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Costs of occupational injuries in construction in the United States

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Abstract

This paper presents costs of fatal and nonfatal injuries for the construction industry using 2002 national incidence data from the Bureau of Labor Statistics and a comprehensive cost model that includes direct medical costs, indirect losses in wage and household productivity, as well as an estimate of the quality of life costs due to injury. Costs are presented at the three-digit industry level, by worker characteristics, and by detailed source and event of injury. The total costs of fatal and nonfatal injuries in the construction industry were estimated at $11.5 billion in 2002, 15% of the costs for all private industry. The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002. Five industries accounted for over half the industry's total fatal and nonfatal injury costs. They were miscellaneous special trade contractors (SIC 179), followed by plumbing, heating and air-conditioning (SIC 171), electrical work (SIC 173), heavy construction except highway (SIC 162), and residential building construction (SIC 152), each with over $1 billion in costs.

Keywords: Cost; Injury; Construction; National; Fatal; Nonfatal

1. Introduction

Construction is one of the most dangerous industries in the United States. Despite efforts to reduce the risk of occupational injuries and illnesses in construction, the industry continues to account for a disproportionate share of work-related injuries and illnesses in the United States. In 2004, construction workers were 7.7% of the U.S. workforce (BLS, 2005a), but suffered 22.2% (1278) of the nation's 5764 reported work-related deaths (BLS, 2005b). In addition, there were more than 150,000 nonfatal injuries and illnesses with days away in construction this year. The rate was 71% higher than that for all industry as a whole (BLS, 2005c).

In spite of the high risk of fatal and nonfatal workplace injuries, there are few estimates of the costs associated with occupational injuries in the construction industry. Most of these are limited to workers' compensation costs and many are specific to a particular geographic area. Cost estimates would combine the frequency and severity of injuries into one measure that can be used to highlight the problem areas in the industry and define the case for safety interventions. Economic evaluations of such interventions would benefit from estimates of the costs associated with occupational injuries. Cost estimates based on individual data on work-related injuries in construction, would reflect the particular patterns of injury, their associated events and sources specific to the construction industry. Given the changes in injury risk as jobs proceed through different stages of the construction process, detailed job- and event-specific costs of injury will be especially useful for the construction industry.

In this paper, we will present costs of fatal and nonfatal injuries for the construction industry at the three-digit industry level using incidence data from the Bureau of Labor Statistics' (BLS) Survey of Occupational Injuries and Illnesses and Census of Fatal Occupational Injuries and cost estimates based on an existing cost model for occupational injuries (Miller et al., 2002; Leigh et al., 2004, 2006; Waehrer et al., 2005, 2004). For nonfatal injuries involving days away from work (DFW), the BLS data allow us to break down construction industry costs for injuries involving days away from work by detailed source and event of injury, as well as by worker characteristics like age, race/ethnicity, and tenure in their current job. Where relevant, we will present analogous costs for all private industry allowing us to gauge the relative severity of injuries in the construction industry. By presenting costs in terms of productivity lost,

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medical expenses, household disruption, and impairment to one's quality of life, our work enables readers to compare the impact of different injuries along several different dimensions.

1.1. Background

Most of the previous cost studies for construction are limited to workers' compensation costs. Using the national survey data, the Center to Protect Workers' Rights (CPWR) estimated that the average level of injury compensation payment (of all types) for a construction worker was nearly double the level for a worker in other industries —$7542 compared with $3943 per year, respectively (CPWR, 2002). A recent study based on data from the construction of the Denver International Airport reported that slips and trips accounted for 25% of workers' compensation payments, or more than $10 million (Lipscomb et al., 2005). Using more than 20,000 workers' compensation claims by Oregon construction employees between 1990 and 1997, Horwitz and McCall (2004) estimated that the average claim cost was $10,084, and structural metal workers had the highest average costs per claim ($16,472). Reviewing more than 30,000 workers' compensation claims among North Carolina Homebuilders Association members and their subcontractors for the period 1986–1994, Dement and Lipscomb (1999) found roofers and carpenters were two major occupations having greater than average medical costs. Shah et al. (2003) estimated that the direct costs of injuries and illnesses from wood framing in residential construction were over $197 million in Washington State based on 33,021 accepted state fund workers' compensation claims from 1993 to 1997.

