Analysis of Construction Injury Burden by Type of Work

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Background *To lay groundwork for identifying patterns of injury etiology, we sought to describe injury experience associated with types of work performed at construction sites by examining workers' compensation (WC) claims for the 32,081 construction workers who built Denver International Airport (DIA).*

Methods *Injury rates and WC payment rates were calculated for 25 types of work based on claims and payroll data reported to DIA's owner-controlled insurance program according to National Council on Compensation Insurance job classifications. By linking DIA claims with corresponding lost-work-time (LWT) claims filed with Colorado's Workers' Compensation Division, we were also able to obtain and examine both total and median lost days for each type of work.*

Results *Injury experience varied widely among the types of construction work. Workers building elevators and conduits and installing glass, metal, or steel were at particularly high risk of both LWT and non-LWT injury. Median days lost by injured workers was highest (202 days) for driving/trucking. Median days lost for most types of work was much greater than previously reported for construction: 40 days or more for 18 of the 25 types of work analyzed. WC payment rates reflect both number and severity of injuries and were generally not significantly different from expected losses. They were, however, significantly higher than expected for driving/trucking, metal/steel installation, inspection/analysis, and elevator construction.*

Conclusion *Analysis of injury data by type of work allows targeting of safety resources to high risk construction work and would be useful in prospective surveillance at large construction sites with centrally administered workers' compensation plans.* Am. J. Ind. Med. 37:390–399, 2000. *© 2000 Wiley-Liss, Inc.*

KEY WORDS: occupational injury; construction injury; workers' compensation; type of work; trades

INTRODUCTION

Workers on construction sites face multiple and varied threats to safety. That risk of injury varies within the construction industry has also been demonstrated. For instance, previous analyses have shown that risk of injury is higher for workers in certain construction domains, such as building construction and site development, than in others, such as roadway construction [Lowery et al., 1998]. Risk has also been found to be higher for special trades

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contractors than for other types of contractors [BLS (Bureau of Labor Statistics), 1995a; Glazner et al., 1998]. Other analyses have shown differences in the proportionate distribution of injuries among trades [Helander, 1991; Hunting et al., in press] and by phase and type of construction [OSHA, 1992b; Construction Safety Association of Ontario, 1995].

While such studies establish the variation in risk of injury among trades, types of contractors and broad construction domains, they are limited in their ability to detect the specific types of work activities associated with injury, information necessary for allocating safety resources and preventing injury. Even studies focusing on a single trade may not accomplish this, insofar as members of that trade are involved in a variety of work activities. Understanding the risk of injury associated with specific types of work, such as iron and steel erection or glass installation, would permit development of safety strategies specific to these activities. Moreover, identifying the types of work associated with high injury rates or particularly severe injuries on construction sites would allow owners, contractors, and safety professionals to direct their safety efforts toward the specific activities presenting particularly high risk.

To describe the injury experience associated with types of work commonly performed at construction sites and to identify particularly hazardous types of work, we examined workers' compensation claims linked with payroll data for the 32,081 construction workers who built Denver International Airport (DIA). This database allowed comparison of injury rates and payment rates among many types of construction work with identical claims management and a designated provider system [Glazner et al., 1998; Lowery et al., 1998].

METHODS

Claims and Payroll

Workers' compensation claims and payroll for the construction of Denver International Airport, which took place between 1990 and 1994, were captured in an administrative database developed under the project's Owner-Controlled Insurance Program. Insurance claims adjusters stationed on site generated claims for all work-related injuries and illnesses, which were treated at the on-site medical clinic. We identified lost-work-time (LWT) claims by using Colorado's definition, injuries resulting in more than three days' absence from work, and obtained information on them from the Colorado Division of Workers' Compensation. For this analysis, claims for work-related illness (less than 10% of all claims) were included as "injuries".

Claims and payroll data were recorded for each of the 2,843 individual contracts completed at DIA and were reported according to job classifications established by the National Council on Compensation Insurance (NCCI). Job classifications define very specific types of work, rather than types of workers or trades, thereby grouping workers into risk categories for the purpose of determining workers' compensation insurance premiums. For example, job classification '5059' is assigned to workers who erect iron and steel frame structures two stories or less in height, whereas job classification '5040' applies to iron workers building frame structures of more than two stories [NCCI, 1995b]. We adjusted payroll for overtime by dividing overtime pay by 1.5. From the adjusted payroll, we estimated person-hours at risk by dividing payroll for each job classification by the prevailing Davis-Bacon wage (required for all project workers) for that job class. We adjusted claims payments for inflation and standardized them to 1992 U.S. dollars [Glazner et al., 1998].

