THE ECONOMIC COST OF FATAL OCCUPATIONAL INJURIES IN THE UNITED STATES, 1980–97

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According to the National Traumatic Occupational Fatalities (NTOF) surveillance system, occupational injuries claimed the lives of over 100,000 American workers from 1980 to 1997. Previous estimates presented aggregate values of life, providing no information on the cost variations for different case or worker characteristics. This research developed an interactive computer program that estimates comprehensive national costs for all occupational fatal injuries reported through NTOF, nearly $85 billion for 1980–97, and specific estimates for the burden on selected groups and characteristics of the fatality. These estimates provide an additional basis for targeting and evaluating the effectiveness of investments in prevention of occupational fatalities. (*JEL* I18)

I. INTRODUCTION

Despite improvements, workplace hazards continue to plague American workers. Each day an average of 9,000 workers sustain disabling injuries on the job, and 16 die from such injuries. Work-related diseases take the lives of another 137 Americans annually (see National Institute for Occupational Safety and Health [NIOSH], 2000). These figures are alarming in terms of both human suffering and economic losses. According to one team of researchers, these losses accounted for over $155 billion in direct and indirect costs, or 3% of gross domestic product in 1994 (see Leigh et al., 2000). Additionally, they concluded that the annual cost to the American public for losses from occupational injury and illness is more than AIDS, on a par with cancer, and almost as great as all circulatory diseases.

The responsibility of NIOSH is to conduct research to promote health and quality of life through prevention and control of work-related disease, injury, and disability. The Division of Safety Research within NIOSH narrows the focus to the study of occupational injury—both fatal and nonfatal. Research directions are determined by a number of methods, including targeting efforts to the highest-risk areas. Traditionally, NIOSH has defined burden in physical terms by focusing on the characteristics and magnitude of injuries and fatalities in the United States, and the mechanisms to prevent or ameliorate those injuries. However, the incidence or magnitude of occupational fatalities in the United States describes only a portion of the burden to the worker, industry, and society. A measure of economic loss associated with the injury or fatality would add a valuable dimension to targeting efforts as well as a tool for assessing cost savings of prevention efforts.

This study developed a computerized costing model for calculating cost consequences, which provides a tool for policy makers to systematically examine current and potential research impacts using standard economic measures. It provides comprehensive national estimates for the economic burden of all

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ABBREVIATIONS

BLS: Bureau of Labor Statistics
CFOI: Census of Fatal Occupational Injuries
CPI-U: Urban Consumer Price Index
CPS: Current Population Survey
DCI: Detailed Claims Information
DHHS: U.S. Department of Health and Human Services
ECI: Employment Cost Index
NIOSH: National Institute for Occupational Safety and Health
NSC: National Safety Council
NTOF: National Traumatic Occupational Fatalities
OES: Occupational Employment Statistics

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occupational fatal injuries, which can be incorporated into evaluative tools, such as cost utility, cost effectiveness, cost benefit, and decision analysis to assist in allocating limited resources more effectively. Unlike earlier works (see Rice, 1965; Rice et al., 1989; Leigh et al., 2000), this model uses a bottom-up approach. It estimates the value of an individual fatality based on the key characteristics of that fatality and then sums the individual fatality costs to arrive at the national burden. It provides national and state estimates for the economic burden of selected groups such as specific industries, occupation groups, minority workers, older workers, and teenage workers. The model supports yearly updates, scenario analysis, and the potential for linking to other fatal and nonfatal databases. These estimates provide an additional reliable basis, economic burden, for targeting and evaluating the effectiveness of investments in the prevention of occupational fatalities.

II. METHODS

A. *Theoretical Model*

For this study, the cost-of-illness theoretical approach was employed. The indirect lifetime cost of an occupational fatal injury is derived by using the human capital approach, calculating the present value of future earnings summed from the year of death until the decedent would have reached age 67, accounting for the probability of survival were it not for the premature death. Mathematically this is represented as follows:

$$(1)\quad PVF = \Sigma P_{y,q,s}(y+1)[Y_{s,j}(n) + Y_s^h(n)](1+g)^{n-y}/(1+r)^{n-y}$$

where

PVF = present discounted value of loss due to occupational fatal injury per person;

$P_{y,q,s}(y+1)$ = probability that a person of age y, race q, and sex s will survive to age $y+1$;

y = age of the individual at death;

q = race of the individual;

s = sex of the individual;

j = occupation of individual at death;

n = age if the individual had survived;

$Y_{s,j}(n)$ = median annual earnings of an employed person of sex s, occupation j, and age n (includes benefits and life-cycle wage growth adjustment);

$Y_s^h(n)$ = mean annual imputed value of home production of a person of sex s and age n;

g = wage growth rate attributable to overall productivity; and

r = real discount rate (3%).

