workers' compensation experience over hundreds of contractors on-site with a centralized

database, to obtain payroll denominator data and to control for comparable medical care delivery for the largest construction project in the world at that time. Other OCIPs or ''wrap-ups'' for large construction projects could likewise support such analyses, as long as three crucial elements were in place: 1) a centralized workers' compensation administrative database, 2) on-site designated providers of medical care, and 3) diligent follow-up by the workers' compensation broker to generate claims whenever treatment was rendered. Replication of the current study at a different site would advance understanding of the burden of construction site injury.

ACKNOWLEDGMENTS

The authors are grateful to Sue Christensen and Ruth Kaslow of the DIA Risk Manager's office, and James Delong, DIA Manager, of the City and County of Denver, for providing the administrative data. As DIA construction risk manager from 1990–93, Stacy Pocrass provided invaluable counsel from project conception through data analysis. We also thank Skip Guarini, former DIA field safety manager, and Dennis C. Lezotte and William M. Marine of the University of Colorado for helpful comments on earlier drafts.

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