Type-of-Work Classification

We categorized NCCI job classifications in DIA's administrative database into 'types of work' (Appendix 1). In many cases, a particular type of work was defined by a single job classification, e.g., 5183, plumbing. For other types of work, we grouped several job classifications denoting similar tasks, e.g., for carpentry, we combined 5020, acoustical ceiling installation; 5146, furniture/fixture installation; 5437, cabinet installation, 5443, lathing; 5445, wallboard installation; and 5403, carpentry, NOC (not otherwise classified).

We categorized both injuries and payroll by contract into 25 type-of-work categories. For most contracts (90%), payroll was reported for the types of work for which injuries were recorded. For 273 contracts, however, we found injuries grouped under types of work for which there was no reported payroll. For example, we found claims recorded under "carpentry work" for a contract for which the entire payroll was reported under "concrete construction". At DIA, as with other construction projects, contractors often combine payroll for workers in different job classifications into a single category describing the majority of the work performed. Although the contract cited above employed carpenters, the type of work performed on the contract, and consequently reported on the payroll, was "concrete construction", the prevailing type of work. In reviewing individual injury reports for the claims made by carpenters on this contract, we verified that these carpenters were indeed performing tasks associated with concrete construction, such as setting and stripping forms.

For the 273 contracts with discrepancies between reported claims and payroll, we reclassified injuries that did not correspond to payroll by type of work into the prevailing type of work for the contract. For 76% (208) of these contracts, identification of the prevailing type of work was straightforward, since all payroll was recorded under a single type of work. To validate this approach, we chose 20 (10%) of the contracts with a single type of work recorded for payroll that we reclassified by using this method and examined individual injury reports for all injuries on those contracts. Specifically, we reviewed the worker's occupation listed on the report, the task the worker was performing at the time of injury and the description of the injury event. We found that we had correctly reclassified these claims.

For the 65 contracts that reported payroll under multiple types of work, however, reclassifying injuries was more involved. When two or more predominant types of work were listed for a contract, we used the guidance of NCCI's Scopes of Basic Manual Classifications [NCCI, 1995b] and of the former construction risk manager for the DIA project to identify which types of work for the contract best corresponded with the type of work associated with the injury. For example, on a contract with payroll reported under both street/road construction and pipefitting, we reclassified injuries reported under ''driving/trucking'' into ''street/road construction'' which we determined to be the ''most probable'' type of work performed by a driver on this contract. For the 24 contracts and 61 injuries for which we could not identify the most probable type of work by using this method, we examined written injury reports. After this examination, there remained only 15 claims among eight contracts that we could not confidently reclassify into type-of-work categories. We excluded all 131 claims and 1,028,147 person-hours for these eight contracts from our analyses.

Lost Work Days

Of the 4,363 claims included in our analyses, 909 claims were made for LWT. To determine the number of work-days lost due to injuries, we linked DIA claims with corresponding LWT claims filed with the Colorado Division of Workers' Compensation and summed the number of whole days a worker received temporary total disability and/or temporary partial disability benefits. We assumed that most workers at DIA worked a five-day week and, therefore, excluded weekend days from our estimates. We converted the number of days a worker was paid temporary partial disability benefits (which serves to offset lost wages due to shortened or modified work schedules) into whole days by dividing the total payment by the average daily wage paid for temporary total disability. We used the sum of this figure and the number of days of temporary total disability to compute both the median and the range of lost work-days by type of work. There were three deaths and ten injuries that resulted in permanent total disability at DIA. We excluded these 13 injuries when computing median and mean days lost, but they are included in the LWT injury rates presented.

Claims Payments

Payments were available for all claims and were categorized into medical, indemnity and ''other'' payments. Claims payment data reported in this analysis comprise medical and indemnity payments and have been adjusted to 1992 U.S. dollars. We excluded ''other'' payments, which accounted for 3% of total payments and consisted of payments for emergency transportation, vocational rehabilitation and litigation services. Payment information was updated in March 1997, at which time approximately 2% of claims remained open. We used insurance reserves set aside to pay open claims as a proxy for payments on those claims.