Combining these indirect costs with direct costs yield the overall lifetime cost of an occupational fatal injury. This method provides a conservative estimate of direct costs, as only medical expenses were included in the total estimate. Medical expenses were only included in the first year calculations because nearly 90% of the fatalities occurred within one day of the injury event (see National Traumatic Occupational Fatality (NTOF), 1980–97).

The model calculates incidence-based costs, the lifetime cost of all injuries occurring in a given year regardless of what year the costs are accrued, rather than prevalence-based costs. The incidence basis was selected because it best measures possible savings from prevention efforts to avoid additional fatalities (see Dickie et al., 1991), and in recent years has been widely adopted (see Miller and Galbraith, 1995; Rice et al., 1989; Leigh et al., 2000). Furthermore, an incidence basis eliminates the significant problem of estimating the varying medical costs over time associated with a prevalence basis identified by Miller et al. (1995).

The study model builds on work by Dorothy Rice (1965). However, because this new model calculates the cost of known fatalities, several assumptions were made to modify the Rice model. First, because the decedents were employed at the time of death, the participation rate in the labor force was eliminated. Because the retirement age of workers has increased over time, calculations were ceased after age 67; however, one iteration of the indirect cost calculation was performed to account for the associated loss of productivity for victims older than 67 at the time of death. Finally, current dollars were converted to constant dollars to permit aggregation across differing years of death.

Data on traumatic occupational injury deaths were extracted from the NTOF surveillance system for the years 1980 through 1997 (see NTOF, 1980–97). This census, maintained by NIOSH, collects death certificates from the vital statistics reporting units in the 50 states, New York City, and the District of Columbia on an annual basis. This system consists of all U.S. death certificates with a positive response to the "Injury at Work" item for workers 16 years of age or older for whom an external cause of death was an injury according to the International Classification of Diseases 9th edition codes E800–E999 (see World Health Organization, 1977). Only fatalities within the civilian workforce were used for this study.

Worker and case characteristics used in the model included age, sex, occupation, and race of the worker; employer industry; external cause of death; state of death; and year of death. Employment information from the death certificate was coded from the usual industry and occupation entries on the death certificate. Studies comparing the reliability of this information to that derived from personal interviews prior to death reported agreement for occupation to be 48% to 76% and 57% to 76% for industry (see Gute and Fulton, 1985; Schade and Swanson, 1988; Schumacher, 1986; Swanson et al., 1984; Turner et al., 1987). The 1987 Standard Industrial Classification system was used to group industry into individual categories (see Executive Office of the President, 1987). Occupation was categorized according to the 1980 and 1990 Bureau of the Census Occupational Classification System (see U.S. Department of Commerce, 1982, 1992).

Indirect costs were adjusted by the probability that the individual would have remained in the labor market were it not for the premature death that resulted from an occupational event or exposure. The probability estimates were developed by the National Center for Health Statistics, Division of Vital Statistics. This agency used data from the 1990 Census of population and deaths occurring in the United States to U.S. residents for three years, 1989–91 (see U.S. Department of Health and Human Services, 1997). These current life tables were based on a complete count of resident deaths in the United States during those years. Separate probabilities were calculated for each sex by selected race categories—black, white, and other. The initial survival table presented the number of persons in the sample surviving to exact age x. The percent of persons who, having attained age x, will survive to age $x + t$ was calculated by dividing $x + t$ by x and multiplying by 100.

The wage component of the cost model consists of four parts: base wage, benefits, economy-wide productivity growth, and life-cycle wage growth. The base wage for this model is an estimate of expected value of the earnings of the decedent established by the decedent's occupation at the time of death. Because of the lack of detailed information, the model assumes that the decedent had worked full-time in that occupation and would not have changed jobs between the time of death and retirement age.