Studies across industries suggest that injury rates and cost rates are higher for construction than for the average of all industries. Leigh et al. (2004) ranked three construction sectors (SIC 176 Roofing, siding, sheet metal; 161 Highway and street construction; and 175 Carpentry and floor work)[1] among the top 15 industries that cost the most; the average cost per worker was $3260, $2749, and $2500, respectively. In an earlier study, Leigh and Miller (1997) reported that construction laborer and carpenter were two occupations with high costs of occupational injury and illness. A study using workers' compensation data from Washington State estimated that average direct workers' compensation costs (medical treatment and indemnity) for construction was four times higher than for most industries (Silverstein et al., 1998).

In spite of the large range of perspectives, none of the previous studies has sought to achieve an integrated estimate for the entire construction industry. A recent exception is a NIOSH report on the costs of workplace fatalities which estimates that construction fatalities cost a total of $10 billion for the 10-year period from 1992 to 2002 (NIOSH, 2006). Similar to this study, the report calculated direct medical costs and indirect wage and household production losses by age and gender for workplace fatalities recorded in the CFOI. Most other studies on the costs of fatal and nonfatal injuries rely on data from workers' compensation, but the definitions of occupational injuries and illnesses, and eligibilities of workers' compensation system vary from state to state. This has made it difficult to provide a national cost estimate of all workplace injuries in construction. Also, workers are not guaranteed full insurance coverage under workers' compensation for work-related disorders. It was estimated that in 1999, workers' compensation paid roughly $8 billion to $23 billion less in medical costs compared with the cost estimated by the numbers from epidemiological studies (Leigh and Robbins, 2004). Additionally, more than 2 million (24%) of construction workers are self-employed (CPWR, 2002), and they are not covered by workers' compensation systems.

2. Data and methods

The costs of occupational injuries and illnesses can be divided into three broad categories—direct costs, indirect costs, and quality of life costs. Direct costs include payments for hospital, physician, and allied health services, rehabilitation, nursing home care, home health care, medical equipment, burial costs, insurance administrative costs for medical claims, payments for mental health treatment, police, fire, emergency transport, coroner services, and property damage. Indirect costs refer to: (1) victim productivity losses which include wage losses and household production losses and (2) administrative costs which include the cost of administering workers' compensation wage replacement programs and sick leave. Quality of life costs refer to value attributed to the pain and suffering that victims and their families experience as a result of the injury or illness. This approach to valuing occupational injury costs has been widely used in other areas such as to estimate the costs of transportation injuries, birth defects, violence, or consumer product injuries (Hendrie et al., 2003; Lopez et al., 1995; Miller et al., 1996; Lawrence et al., 2000).

Our estimates of costs for the construction industry inflate per-case costs from our 1993 cost model (Miller et al., 2002; Leigh et al., 2004, 2006; Waehrer et al., 2005, 2004) to 2002 dollars and apply these to incidence data from 2002. Our estimates for nonfatal injuries are based on the 1993 and 2002 Survey of Occupational Injuries and Illnesses (Annual Survey) collected by the BLS. The Annual Survey is a federal/state program that has collected occupational injury and illness data on an annual basis since 1972 from logs that employers maintain according to Occupational Safety and Health Administration (OSHA) guidelines. It excludes work fatalities and nonfatal work injuries and illnesses to the self-employed; to workers on farms with fewer than 11 employees; to private household workers; and to employees in federal, state, and local governments. In 1993 and 2002, employer reports of worker injuries were collected from about 250,000 and 183,000 private industry establishments respectively. These establishments reported on the numbers of injuries and illnesses of various types (without lost work, with only restricted-work days, or with days away from work) that occurred in the previous year. Since 1992, the summary data for each establishment were supplemented by case and demographic data from OSHA logs for injuries and illnesses that involved one or more days away from work.

[1] SIC = 1987 Standard Industrial Classification.

Despite some known gaps (Leigh et al., 2000), the Annual Survey is the best and largest national establishment-based survey of nonfatal occupational morbidity currently available. The cost model used data from the 1993 Annual Survey to estimate the mean days away from work and associated wage, medical, and pain and suffering costs associated with each reported injury (see Leigh et al., 2004 for a discussion on the costs of occupational injuries). In 1993, there were 2.25 million such injuries estimated to cost approximately $80 billion (Leigh et al., 2004).