Injury and Payment Rates

From claims and person-hours, we calculated LWT and non-LWT injury rates as the number of workers' compensation claims per 200,000 person-hours at risk. In addition, we calculated payment rates according to type of work as the workers' compensation payment per $100 payroll. In order to make DIA payment rates comparable to expected loss rates (described below), with which we sought to compare them, we capped payments at $126,000, as NCCI does when it calculates expected loss rates.

Expected Loss Rates

In order to assess safety performance at DIA, we compared workers' compensation payment rates for DIA claims with average payment rates for similar types of work in Colorado by using 1992 Colorado-specific expected loss rates (ELR) obtained from the National Council on Compensation Insurance [NCCI, 1995a]. ELRs are a measure of prevailing risk in that they reflect average workers' compensation payments for particular job classifications across industries. ELRs are computed by NCCI from claims and payroll data submitted by insurance carriers and are used by carriers in setting workers' compensation insurance premiums across all industries. We calculated an ELR for each type of work at DIA by using a weighted average of NCCI's ELRs, weighting by the proportion of payroll for each job classification included in the type of work.

Statistical Analysis

We tested each type of work for a statistical difference between the DIA payment rate and the corresponding ELR by using a one-sample chi-square goodness-of-fit test in which the observed value was the DIA rate and the expected value was the ELR. Both DIA's payment rates and ELRs are reported per $100 of payroll. It is important to note that the statistical significance of the test statistic is dependent on the size of payroll to which the rate is standardized. For example, a statistically nonsignificant difference in payment rates per $100 payroll ($4.72 vs. $3.39) becomes a significant difference in payment rates per $1,000 payroll ($47.20 vs. $33.90). While the standardization of payment rates to $100 payroll is somewhat arbitrary, the insurance industry reports workers' compensation experience in this manner. Therefore, we performed our tests at the same level (rates per $100 payroll), and the results of our statistical tests reflect differences at this level. Two-sided tests were conducted at the 0.05 significance level.

RESULTS

Injury Rates

Disaggregation of the DIA project's injury data according to type of work revealed wide differences in injury experience for 25 principal types of work (Table I). Among all types of construction work performed at DIA, the LWT injury rate varied from 0.6 per 200,000 person-hours for construction supervision to 12.2 per 200,000 for elevator construction, a 20-fold difference. The non-LWT injury rate varied somewhat less: from 4.1 per 200,000 person-hours to 46.9, an 11-fold difference. LWT injury rates were correlated with non-LWT injury rates among types of

TABLE I. Lost-Work-Time (LWT) and Non-LWT Injury Rates per 200,000 Person-Hours by Type of Work, Denver International Airport Construction Workers, Colorado

Type of work	Person-hours	Total number of injuries[a]	LWT injury rate	Non-LWT injury rate
1. Elevator construction	229,875	56	12.2	33.9
2. Metal/steel installation	439,656	130	11.8	46.9
3. Conduit construction	463,691	117	11.2	39.3
4. Glass installation	436,520	102	11.0	35.7
5. Concrete construction—general	3,258,738	664	10.7	29.5
6. Carpentry	1,227,122	243	10.1	29.3
7. Roofing	120,689	22	9.9	24.9
8. Masonry	702,281	116	8.8	23.6
9. Driving/trucking	181,634	20	8.8	13.2
10. Street/road construction	5,222,795	728	8.2	19.3
11. Iron/steel erection $>$ 2 stories	837,219	199	7.9	39.4
12. Inspection/analysis	585,755	84	7.5	20.5
13. Heavy equipment installation	1,669,210	321	6.4	32.1
DIA Overall[b]	30,198,487	4,490	6.2	23.6
14. Painting	341,505	35	5.9	14.6
15. Plumbing	1,785,070	344	5.6	32.9
16. Concrete work—plastering/finishing	37,484	6	5.3	26.7
17. Insulation work	156,642	13	5.1	11.5
BLS 1993—construction industry[c]			4.9	7.3
18. Pipefitting	829,460	87	4.8	16.2
19. Electrical wiring—buildings	3,800,022	744	4.2	34.4
20. Sheet metal work	643,827	94	4.0	25.2
21. Iron/steel erection $\leq$ 2 stories	122,297	24	3.3	36.0
22. Pile driving/drilling	74,948	7	2.7	16.0
23. Concrete construction—bridges/culverts	247,998	20	2.4	12.9
24. Electrical—low voltage specialty	337,620	10	1.8	4.1
25. Construction supervision	2,833,998	116	0.6	7.6