Base wages were derived from the Current Population Survey (CPS), a monthly household survey of the noninstitutional population 16 years of age collected by the Bureau of the Census for the Bureau of Labor Statistics (BLS) (see U.S. Department of Labor, 1980–98). This population-based survey includes wage and salaried workers, the self-employed, and all agricultural workers. These data were presented in current dollars and adjusted for inflation using the All Urban Consumer Price Index (CPI-U) for a base year of 1999 (see U.S. Department of Labor, 2000). Occupation and industry are classified using the *1980* and *1990 Census of Population: Alphabetic Index of Industries and Occupations* from the Bureau of Census (see U.S. Department of Commerce, 1982; 1992). Base wages were defined as median annual earnings before taxes and other deductions. The values were enumerated by detailed occupation, sex, and age. Where data were not available for a specific detailed occupation, wages from the next hierarchical level were substituted.

The second component of wages, the value of employee benefits, was added to the base wage to more closely represent the market value of the worker. These data were taken from the U.S. Chamber of Commerce annual survey of employee benefits administered to a sample of employers based on the distribution of U.S. employment (see U.S. Chamber of Commerce, 1981–96). Benefits were presented as a percent of payroll for this study that included the employer's share of legally required payments, retirement and savings plan payments, life insurance and death benefits payments, medical and medically related benefit payments, and miscellaneous benefit payments, such as employee education expenditures, child care, and discounts on goods and services purchased from the company by the employee. To avoid double counting, categories of paid rest periods, lunch periods, wash-up time, travel time, clothes changing time, get-ready time, and so on, and payments for time not worked, such as paid vacations, holidays, sick leave, or State or National Guard duty are excluded. These values were presented as nominal before-tax dollars for each industry group. The benefit amounts were adjusted for inflation to a base year of 1999.

The Employment Cost Index (ECI) was employed to estimate the amount that wages rose in concert with U.S. productivity growth (see U.S. Department of Labor, 2000). The ECI measures the change in the cost of labor and includes both changes in wages and salaries as well as employee benefits costs.

Finally, estimates of the life-cycle growth, or the salary growth due to experience of the individual worker, were derived. This rate was based on mean wages from the historical income tables of the CPS for the years 1967 through 1998 (see U.S. Department of Labor, 1967–98). Mean wages were presented in constant dollars by sex, race, and age group for each year. The rate of change for mean wages was determined for each sex and race within a specific age group. The wage for the initial age group (x) was subtracted from the wage of the next age group ($x+1$) and divided by the initial age group wage: $[(x+1)-x]/x$. This process was repeated for both males and females within each race category. For this study, it was assumed that the salary growth rate is constant within age groups (i.e., equal increments for each year of age within that age group).

Two assumptions were made concerning wage growth for this study. First, the numbers of deaths were assumed to be approximately the same in each month. As a result, the wage-growth rate calculations in the first year were reduced by one-half. Second, because the model forecasts the decedent's wages for up to 50 years into the future, a long-term economic growth rate was employed.

Nonmarket losses, or lost household production, were derived from time-diary data captured in the National Human Activity Pattern Survey study commissioned by the Environmental Protection Agency (Triplett's work as cited in Expectancy Data, 2000). This two-stage Mitofsky-Waksberg random digit telephone dial sample design was used in the survey that covered the period from 17 September 1992 to 1 October, 1994. Quarterly samples, stratified by the four major census regions (Northeast, Midwest, South, and West) and day of week (weekend versus weekday), were drawn with a total sample of 14,908 households yielding 9,386 interviews. The University of Maryland's Research Center conducted the survey interviews and requested the following for each activity the respondent performed during a 24-hour period: start and end time of the activity, actual description of the activity, location where activity occurred, and whether smoking occurred during the activity. The activities were initially coded into 11 broad categories and then into 91 micro-categories and 82 locations. Expectancy Data regrouped these data into five super-categories: household production, providing care, hygiene and personal care, leisure, and employment and education (Expectancy Data, 2000). Further refinement classified these categories into economic allocation of work and leisure. Finally household production time was defined as activities that could produce benefit for all members of the household—housework; food cooking and cleanup; outdoor chores, plants, and animals; home and auto maintenance; and obtaining goods and services. Providing care includes child care, child guidance, playing with children, transporting children, and providing care to others. This subcategory was defined as the time spent providing services that are channeled toward one or more persons. The market replacement value of this time was reported in 1998 dollars and based on the hourly wages plus the employer's legally required benefit costs from the BLS Occupational Employment Statistics (OES) survey and the employer compensation cost report. Values of time for each subcategory were from a shorter list of the OES occupations that more accurately correlate with those activities involved in household production or providing care. Finally, daily values were distributed by age and sex for each subcategory (Expectancy Data, 2000). For this study values of household production and providing care were combined within each age and gender category and multiplied by 365 to obtain annual values. Dollar values were adjusted for inflation using the CPI-U.