Our results for fatality costs are based on the 1993 and 2002 Census of Fatal Occupational Injuries (CFOI) also collected by the BLS. This data was combined with other datasets for the calculation of medical costs, as well as the construction of injury code maps between the International Classification of Diseases (ICD 9) system and other coding systems. Note that our use of the 1993 cost model for 2002 injuries assumes that the composition of injuries at the three-digit SIC level or by detailed source or event code, is similar between 1993 and 2002.

To inflate medical costs, we use data on personal consumption expenditures for medical care services from the Bureau of Economic Analysis' Economic Report of the President (ERP) (White House, 2006; Table B-16, last column). We divide this by the population of the Unites States, including Armed Forces overseas, as estimated by BEA and the Bureau of the Census (ERP Table B-31, last column). Work-loss and quality-of-life losses are inflated by an index of total compensation in private industry (ERP Table B-48, first column). This index, estimated by BLS, measures the total cost of employing workers, including wages and fringe benefits.

The costs presented here are incidence-based. That means they represent the costs over victims' lifetimes of injuries in 2002. Preventing the injuries would avert all of these costs. Incidence-based costs, thus, are the appropriate costs to use to estimate cost savings in an evaluative or resource allocation context. They do not, however, describe the total costs during 2002 on victims of occupational injury, including victims being treated for injuries in prior years. Below, we present a brief description of our methods. Thorough descriptions are available in Appendices A and B, available at the bottom of http://www.epm.ucdavis.edu/Fac/Leigh/CostsAcrossIndustries.htm.

2.1. Direct costs

For nonfatal injuries, direct costs were estimated separately for those hospitalized and those not hospitalized by diagnosis. The same procedure is used by the U.S. Consumer Product Safety Commission in its regulatory impact analyses (Miller et al., 1998). The direct costs for hospitalized victims are the product of five diagnosis-specific factors involving: length of stay; hospital cost per day; ratio of professional fee payments to hospital payments; ratio of cost in the first 6 months to costs during the initial admission; and ratio of the present value of lifetime medical payments to payments in the first 6 months. The direct costs for nonhospitalized victims are the product of diagnosis-specific factors involving: the probability that an injury or illness will require medical treatment; the number of visits to physicians' offices or emergency departments; payments per nonhospitalized visits; ratio of payments, including pharmaceutical and ancillary expenses to payments for medical visits; and ratio of the present value of lifetime medical payments per nonhospitalized case to payments in the first 6 months.

To weight the admitted and nonadmitted cases to obtain costs for an average victim, we used probabilities of hospital admission for lost-work injuries by injury diagnosis group and age group. Medical costs were estimated for International Classification of Diseases, 9th ed., Clinical Modification diagnoses, then mapped to the American National Standards Institute (ANSI) Z-16.2 coding system used in BLS data.

For nonfatal illnesses, direct costs were computed in a simpler manner because less information was available. The annual medical spending for hospitalizations, for example, was computed as the product of length of stay, cost per day, and the ratio of hospital plus professional fee payments to hospital payments.

We attribute a constant medical cost of $777 (in 2002 dollars) to medically treated cases without any work loss and $618 for cases with restricted work activities, some of them not medically treated. These $777 and $618 were estimated from the National Health Interview Survey (Miller et al., 2002). Following Miller and Galbraith (1995), we attribute a constant medical cost of $18,300 to each fatality.

2.2. Indirect costs

Indirect or productivity losses for nonfatal cases can be divided into short-term and long-term losses as well as wage and household productivity losses. To account for the censoring in reported days away from work on 31 December, we estimated survival models to estimate the length of time these censored cases would have taken to be resolved (Miller et al., 1998, 2002). The model predicted duration (days away from work) separately for 20 different injury and illness categories using age, gender, race, tenure with firm, firm size, and body part as explanatory variables with each diagnosis category. Cases that were assigned as permanent total disability cases were excluded from these duration models. Our adjustments result in increasing the overall estimate of days away from work by approximately 12%.