[a]The total number of injuries includes 40 claims for which lost-work-time status was unknown. These 40 claims are not included in either the LWT or non-LWT injury rates.
[b]The overall rate includes claims ($N = 127$) and payroll for clerical work; other and non-specified work not shown in the table.
[c]Bureau of Labor Statistics, Survey of occupational injury and illness, 1993 (1995). Washington DC: U.S. Department of Labor.

work (Spearman Rank Correlation coefficient r = 0.59, $P < 0.01$).

Injury rates for most types of work were higher than those reported for the construction industry (Standard Industrial Classifications 15–17) for 1993 [BLS, 1995a]: for 17 types of work, LWT injury rates were higher, and for nearly all types of work, non-LWT injury rates were higher. For several types of work, most notably elevator construction, metal/steel installation, conduit construction, glass installation, general concrete construction, and carpentry, LWT injury rates were more than twice the rate reported by BLS.

Lost Work Days

Inspection of data for number of days lost because of injuries at DIA revealed not only a much higher overall median number of days lost per injury than was reported by BLS [1995b], but also a large range of medians among types of work (Table II).

Every type of work exhibited higher median days lost than was reported by BLS for the construction industry. Even after making BLS's figure more comparable to DIA data (DIA's figures reflect Colorado's lost-work-time definition

TABLE II. Median Number and Interquartile Range[a] of Days Lost to Injury by Type of Work, Denver International Airport Construction Workers, Colorado

Type of work	Total LWT injuries	LWT injuries as a percent of total injuries	Median number of days lost	Interquartile range of days lost
1. Driving/trucking	8	40%	202	27–314
2. Electrical work—low voltage	3	30	98	NA
3. Pile driving/drilling	1	14	97	NA
4. Concrete construction—general	174	26	91	30–178
5. Roofing	6	27	90	14–208
6. Concrete work—plastering/finishing	1	6	86	NA
7. Glass installation	24	24	75	22–111
8. Metal/steel installation	26	20	69	21–112
9. Electrical wiring—buildings	79	11	66	16–205
10. Heavy equipment installation	52	16	61	20–133
11. Painting	9	26	60	14–125
12. Iron/steel erection $\leq$ 2 stories	2	10	58	NA
DIA Overall	909	21	52	17–140
13. Iron/steel erection $>$ 2 stories	32	16	50	21–165
14. Masonry	31	27	49	30–111
15. Carpentry	62	26	48	15–105
16. Street/road construction	208	29	47	16–152
17. Elevator construction	14	25	46	14–218
18. Conduit construction	26	22	40	18–63
19. Inspection/analysis	22	26	39	15–167
20. Sheet metal work	13	14	35	22–66
21. Pipefitting	19	22	30	8–104
22. Plumbing	50	15	27	15–80
23. Insulation work	4	31	24	5–71
24. Construction supervision	8	7	20	12–178
25. Concrete construction—bridges/culverts	3	15	15	NA
BLS Construction 1993[b]	204,800	ND	7	ND
BLS Recalculated[c]	149,709	NA	31 or more[c]	NA

[a]The interquartile range is the 25th percentile and the 75th percentile value of the distribution.
[b]Bureau of Labor Statistics, Work injuries and illnesses by selected characteristics, 1993. (1995). Washington D.C.: U.S. Department of Labor.
[c]BLS estimates were recalculated from BLS data, excluding data for one or two days of lost work from the distribution. Since BLS groups days for all injuries resulting in more than 31 days lost into a single category, our best estimate is that the recalculated BLS median is at least 31 days.
NA = range not appropriate; too few injuries.
ND = no data available.

of more than three shifts of work lost) by recalculating the reported BLS median for construction to eliminate the one- and two-day injuries, median days lost for most types of work remained higher than BLS's.

Since the BLS report combines 3, 4, and 5 lost work-days into one category, we were unable to isolate and exclude those cases involving three lost work-days. Similarly, the BLS groups injuries with 31 or more lost days into a single category, so we were able to conclude only that the recalculated median falls into the category of 31 days or more. The data indicated that the recalculated median falls near the lower end of this category, suggesting that it is lower than the overall DIA figure.