For public health evaluations, which normally assume a societal perspective, the social discount rate—the rate at which society as a whole is willing to exchange present costs for future benefits—is appropriate. This implies that the discount rate should be consistent with the shadow-price-of-capital or the real riskless rate (see Lipscomb, 1989). However, the value of the real riskless rate is difficult to determine. Over the years, discount rates selected for social analysis have varied from 1% to 10% (see Rice et al., 1989; U.S. Department of Health and Human Services [DHHS], 1996), with the most common rate being 5% (see Haddix et al., 1996). The Panel on Cost-Effectiveness in Health and Medicine (the Panel), under the auspices of the Public Health Service, recommended a 3% real discount rate, a rate exclusive of adjustment for inflation. The World Bank in 1993 concurred, stating that this rate represented only the time preference (see DHHS, 1996). Because this rate is suggested for all agencies within DHHS Human Services, it was selected for the initial calculations in this model. As was the case in determining the value of the discount rate, the recommendations of the Panel were accepted for this study and a constant discount rate employed. Additionally, for these calculations, cash flows were assumed to occur at the beginning of each time interval.

The single nominal value for medical costs in 1998 dollars of $11,276 was obtained from the Detailed Claims Information (DCI) database from the National Council on Compensation Insurance (see Detailed Claims Information, 1992–95). This database provides estimates of the costs of injury and fatality to workers based on a nationally representative sample. The administrative data collected from state workers' compensation experiences contain information on injuries with lost workdays and fatalities. Because each state varies in the requirements for workers' compensation payment, the number of days lost prior to inclusion in this database ranges between two and seven days. However, this limitation does not affect the reporting of information for work-related fatalities. For this study, the mean medical costs for fatalities over a four-year period from the DCI was used. The dollar value was adjusted to 1999 dollars using the CPI-Medical Care Index (see U.S. Department of Labor, 2000).

B. *Computer Application Program*

A PC-based computer application program was developed for users with minimal computer skills. The cost model contains an initial selection screen that includes eight variables. Options for each variable selected from the initial screen will appear on subsequent individual screens. The options selected and the numbers of subjects fitting the requirements of that query are displayed prior to calculation. This allows the user to revise the query or run the calculation for the current number of subjects. The last screen displays the options chosen for inclusion in the query and the results of the cost calculation. These values include the number of subjects meeting the query criteria, the total cost for those fatalities, the mean cost per fatality, and the median cost per fatality.

Updates and modifications to the calculations are easily implemented because each element required for the cost calculation is stored as a separate database. For example, wages and benefits can be updated by adding an additional column of data to the existing file or replaced completely by changing the address found in the execution program. Updating information on traumatic occupational fatalities is accomplished in a similar manner. The program can express the cost estimates in dollar values ranging from 1980 to 2000 constant dollars. The program can employ various discount rates to accommodate either differing assumptions concerning the value of time, changes in the economy that would alter the "true" value of time, or to conduct sensitivity analyses.

III. RESULTS

The overall goal of this study was to produce a user-friendly computer program capable of producing reliable lifetime cost estimates of work-related fatal injuries. It was not intended to be a study or analysis of the cost estimates. Therefore the following is meant to serve only as a cursory analysis of cost estimates for selected major categories. Future studies will be responsive to the need for a thorough investigation of the relationship between the cost of fatalities and the associated characteristics as well as trend analysis.