For short-term wage losses, we multiplied the number of days away from work by the predicted daily wage rate received by a worker of the same age group, race, gender, industry and occupation as the injury victim. The predicted wage rates are derived from a linear regression of hourly wages on these characteristics using the monthly files of the 1993 Current Population Survey. We combined these with estimates of daily hours worked from the CPS to yield a daily wage rate. Finally, to account for the total compensation due a worker, we adjusted for fringe benefits attributable to different occupation groups using data from the BLS' Employment Cost Index (Bureau of Labor Statistics, 1995).

Long-term wage losses resulting from permanent total disability were based on estimates of lifetime wage loss calculated using a 2.5% discount rate and a standard age-earnings model for different age (5-year age groups) and gender categories (Hodgson and Meiners, 1982). To reflect the worker's current industry and occupation more accurately, the long-term wage losses for all permanent disabilities were multiplied by the ratio of hourly wages by age, race, sex, industry, and occupation to the hourly wages for different age and sex categories.

Following Miller et al. (1998) we estimated household work loss duration by the number of days away from work times 365/243 times 0.9. These adjustments account for the fact that household work may be lost on days when wage work is not and also reflect results showing that 90% of the time lost to wage work is also lost to household work (Douglass et al., 1990).

For fatalities, we calculated *lifetime wage losses* using a 2.5% discount rate and a standard age-earnings model (Hodgson and Meiners, 1982) for different 5-year age groups and sex categories. Age-gender lifetime wage losses were adjusted for industry and occupation where possible, using average wages by age, gender, industry, and occupation based on 1993 CPS data. Using the specialist cost approach outlined in Douglass et al. (1990), *lifetime household work losses* were also calculated for different age and sex groups.

2.3. *Quality of life costs*

Quality of life costs for nonfatal injuries were estimated using jury verdicts in tort liability lawsuits. Cohen (1988), Viscusi (1988), and Rodgers (1993) establish the theoretical framework underpinning this increasingly popular costing method. The method assumes that the quality of life costs of an injury survivor can be approximated by the difference between the amount of compensatory damages awarded by a jury and the out-of-pocket costs claimed by the victim.

In large numbers, the quality of life component of U.S. jury verdicts to injury survivors is reasonably predictable with regression analysis. Regressions based on verdicts yield values that are diagnosis-specific and appear to closely approximate values from the willingness to pay method that economic theory suggests using in benefit-cost analyses of preventive effort (e.g. Cohen and Miller, 2003). Miller et al. (1996) finds that the willingness to pay to avoid physical assaults has a 0.6 correlation with estimated pain and suffering awards for physical assaults from jury verdict regressions.

We coded approximately 2000 jury verdicts and settlements related to occupational injury from data leased from Jury Verdicts Research, Inc. Since workers' compensation was designed to be a tort-free system and tends to reduce the propensity for litigation, occupational injury cases that go to trial are a selected sample of all occupational injuries. Estimating quality of life costs on this selected sample may result in an overestimate of the costs associated with the bulk of occupational injury cases that do not go to trial. We reduce this bias using the well-known Heckman correction for sample selection bias, which allows us to predict costs for the Annual Survey cases if they were to go to trial (Heckman, 1976). Preliminary estimates put the quality of life costs for approximately 480,000 nonfatal injury cases at $25 billion. Punitive damages were excluded from the analysis.

The quality of life costs due to a fatality can be calculated as the difference between the willingness to pay to avoid the injury and the victim wage and household work loss costs associated with it. Miller (1990) surveyed 30 studies of the influence of job risk on worker wages and computed an average willingness-to-pay of approximately $2.7 million in after-tax compensation (1993 dollars) per workplace fatality. After subtracting the indirect costs, the quality of life costs were estimated for the average worker at $1.9 million per workplace fatality. This estimate was adjusted for different age group using average life expectancies for each group.

3. Results

Table 1 presents the total costs of all fatal and nonfatal occupational injuries in the construction industry in 2002. Construction is a disproportionately costly industry, accounting for only 5.2% of all private industry employment in 2002 (BLS, 2006) but 15% of all private industry injury costs. Construction injuries cost $11.5 billion, with $4 billion in fatalities (40%) and $7 billion in nonfatal injuries, primarily driven by cases with days away from work.