The types of work exhibiting the most striking (and stable) differences from the BLS number were driving/trucking, general concrete construction, and roofing. The median days lost for these types of work ranged from three to six times of BLS's recalculated median. (Median days lost for both low-voltage electrical work and pile driving/drilling were also quite high, but these categories accounted for very few injuries, resulting in medians that may not be meaningful.)

The median number of days lost for DIA as a whole was 52 days, representing medians ranging from 15 (concrete construction, bridges/culverts) to 202 (driving/trucking) for different types of work—a 13-fold difference.

Payment Rates

While DIA's overall workers' compensation payment rate was higher than its overall ELR, payment rates for specific types of work were most often lower than the corresponding ELRs (Table III). For only 10 of 25 types of work was the payment rate higher than the ELR, and, of those, only four were significantly higher. The types of work with the highest payment rates were driving/trucking, with a payment rate nearly three times its ELR, and roofing, with a payment rate nearly identical to its ELR. Of the 15 types of work with payment rates lower than their ELRs, only four had significantly lower payment rates. Payment rates were not correlated with ELRs (Spearman Rank Correlation coefficient $r = 0.02$, $P = 0.93$).

Significantly lower-than-expected payment rates were observed for several types of work expected to be hazardous, such as iron/steel erection (≤ 2 stories), concrete construction (bridges and culverts and plastering and finishing), and insulation work, indicating good safety performance at DIA. The opposite was true for several less dangerous types of work (as measured by ELRs); that is, safety performance at DIA was poor compared with similar work performed across all industries in Colorado. For instance, the highest payment rate at DIA was for driving/trucking, for which the ELR was relatively low. Payment rates were also significantly higher than expected for inspection/analysis, elevator construction and metal/steel installation. In general, payment rates for LWT injuries accounted for more than 85% of the total payment rate for each type of work. Exceptions were metal/steel installation, iron/steel erection of all types, electrical wiring in buildings, sheet metal work, concrete construction of bridges/culverts, and construction supervision.

DISCUSSION

Understanding the distribution of the burden of injury among workers performing different types of work requires examining several measures, because no single indicator captures all of the dimensions of injury burden. Injury rates encompass the experience of all workers, injured and uninjured alike, while median days lost describes the experience of injured workers only. In our data, LWT injury rates and median days lost for the 25 types of work we analyzed were not correlated (Spearman Rank Correlation coefficient: $r = 0.21$, $P = 0.30$), indicating that these statistics are indeed measuring different attributes. Payment rates may be influenced by both the rate of injury and median work days lost. In the DIA data, payment rate rankings for the 25 types of work we analyzed were strongly correlated with those of LWT injury rates, ($r = 0.86$, $P = 0.0001$) but only weakly correlated with those of lost work days ($r = 0.37$, $P = 0.08$).

Injury Rates

While high injury rates have motivated increased research attention to the construction industry, analyses of injury data by type of work allow one to focus on particularly high-risk activities within the industry. The DIA experience supports further pursuit of patterns of injury etiology in at least six types of work whose LWT injury rates were more than twice as high as the rate reported for the construction industry for 1993 [BLS, 1995a] and were the highest for all types of work performed at DIA; these were elevator construction, metal/steel installation, conduit construction, glass installation, general concrete construction, and carpentry. We believe that the excess risk for these types of work, in comparison with other types of work performed at DIA, is not likely to have been site-specific, because no component of the project was unusual. The project was unusual only in its size, the number of contracts involved, and engineering complexities associated with connecting a number of different structures [Glazner et al., 1998].