Over the 18-year period from 1980 through 1997, NTOF reported 103,845 traumatic occupational injury deaths, ranging between the high of 7,330 in 1980 and the low of

TABLE 1
Number and Lifetime Cost of Occupational Fatal Injury by Year, 1980–97 (1999 Dollars)

Year	Number of Fatalities	Total Cost	Mean Cost	Median Cost
All years	103,845	$83,223,558,201	$801,421	$816,811
1980	7,330	5,746,797,124	784,011	817,044
1981	7,054	5,558,069,620	787,932	818,259
1982	6,372	5,073,054,964	796,148	821,612
1983	5,781	4,702,801,951	813,493	837,426
1984	6,109	5,005,221,956	819,319	843,323
1985	6,180	5,051,786,006	817,441	825,959
1986	5,616	4,649,387,226	827,882	841,014
1987	5,808	4,683,265,936	806,347	827,922
1988	5,707	4,603,599,038	806,658	819,298
1989	5,671	4,623,822,358	815,345	823,646
1990	5,382	4,353,889,817	808,972	809,133
1991	5,215	4,173,042,657	800,200	813,679
1992	5,031	4,001,006,167	795,271	791,602
1993	5,281	4,281,898,909	810,812	821,672
1994	5,399	4,286,275,028	793,902	795,507
1995	5,307	4,248,739,603	800,592	807,296
1996	5,320	4,085,623,575	767,974	772,127
1997	5,282	4,095,276,266	775,327	780,902

5,031 in 1992 (Table 1). The total lifetime cost to society of these premature deaths ranged from the highest burden in 1980 at nearly $6 billion to the smallest burden in 1992 at just over $4 billion. The total cost for all 18 years was about $83 billion (1999 dollars). Generally, the higher the number of fatalities, the greater the societal burden. However, an examination of the mean cost of a fatality illustrates that this is not always the case.

Overall the mean lifetime cost for the period was $801,401, and the median was $816,811. The mean costs ranged from $767,974 in 1996 to $827,882 in 1986, and the median costs ranged from $772,127 in 1996 to $843,323 in 1984. In all years, the median cost of an occupational fatality is less than the mean cost, which is indicative of a positively skewed distribution of the costs of an occupational fatal injury. There are outlying higher cost(s) that increase the mean value above the median departing from the symmetrical distribution where the mean equals the median.

A. *Gender, Race, Age*

The estimated cost—including total, mean, and median—of fatal occupational injuries to females was lower than those to males (Table 2). This pattern persisted in each of the years estimated. However, the difference between the male and female mean cost diminished by nearly 10% in the latter years. Those decedents identified as white experienced the highest total lifetime costs for these years. Total costs ranged by race from a low of just under $0.5 million for the Native American classification to just over $68 billion for the white classification. However, the mean costs showed a somewhat different pattern. The overall estimated costs for those decedents classified as Other or Asian Pacific Islanders were the highest at $853,345 and $833,813 respectively. Overall, mean, and median costs for the black and Native American classifications were lower than the white classification. Because nearly 10% of the fatalities did not have a race identified on the source documentation, and the classification structure changed in 1990, these estimates by race are suspect.

The greatest number of fatalities occurred in the 25–34-year-old age group, as did the highest total lifetime cost. The fewest number of fatalities occurred to those in the 16–19-year-old age group, and the lowest total cost was found in the 65-and-over age group. The highest mean and median costs were associated with the 35–44-year-old group and the lowest for the

TABLE 2
Number and Lifetime Cost of Occupational Fatal Injury by Demographic Characteristics, 1980–97 (1999 Dollars)

Characteristic	Number of Fatalities	Total Cost	Mean Cost	Median Cost
Total	103,845	$83,223,558,201	$801,421	$816,811
Sex				
Male	96,957	77,901,817,223	803,468	818,190
Female	6,882	5,315,339,295	772,354	795,887
Unknown	6	6,401,684	1,066,947	864,907
Age group				
16–19 years	3,683	2,636,627,708	715,891	706,512
20–24 years	10,791	9,263,994,709	858,493	830,578
25–34 years	26,390	26,599,979,757	1,007,957	975,447
35–44 years	22,881	23,687,696,967	1,035,256	992,166
45–54 years	18,213	14,492,010,950	795,696	757,997
55–64 years	14,108	5,998,516,188	425,185	408,017
Over 65 years	7,779	544,731,922	70,026	56,013
Race				
White	84,533	68,276,526,331	807,691	828,586
Black	11,457	8,611,670,640	751,651	770,239
Hispanic	3,801	3,009,934,345	791,880	795,538
Native American	532	426,901,709	802,447	781,162
Asian Pacific Islanders	1,956	1,630,937,593	833,813	810,073
Other	671	572,594,197	853,345	816,373
Unknown	895	694,993,382	776,529	774,748

Note: Data for the Hispanic category were only available for 1980–89.