The five costliest construction industries accounting for over half the industry's total fatal and nonfatal injury costs were miscellaneous special trade contractors (SIC 179) at $1.5 billion, followed by plumbing, heating, and air-conditioning (SIC 171) at $1.3 billion, electrical work (SIC 173), heavy construction except highway (SIC 162), and residential building construction (SIC 152), each with approximately $1.2 billion in costs. Of these five, three industries (electrical trades, miscellaneous special trade contractors, and residential construction) also ranked in the top five when only nonfatal injuries were considered. Heavy construction except highway, and roofing, siding, and sheet metal work ranked among the top five industries for fatality costs.

The average construction fatality was estimated to cost $4 million. Nonfatal days-away injuries in construction were more costly than average, at $42,000 per case compared to $37,000, in all private industry. Our prior analysis of work loss for days-away cases estimates the expected lifetime work loss per construction days-away case to be 115 days compared to 100 days for the average worker (Miller et al., 2002). The higher injury severity is reflected in a higher estimate of lifetime wage losses of $21,600 for the average construction worker compared to $16,000 for the private industry worker. Restricted work and no-lost-work cases (not shown in Table 1) are estimated to cost $618 and $777 per-case, respectively.

Within construction, workers in the roofing, siding, and sheet metal work industry (SIC 176) have the highest nonfatal injury rate of 9.5 cases per 100 full-time equivalent employees, 79% higher than the risk for average private industry worker and 34% higher than the average construction worker. However, the cost per days-away case in this SIC was comparable to the average for the construction industry as a whole, and only 12% higher than the per-case cost for the average private industry worker. In contrast, water well drilling (SIC 178) had the highest per-DFW cost within construction at $53,000 per case, 26% higher than the average construction DFW case and 44% higher than the average for all private industry.

In Table 2, the total costs of DFW injuries in construction are presented by worker's age, gender, race/ethnicity, and job

Table 1
Total costs of fatal and nonfatal occupational injuries and illness in construction, 2002

SIC	Detailed industry	2002 Fatals	2002 Cost/ fatal ($)	2002 DFWs	2002 Cost/ DFW ($)	2002 Nonfatal injury rate	Total cost of fatalities (millions) ($)	Rank by total cost of fatalities	Total cost of DFW cases (millions) ($)	Rank by total DFW cost	Total cost of all injuries (millions) ($)	Rank by total cost of all injuries
	All private industry	4978	3816128	1436200	37016	5.3	18997		53162		74527	
	Construction	1125	3954669	163700	42093	7.1	4449		6891		11527	
152	Residential building construction	92	3759723	17062	49312	5.7	346	5	841	2	1203	5
153	Operative builders	6	0		38016	3.2	0	14	0	14	1	14
154	Nonresidential building construction	75	3993029	12833	37183	6.9	299	7	477	8	797	8
161	Highway/street construction	84	3760270	6482	42856	6.8	316	6	278	11	603	10
162	Heavy construction, except highway	159	4100056	13414	40987	6.2	652	2	550	6	1217	4
171	Plumbing, heating, air-conditioning	68	3648467	27278	37772	8.9	248	9	1030	1	1315	2
172	Painting and paper hanging	43	3876923	4159	48560	4.8	167	11	202	12	373	12
173	Electrical work	105	4334176	17539	42207	6.4	455	3	740	5	1218	3
174	Masonry, stonework and plastering	51	3825669	18036	43179	8.1	195	10	779	4	990	6
175	Carpentry and floor work	64	4065853	10941	48571	7.9	260	8	531	7	801	7
176	Roofing, siding and sheet metal work	113	3954875	7786	41456	9.5	447	4	323	9	778	9
177	Concrete work	27	3581265	8933	36001	7.2	97	12	322	10	427	11
178	Water well drilling	8	3677746	612	53153	6.7	29	13	33	13	62	13
179	Miscellaneous: special trade contractors	184	4088801	18219	43366	6.9	752	1	790	3	1563	1

Table 2
Mean costs per construction industry case of nonfatal occupational injury with days away from work