Lost Work Days

Injury burden is most dramatically conveyed by median days lost to injury. This measure dictates increased attention to concrete construction, with median days lost totaling 18

TABLE III. Payment Rate, Expected Loss Rate, Median and Interquartile Range[a] of Claims Payment by Type of Work, Denver International Airport Construction Workers, Colorado

Type of work	Payment rate[b] (per $100 payroll)	Expected loss rate (per $100 payroll)	Median claim payment[c] ($)	Interquartile range of claim payment ($)
1. Driving/trucking	19.60*	6.56	1,691	221–39,544
2. Roofing	18.19	18.57	211	106–5,597
3. Concrete construction—general	14.26	9.58	368	129–3,034
4. Metal/steel installation	14.06*	6.84	351	147–1,869
5. Glass installation	10.86	7.77	243	95–1,192
6. Elevator construction	10.58*	3.20	497	142–1,365
7. Street/road construction	9.76	7.01	458	164–3,423
8. Iron/steel erection $>$ 2 stories	8.99	18.13	243	107–882
9. Carpentry	7.07	9.04	274	107–1,707
10. Inspection/analysis	7.02*	0.95	342	168–2,481
11. Conduit construction	6.95	5.09	213	118–800
12. Heavy equipment installation	6.76	5.80	305	104–1,054
DIA Overall	6.41	5.71	305	119–1,439
13. Painting	6.25	7.61	454	116–2,297
14. Masonry	6.18	9.40	259	105–2,492
15. Electrical wiring—buildings	4.72	3.39	246	104–1,129
16. Pipefitting	3.82	6.72	311	151–1,377
17. Plumbing	3.35	5.19	250	113–690
18. Pile driving/drilling	2.86	8.56	216	87–794
19. Concrete work—plastering/finishing	2.78*	10.75	110	66–542
20. Sheet metal work	2.75	7.01	280	120–1,007
21. Concrete construction—bridges/culverts	2.34*	10.47	256	161–672
22. Electrical—low voltage specialty	2.32	2.66	621	121–1,016
23. Iron/steel erection $\leq$ 2 stories	1.33*	23.67	195	102–567
24. Insulation work	1.30*	12.72	309	107–1,438
25. Construction supervision	1.14	1.29	219	94–718

[a]The interquartile range is the 25th percentile and the 75th percentile value of the distribution.
[b]Payment rate reflects medical and indemnity payments per $100 payroll. Claims payments were capped at $126,000 and adjusted to 1992 U.S. dollars in order to make payment rates comparable to expected loss rates.
[c]Median claims payments reflect medical and indemnity payments adjusted to 1992 U.S. dollars.
*DIA payment rate significantly different from ELR at 0.05 significance level.

work-weeks. The median work loss for electrical wiring and heavy equipment installation, types of work that, like concrete construction, had enough injuries from which to confidently estimate medians, was more than 12 weeks. That median lost-work-day figures were greatest for driving/trucking, general concrete construction, and roofing suggests that the workers performing these types of work experienced the most severe injuries among all workers at DIA. High medians may also indicate unavailability of return-to-work or modified duty programs. Focus on injury prevention and amelioration for types of work associated with unusually high median days lost to injury should reduce ‘‘shock losses’’ (individual cases in which the payment exceeds a certain amount; this threshold usually triggers reinsurance payment). These losses can affect a contractor's ability to obtain insurance, since insurers or reinsurers will often ask the prospective insured party (usually the contractor) for a list of ‘‘shock losses’’ for a prior period before deciding whether to provide coverage. In addition to protecting the company's financial interests, successful interventions would reduce the burden of injury for workers.

Use of workers' compensation insurance data to determine days lost due to injury is likely to be a much more accurate means of counting lost work-days than is reliance on company reports to the BLS. The striking difference between BLS-reported median work-days lost for construction and medians for specific types of work at DIA is probably the result of several factors: BLS's reporting of one median figure based on grouping of all construction work, the difference between Colorado's and BLS's definitions of LWT, and, most importantly, contractors' reporting practices to BLS. When a worker has a long period of LWT, his workers' compensation substitutes for wages, and he no longer appears on the contractor's payroll records. In such cases, contractors may not report to BLS the work-days lost beyond the point at which those workers go off their payroll. Such days are, however, recorded in workers' compensation records, and are, therefore, included in DIA figures. Moreover, for workers whose LWT extends beyond the end of the calendar year, BLS requires that companies estimate future lost days (personal communication, Jim Barnhardt, Economist, BLS, January, 1999). These two factors are likely to result in censoring of lost work-days for serious injuries and for injuries occurring in the later months of the year by companies reporting to BLS. The lost-work-day figures presented here are more apt than are BLS figures to reflect the full burden of LWT injury in construction, insofar as the DIA construction experience is generalize-able.