65-and-over age group. The disparity of cost between age groups was substantial, with the lowest mean cost being only 7% of the highest mean cost.

B. *Industry and Occupation*

During this time period, the highest total lifetime costs of traumatic occupational injury was seen in the construction industry—nearly $16 billion, or almost 20% of the overall burden both in costs and number of fatalities (Table 3). An additional 15% of the overall cost and number of fatalities was found in the transportation and public utilities industry division. In every industry division, with the exception of the agriculture, forestry, and fishing industry, the proportion of all fatalities mirrored the proportion of overall costs. For the agriculture industry, workers experienced 11% of the overall fatalities but contributed only 7% to the overall costs. Of all the industry divisions, only the agriculture, manufacturing, and retail trade industries had lower overall industry mean lifetime cost. The mining industry experienced the highest mean lifetime cost of an occupational fatal injury—just over $1 million per fatality.

The total lifetime cost of traumatic occupational fatal injury for these years ranged from just over $1.5 billion for those employed in clerical occupations to nearly $20 billion for those employed in precision production, craft, and repair occupations (Table 4). The classification with the second highest total cost of just over $15 billion, transportation and material-moving occupations also experienced the second highest number of fatalities. The highest mean lifetime costs were among those employed in technicians and related support occupations. This mean cost was 2.5 times greater than the mean estimated cost for farming, forestry, and fishing occupations (farmers), which was the lowest for all categories.

C. *External Cause of Death*

Motor vehicle incidents had the highest overall total lifetime costs of fatal injury, accounting for nearly 25% of the burden for

TABLE 3
Number and Lifetime Cost of Occupational Fatal Injury by Industry Division, 1980–97 (1999 Dollars)

Industry Division	Number of Fatalities	Total Cost	Mean Cost	Median Cost
All divisions	103,845	$83,223,558,201	$801,421	$816,811
Construction	19,170	15,917,738,098	830,346	842,862
Trans/comm/PU	17,476	15,680,469,147	897,257	922,260
Manufacturing	15,484	12,206,127,133	788,306	797,127
Ag/for/fish	11,795	5,843,804,033	495,448	555,371
Services	11,356	9,406,516,203	828,330	809,011
Retail trade	9,728	7,188,333,398	738,932	733,595
Public admin	4,839	4,678,007,851	966,730	1,057,704
Mining	4,314	4,390,847,244	1,017,813	1,064,300
Wholesale trade	2,997	2,477,274,588	826,585	877,808
Finance/insur/RE	1,428	1,199,814,722	840,206	854,756
Nonclassified	5,258	4,234,625,791	805,368	836,279

TABLE 4
Number and Lifetime Cost of Occupational Fatal Injury by Occupation Division, 1980–97 (1999 Dollars)

Occupation Division	Number of Fatalities	Total Cost	Mean Cost	Median Cost
All divisions	103,845	$83,223,558,201	$801,421	$816,811
Crafts	21,407	19,356,343,770	904,206	955,116
Transport	18,238	15,049,152,311	825,154	903,580
Farm/for/fish	13,577	6,551,602,045	482,552	571,101
Laborers	11,293	7,647,679,457	677,205	730,276
Service	7,449	5,615,857,187	753,908	731,256
Sales	7,129	5,364,290,283	752,460	775,943
Exec/admin/mgr	6,591	7,023,663,300	1,065,645	1,185,763
Machine operators	5,010	3,822,755,122	763,025	841,075
Prof/spec	4,187	4,581,711,979	1,094,271	1,181,134
Tech/support	2,686	3,342,821,218	1,244,535	1,238,952
Clerical	2,132	1,608,459,989	754,437	830,108
Miscellaneous	1,528	1,200,485,672	785,658	916,711
Unknown	2,618	2,058,735,866	786,377	834,134

all incidents during 1980–97 (Table 5). An additional 8% of the overall burden is associated with the remaining three transportation incident categories (air, rail, and water) accounting for just under $8 billion dollars. The category of homicide had the second highest total costs at about $11.5 billion. The estimated mean cost of the air transportation incident category was $1.2 million, a value higher than any other single category.