	2002 N	Total cost/DFW ($)	Wage loss ($)		Household loss ($)	Medical cost ($)	Quality of life cost ($)
			Total	Short-term			
Age group							
≤24 years	24792	38378	22764	2660	3056	2903	7813
25–34 years	49727	43182	23071	5377	3796	3216	11386
35–44 years	49387	43003	21465	7436	4227	3585	12187
45–54 years	26615	43286	19288	8673	4022	4342	14302
55–64 years	10448	39518	14080	9109	3374	5494	15554
≥65	1402	34575	10507	8333	3162	5831	14302
Sex							
Male	159621	42149	21836	6066	3711	3519	11464
Female	4020	39308	12307	4132	7425	3352	15266
Race							
White non-hispanic	98674	41952	21410	6141	3710	3595	11652
Black non-hispanic	7070	46320	24294	5747	4584	3968	11675
Hispanic and other	28365	46952	25567	6325	4527	3113	11805
Missing	29532	37602	18926	5366	3294	3258	10740
Tenure in current job							
≤11 months	69956	42994	22578	5926	3935	3423	11373
1–5 years	59165	39905	21202	5772	3649	3141	10321
Greater than 5 years	33314	43270	20287	6686	3636	4288	13598
Missing	1206	37632	19207	5663	3366	3118	10539

tenure. Workers aged 25–44 years incur the highest costs of injury, accounting for half of the industry's total DFW costs. This is not surprising because these workers are in their prime working years and are likely to have the highest productivity losses as a result of their injuries. Men account for the vast majority of construction injury costs, reflecting their dominance in this industry's workforce and their associated exposure to many of its riskiest occupations. When DFW costs are tabulated by race/ethnicity, Hispanic workers are shown to bear a significant 15% share.

Table 3 presents information on the costliest injury events leading to DFW injuries in construction. Falls to a lower level and overexertion are the top two costly events in construction, each generating $950 million in DFW costs. Falls to a lower level account for 13.8% of the cost of all construction DFW injuries in 2002, proportionate to their share of DFW injuries. These falls also rank highly in severity of cases, ranking 9th in per-case costs with $58,000 per DFW case. By contrast, overexertion injuries account for 21% of DFW injuries in construction, but only 13.7% of DFW costs, reflecting their lower per-case cost.

A scan of the injury events with high total costs or costs per case reveal the importance of bodily conditions including overexertion and repetitive motion. While overexertion injuries are more frequent, repetitive motion injuries rank highly in both total costs (158 million, ranked 8th in total costs) and in costs per DFW case ($75,000 per case, ranked 5th in per-case costs). Unclassified bodily conditions hold the top rank for per-case costs at $136,000 per case. Other injury events that rank highly in both total and per-case costs include being caught in or com-

Table 3a
Ten costliest DFW injury events in construction

BLS event code	Event of injury	2002 N	Cost/DFW	Total cost of DFW cases ($)	Rank by total cost of DFW		Rank by cost per DFW	
					Construction	All industry	Construction	All industry
Top 10 total DFW costs								
11	Fall to lower level	22421	58019	953379260	1	6	9	20
22	Overexertion	33799	38596	951230268	2	1	21	37
2	Struck by object	32281	36185	854923225	3	2	25	40
21	Bodily reaction	18585	33667	458063937	4	4	28	43
13	Fall on same level	12308	43466	391609175	5	3	16	36
3	Caught in or compressed by equipment or objects	6950	69041	352174918	6	7	6	11
1	Struck against object	12336	33886	305981280	7	8	27	42
23	Repetitive motion	2866	75254	158270350	8	5	5	9
41	Highway accident	4195	44388	136028832	9	9	14	23
32	Contact with temperature extremes	1884	55078	75191118	10	11	12	22

Table 3b
Construction injury events with the 10 highest per-DFW costs

BLS event code	Event of injury	2002 N	Cost/DFW	Total cost of DFW cases ($)	Rank by total cost of DFW		Rank by cost per DFW	
					Construction	All industry	Construction	All industry
Top 10 per DFW costs								
25	Bodily conditions, n.e.c.	202	136222	19599981	19	16	1	7
31	Contact with electrical current	613	86829	38966117	17	21	2	13
43	Pedestrian, nonpass. struck by vehicle, mobile equipment	901	81914	54175112	14	15	3	19
61	Assaults and violent acts by person(s)	206	80755	12152785	22	12	4	15
23	Repetitive motion	2866	75254	158270350	8	5	5	9
3	Caught in or compressed by equipment or objects	6950	69041	352174918	6	7	6	11
51	Fire-unintended or uncontrolled	81	67924	3968810	30	28	7	10
52	Explosion	348	63332	15889844	20	24	8	6
11	Fall to lower level	22421	58019	953379260	1	6	9	20
42	Nonhighway accident, except rail, air, water	1364	57965	57921496	11	14	10	16

pressed by objects, and nonhighway accidents excluding rail, air, or water.