Workers' Compensation Payment Rates

Payment rates reflect both rate and severity of injuries and are therefore a composite measure, which has different meanings for different types of work. Workers employed in driving/trucking at DIA did not have high rates of LWT injury, but those who were injured were seriously injured, as is reflected in lost-work-day figures and high payment rates, which include indemnity payments. On the other hand, workers in metal/steel installation had a very high LWT injury rate, which, in spite of a moderate median-days-lost figure, resulted in one of the highest payment rates.

The driving/trucking payment rate far exceeded its expected loss rate, which is calculated across industries. Most driving/trucking occurs on highways where conditions are likely to be very different from those on a construction site. DIA's workers' compensation plan covered only on-site driving/trucking. Examination of injury reports for the LWT injuries to drivers on site revealed that only two injured workers were actually driving at the time of injury; the injuries in these cases were related to conditions such as wind rows not present on highways. Another two were related to handling concrete mixer equipment while standing outside the truck. None of the injuries resembled those one would expect to occur while driving on highways. Our findings suggest that this type of work in construction merits future attention in order to confirm whether high risk for driving/trucking exists at other large construction sites.

Discrepancies between high payment rates and low ELRs also occurred in metal/steel installation, elevator construction, and inspection/analysis, suggesting that these types of work were performed at DIA less safely than expected. These findings raise questions, among them whether workers perceived as "low risk", as indicated by ELRs, were given adequate attention with respect to safety training and supervision; whether ELRs accurately reflect risk for certain types of work occurring on construction sites; and whether work at DIA was inherently different from that of other projects. The project's safety program targeted several types of work perceived to involve great risk; these were jobs that entailed working at heights, including iron/steel erection and concrete construction involving working overhead (personal communication, Skip Guarini, Safety Manager, DIA construction, January, 1999). Our findings suggest that these efforts may have been effective in reducing injury in these workers, since payment rates for iron/steel erection (up to two stories in height), concrete construction (both plastering/finishing and bridges and culverts), and insulation work were significantly *lower* than the corresponding ELRs. While not a statistically significant difference, the payment rate for iron/steel erection (over two stories) was less than half its ELR.

Strengths and Limitations

Other researchers have had to resort to trade union membership to establish cohorts of construction workers because of the difficulty of working with the employment lists of many employers with typically short-term contracts. We had the advantage of analyzing a cohort established through an insurance administrative database, whose type-of-work categories crossed trade union lines and which included nonunionized construction workers. The difference between trade and type-of-work categorization is most clearly illustrated by construction laborers, who are involved in many types of work. Although the type-of-work categories we developed by using relatively specific job classifications may include workers performing various tasks, they likely define, in most cases, a narrower set of exposures to particular tasks and work environments than do trade categories. Workers in a given trade perform a wide range of tasks, as Lipscomb et al. [1996] found in their study of union carpenters in Washington state and as others have shown in their analyses of the distribution of injuries by trade across industries and types of construction [OSHA, 1992a,b; Construction Safety Association of Ontario, 1995]. Likewise, our own evaluation of some of DIA's written injury reports showed some discrepancies between the task the worker was performing at the time of injury and his/her self-reported occupation or trade. If construction workers within a trade are commonly assigned to a range of types of work, risk analyses that focus on trade will be assessing a heterogeneous set of experiences and may miss differences in risk associated with specific types of work. Injury prevention is the province of the employer, who must address risk specific to the work performed; therefore, type-of-work analysis may be more useful than trade-specific analysis for developing safety interventions specific to tasks or work performed. A consequence of our approach, however, is that we cannot compare our findings with existing trade-specific studies, for example, those describing injuries for construction laborers [OSHA 1992a, b; Hunting et al., 1994].

While we were able to identify and confidently reclassify several claims that did not correspond with payroll by type of work, we do not know to what extent misclassification of claims may have occurred for contracts without such discrepancies. Contracts with the greatest potential for misclassification were those having a large scope of work, e.g., general contracts, which employed multiple trades to perform various types of work. We would not expect misclassification to occur on more specialized contracts. Mis-classification of claims may have resulted in an over-estimation or underestimation of injury rates (and payment rates) for specific types of work. For example, if claims among carpenters on contracts with payroll for both carpentry and concrete construction were more commonly classified under ‘‘concrete construction’’, we would expect that our rates for carpenters and concrete construction workers would under- and over-estimate their risks, respectively.