IV. DISCUSSION

A. *Comparative Studies*

Because these estimates are derived from existing theory, it is important to determine if these costs are similar in magnitude to those derived by comparable studies. Unfortunately, there are few studies that are comparable. Most studies do not calculate separate mortality and morbidity estimates, separate injuries and illnesses estimates, and employ the cost-of-illness method together. However, where comparisons could reasonably be made, estimates from this method are well within the norms of previous research efforts. The following examples demonstrate the complexities of comparing estimates and explanations for differences in values between this study and prior work.

In 1989, one of the first studies using the cost-of-illness approach in public health was

TABLE 5
Number and Lifetime Cost of Occupational Fatal Injury by External Cause of Death, 1980–97 (1999 Dollars)

External Cause of Death	Number of Fatalities	Total Cost	Mean Cost	Median Cost
All causes	103,845	$83,223,558,201	$801,421	$816,811
Motor vehicle	24,385	19,613,150,003	804,312	856,217
Homicide	14,421	11,594,987,379	804,035	790,859
Machine	13,488	8,985,882,146	666,213	710,228
Falls	10,236	7,625,375,450	744,957	783,861
Electrocution	6,735	6,217,501,069	923,163	921,114
Struck by falling object	6,621	4,991,308,569	753,860	769,254
Air transportation	3,581	4,354,159,060	1,215,906	1,247,981
Suicide	3,570	3,008,704,399	842,774	840,729
Other	3,133	2,262,204,483	722,057	754,231
Nature/environment	2,687	1,932,263,422	719,116	750,658
Explosion	2,512	2,251,889,972	896,453	908,202
Caught by flying object	2,370	1,867,734,129	788,073	797,872
Water transportation	1,948	1,653,005,348	848,565	749,711
Suffocation	1,895	1,540,595,461	812,979	815,689
Fires	1,710	1,402,494,593	820,172	862,321
Poisoning	1,606	1,435,284,661	893,702	873,045
Drowning	1,496	1,190,821,226	796,003	774,148
Rail transportation	731	713,336,296	975,836	961,545
Unknown	720	582,860,539	809,529	830,166

presented to Congress (see Rice et al., 1989). The Rice estimates differ from estimates reported in this study for a number of methodological reasons. The 1985 estimates include additional direct costs that were not included in this study (such as administrative costs and legal costs), used different sources of data, and based the value of household production on the prevailing wage for the task rather than the opportunity cost to the decedent. Additionally, the study employed annual mean earnings of the decedent that were not linked to the occupation of the decedent. Depending on the overall distribution of lower-income workers, this could have a significant influence on the total cost estimates. In addition, as evidenced in the CPS, annual mean earnings are typically much higher than median earnings that were employed in this study. Furthermore, Rice recognized and documented that the mortality cost may be overestimated for decedents with lower than average earnings. The Rice study was also used to estimate the cost of all fatal injuries, not just work-related deaths. Finally, estimations were calculated in the aggregate and then divided by the estimated number of fatalities.

A 1988 study (see Neumark et al., 1991) estimated the value of fatal occupational injuries and illnesses in Pennsylvania using the cost-of-illness method. Neumark altered the retirement age, productivity growth, and the discount rate to develop three distinct estimates—$296,000, $388,000, and $511,000 per fatality in 1992 dollars. None of the discount rates or the retirement ages selected mirrored the data used in this study's model. The Neumark study also differed because it included fatal occupational illnesses and made no adjustments for individual salary growth. Despite these differences, 1992 dollar estimates derived from this study's model, which ranged from $343,287 to $513,088 per fatal occupational injury using a 5% and 10% discount rate, respectively, compare favorably to the Neumark et al. study.

The state of New Jersey estimated the cost of occupational injury fatalities for 1992 at just over $1 million per fatality (Roche, 1995). This number is substantially higher than the estimate produced by this study. One explanation is the use of New Jersey–specific costs, which are substantially higher than national costs. New Jersey employed an upward adjustment of 1.333. Considering the increase in the initial wages of the decedent, the overall impact on the final estimate will exceed that of the 1.333 adjustment factor. Additionally, the study did not account for the probability of survival from one age to the next. Furthermore, the study used wage data that was specific to age and sex but not to occupation. Age, sex, and occupation characteristics associated with fatalities within a specific state may differ from the national distribution. Depending on that distribution, the estimates could be biased either upward or downward. Finally, as seen in the prior studies, Roche included additional direct costs increasing the overall value by an estimated $30,000–$40,000 per fatality.