Are the costly injury events in construction similar to those in other private industry? According to Table 3, there is a remarkable similarity in the events resulting in the most DFW costs. Ranked by per-DFW cost, exposure to noise results in the highest per-case cost in private industry but is relatively infrequent with only 300 cases in 2002. There are no recorded construction cases resulting from this event in 2002.

In Table 4, we rank the source of injury for DFW cases by their associated cost for all DFW cases, as well as by their per-DFW case cost. Consistent with the high costs of falls in construction, floors, walkways and ground surfaces were the most costly source of DFW injuries, with $1.8 billion worth of costs, followed by building materials, solid elements with $900 million worth of DFW costs. Together these injury sources account for 35% of DFW injuries in construction and 39% of DFW costs in 2002. Floors and other surfaces alone caused one out of every five cases and one of out four dollars of DFW costs in construction.

The 10 injury sources resulting in the costliest DFW cases are also presented in Table 4. Unspecified machinery leads with $161,000 per DFW case followed by unspecified other sources with approximately $71,500 per case. Parasitic agents and a person other than the injured worker are other sources of injury that rank among the top five in per-DFW case costs. From Table 4, we see that injuries related to construction, logging, and mining machinery result in both a high cost of all DFW cases (ranked 7th) and a high cost per case (ranked 6th). Metal, woodworking, special machinery, and miscellaneous machinery are the other sources of injury that rank in the top 20 for both all-case and per-case costs.

Table 4 allows us to gauge whether the costliest injury sources in construction are also important for private industry as a whole. The 10 sources with the highest total costs of DFW injuries appear to be highly ranked in private industry as well. Unsurprisingly, sources like powered tools and fasteners, connectors, ropes and ties are more important contributors to DFW costs in construction than in other private industry. However, except for machinery (unspecified machinery; construction, logging, and

Table 4a
Top 10 costliest DFW injury sources in construction

BLS source code	Source of Injury	2002 N	Cost/DFW ($)	Total cost of DFW cases ($)	Rank by total of DFW		Rank by cost per DFW	
					Construction	All industry	Construction	All industry
Top 10 total DFW costs								
62	Floor surfaces	33558	53100	1781922582	1	2	14	45
41	Building material	23212	39978	927973929	2	6	30	47
56	Injured/ill person	21349	39976	853449327	3	1	31	26
82	Vehicle, motor	7067	44626	315375021	4	4	23	33
71	Tools: nonpowered	7985	30252	241563978	5	8	53	68
72	Tools: powered	5280	43746	230980351	6	16	25	34
32	Construction/logging/ mining machineries	3221	64460	207624961	7	27	6	8
63	Other structure	5037	40221	202595606	8	9	29	63
11	Cont-nonpressur	5476	35767	195858446	9	3	44	71
42	Ropes/ties	5913	26475	156544161	10	24	60	75

Table 4b
Construction injury sources with the 10 highest per-DFW costs

BLS source code	Source of injury	2002 N	Cost/DFW ($)	Total cost of DFW cases ($)	Rank by total of DFW		Rank by cost per DFW	
					Construction	All industry	Construction	All industry
Top 10 per DFW costs								
30	Machinery, unspecified	322	161191	51903589	22	29	1	10
98	Other source nec	708	71461	50594720	23	39	2	40
69	Structure nec	89	68513	6097648	50	81	3	20
53	Parasitic agents	118	66815	7884172	46	54	4	24
57	Other person	250	65834	16458551	40	5	5	54
32	Construction/logging/ mining machineries	3221	64460	207624961	7	27	6	8
35	Metal woodwork	1795	63788	114500121	13	7	7	7
80	Vehicle, unspecified	131	58976	7725914	47	57	8	39
02	Alkalies	494	58340	28820088	35	60	9	19
39	Miscellaneous machines	1089	56672	61716341	18	23	10	14

mining machinery; and metal, woodworking and special material machinery), the construction injury sources resulting in the highest costs per DFW case do not bear much resemblance to the most severe sources for all industry. Infectious and parasitic agents, which result in the fourth highest per-DFW cost in construction, do not figure in the top 20 for private industry as a whole. Metallic minerals which result in the costliest DFW cases for private industry as a whole are not recorded in construction.