Implications for Surveillance

Project owners and employers have limited means at their disposal for surveillance of their workers' injury burden during the construction period. Neither lost days nor payment rates are available until long after injuries occur, often after construction has ended. Injury rates, which we found to be correlated with payment rates, can, however, be calculated on an ongoing basis from payroll data and workers' compensation claims. Ongoing surveillance of injury rates by type of work would allow safety programs' attention to be focused on types of work with the greatest burden of injury and to monitor effectiveness of specific prevention efforts.

CONCLUSION

By the measures analyzed in this study, the burden of injury in DIA construction was distributed unequally among different types of work. Workers involved in driving/trucking, general concrete construction, roofing, metal/steel installation, glass installation, and elevator construction appeared to shoulder the greatest injury burden on this project. These findings were surprising, since, with the exception of roofing, the prevailing risk, as measured by expected loss rates, was low to moderate for these types of work. In addition to finding great disparity in injury burden among types of work, we found that, as measured by injury rates and especially days lost, the magnitude of the burden of injury for a large majority of the types of work we analyzed was far greater than that reported by BLS for construction. Similar analysis performed on other large construction sites would be useful in determining whether these findings were specific to the DIA project or whether the types of work that we have identified as bearing a particularly large burden of injury warrant special attention for additional safety intervention on construction sites.

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APPENDIX I. Type-of-Work Classifications as Defined by NCCI Code

Type of work	NCCI job classification code(s)
Carpentry work	5020: acoustical ceiling installation
	5146: furniture and fixture installation
	5403: carpentry NOC
	5437: installation of cabinet work or interior trim
	5443: interior/exterior lathing
	5445: wallboard installation/drywall
Concrete construction	5213: concrete construction (self-bearing floors—above general ground)
	5221: cement work—ground supported (floors, sidewalks, driveways—not for roads, airfields)
Concrete construction—bridges/culverts	5222: bridges and culverts
Concrete work—plastering/finishing	5480: interior plastering (mixing of plaster, troweling)
Conduit construction	6325: conduit construction (laying coaxial cable underground)
Construction supervision	5606: construction superintendent (above foremen)
Driving/trucking	7219: trucking NOC
	7380: drivers (distributors, concrete mixers)
Electrical work—indoor wiring	5190: electrical wiring—within buildings
Electrical work—low voltage specialty	7600: telephone line maintenance and operation (stringing overhead low voltage wires and laying underground cable)
	7601: low voltage cable installation for communications
	7605: burglar alarm and sound system installation, computer cable
	7610: radio and television production crews

Type of work	NCCI job classification code(s)
Elevator construction	5160: elevator erection or repair
Engineering/architecture	8601: consulting only, not involved in actual construction
Glass installation	5462: glazier (deliver and install plate glass in buildings)
Heavy equipment installation	3724: machinery or equipment erection or repair (electrical equipment, substation equipment, air conditioning, satellite dish)
Inspection/analysis	4511: analytical chemist
Insulation work	5479: insulation work NOC (specialty contractors involved only in installation and application of acoustical or thermal insulation in buildings)
Iron/steel erection ($>$ 2 stories)	5040: erecting iron or steel frame structures ($>$ 2 stories high)
Iron /steel erection ($\leq$ 2 stories)	5057: iron/steel erection at ground level (no framing, welding)
	5059: iron/steel framing ($\leq$ 2 stories high, welding)
Iron work-metal/steel installation	5102: installation of metal doors, erection of steel windows, decorative iron work, awnings and tents)
	6400: metal fence erection
Masonry	5348: tile, stone mosaic or terrazzo work—inside
	5022: masonry NOC
Painting	5474: painting or paperhanging
	9501: sign painting and lettering
Pile driving/drilling	6003: pile driving
	6204: excavation (ditches, filling, backfilling, grading)
	6252: shaft sinking (pile driving, excavation, concrete work)
Pipefitting	3365: welding or cutting NOC
	5188: auto sprinkler installation
	6319: gas main or connection construction (utility companies)
	6306: sewer line construction
Plumbing	5183: plumber
Roofing	5551: roofing—all kinds
Sheet metal work	5538: sheet metal work NOC
Street/road construction	5506: street or road paving—runways, asphalt surfacing
	5507: street or road construction—excavation, grading
	6217: excavation for road construction
	6229: irrigation or drainage system construction (digging canals, installation of irrigation equipment)

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