4. Discussion

This paper presents a comprehensive estimate of the societal costs of occupational injury in the construction industry including both direct medical costs, indirect losses in wage, and household productivity, as well as an estimate of the quality of life costs due to injury. The total costs of fatal and nonfatal injuries in the construction industry were estimated at $11.5 billion in 2002, a disproportionately high 15% of the costs for all industries. The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002.

Because of the comprehensive accounting of costs in our model, the cost estimates presented here are higher than those based on workers' compensation data, which range from an average of $7500 for all construction injury types in construction to $10,000 for workers in the Oregon workers' compensation system (CPWR, 2002; Horwitz and McCall, 2004). The average per-fatality cost of $4 million in construction is also higher than the recent NIOSH estimate of $864,000 which did not include quality of life losses (NIOSH, 2006). Subtracting quality of life costs from our estimate results in a more similar cost per fatality of approximately $1 million. Our results show that falls and overexertion result in the highest costs of DFW injuries in construction. This is not surprising—these two events dominate the incidence of injuries in the industry. Falls to a lower level and repetitive motion were two injury events that ranked highly when looking at both total costs and per-case costs of DFW injuries.

We examined the sensitivity of our estimates to key parameters. If the estimated number of injuries was one standard error from the estimated mean, total costs would vary by 2.5%. If the Consumer Price Index-Medical Care was used as the medical cost inflator, costs would decline by 0.65%. If the value of lost quality of life varied by one standard deviation from its estimated mean (about 29% of its value), costs would shift by 16%.

A comparison of our estimates of injury costs in construction with estimates from Leigh et al. (2004) using the same cost model shows that the total costs of injury remained relatively stable from 1993 to 2002 reflecting the secular decline in occupational injuries over this period. For example, in 1993, heavy construction, except highway, was estimated to cost $1.12 billion in lost wages, household productivity, medical costs and quality of life losses. In 2002, total costs for this sector increased only marginally to $1.2 billion suggesting that the 30% reduction in the incidence of occupational injuries for this sector has largely offset increases in medical costs and wages over the 9 years.

As stated earlier, our cost estimates for detailed construction industries combine 2002 estimates of injury incidence with 1993 per-case costs that are inflated to 2002 dollars. Thus, we assume that the composition of construction injuries within each industry remains stable between 1993 and 2002. A simple comparison of the injury distribution between the 2 years reveals that this is a reasonable assumption. Back sprains and other injuries to the muscles, tendons, or ligaments account for approximately 37% of the construction days-away cases in both years. Similarly, fractures and dislocations account for a stable 12% of these cases for both years.

One drawback to our estimates of long-term losses is the lack of information on the actual disability status of each injured worker in the Annual Survey. However, assuming that the cases in the Annual Survey are a fair reflection of permanent disability cases, conditional on diagnosis, our methods will still provide reasonable estimates of the average productivity losses by various categories.

Our estimates of work losses capture the loss to injured workers but ignore any employment opportunities that arise because the injured are no longer able to work. We also put a zero dollar value on productivity losses among persons with restricted (light duty) work. This is a conservative assumption because persons working on restricted or light duty are probably not producing as much as they would be if they were working at their usual job. Our calculation of medical costs also ignores the effect of construction injuries on the time that less serious injuries spend waiting for treatment in emergency departments.

Occupational diseases, many of which are not apparent until years after exposure, are likely to be underestimated in our data. The Annual Survey is also limited by excluding federal, state, and local government workers, workers on farms with fewer than 11 employees, and the self-employed. This is especially a problem for the construction workers, 24% of whom are self-employed (CPWR, 2002). Inspite of these data limitations, this study provides a comprehensive estimate of construction injury costs and a detailed breakdown by source and event. These estimates will allow for better-grounded cost-benefit analyses of preventive interventions aimed at reducing occupational hazards.

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