The National Safety Council (NSC) estimated that a fatal occupational injury cost $890,000 in 1997 (see NSC, 1998). This estimate includes a number of additional direct costs, which include administrative expenses, property damage, police costs, travel delay costs, and employer costs for productivity losses. The indirect costs were calculated in a similar fashion; however, the NSC used different data sources that could also lead to differing cost estimates. Finally, because the cost per fatality is disaggregated from an overall cost to society, the number of fatalities included in the estimate could bias the estimates upward.

More recently, Leigh et al. (2000) developed cost-of-illness estimates for occupational injury and illness. This study presented an indirect cost estimate for an occupational fatal injury using 1992 dollars of $578,638. Using this study's model, the cost per indirect cost of an individual occupational traumatic fatal injury was $665,921. Although a 15% disparity, the cost is within reasonable expectations when applying the same basic methodology. As discussed in the prior comparisons, the methodological differences between Leigh's study and this study's model—sources of data, assumptions regarding the level of wages and benefits—account for this magnitude of cost differences.

In addition to specific studies, there is also anecdotal evidence that suggests that estimates from this study's model are reasonable. For example, the highest costs are those associated with airline incidents. This high mean cost bears out the assumptions in a 1988 RAND study (see King and Smith, 1988), that those traveling on airlines tend to have higher wages and hence higher costs.

B. Study Limitations and Future Research Needs

Although the underlying theoretical approach of the model presented in this study is easy to understand and relatively easy to calculate and the necessary data are inexpensive to acquire, it is not without limitations. The human capital measure is often criticized because it ignores one of the fundamental constructs of economic theory—the individual's preferences. Another concern of this approach is the reliance on the market earnings to represent the value of life. Using these values underestimates the value of most working minority groups and youth, if the market failures or imperfections result in an inefficient distribution of wages and salaries. If earnings are lower for a specific age group, ethnicity, or sex—such as lower wages for black compared to white workers in the same occupation—this deviation will be incorporated into the human capital measure. However, employing this theoretical model is equally (if not more) appropriate than any of the competing economic theories of valuation that have different limitations.

The model produces a conservative, if not lower-bound estimate for lifetime economic costs of traumatic occupational fatalities. This is in part due to limitations in the specification of the model and limitations associated with the data. This study does not provide a "complete" cost of occupational fatalities in that intangible losses that are associated with premature death are not included. Although intuitively appealing, the costs of these losses—pain, suffering, and emotional damage to the injured and the family—are immeasurable (see Fahs et al., 1989). Despite the claim that these losses cannot be measured, some researchers have incorporated these costs into a human capital framework using the willingness-to-pay approach (see Miller et al., 1995). However, by including such estimates, willingness-to-pay and human capital theoretical models may be inappropriately intertwined.

Many of the limitations of this study are associated with wage data or model specification for wage calculation. Second- or multiple-job information for the decedent is not available on the source documentation; therefore the wage calculations do not account for these additional losses. The wage calculations do not include a mechanism for identifying changes in career that may have occurred had the worker lived. Because of these limitations, this model will underestimate the full economic loss of premature traumatic occupational fatalities. Improvements in the wage data should include employing state-specific estimates, values for multiple-job holders, and age-specific estimates. Additionally, the accuracy of the estimates would benefit from a comprehensive analysis of the career growth rate estimates. A longitudinal cohort study would shed needed light on the best method of deriving these estimates for the overall population.

Use of time diaries may introduce additional study limitations. Although they have been shown to produce reliable estimates, they may have questionable validity because they rely on self-reported data (see Robinson and Bostrom, 1994). For example, some respondents may report nonwork activity undertaken during working hours as a nonwork activity, whereas others perceive that same activity as a work activity. However, the alternative estimation technique, direct questions about the use of time, also suffers from limitations. For example, recall bias can contribute to lower estimates if the activity in question occurs infrequently.

Employing a minimal number of direct cost categories in the model also contributes to the conservative nature of these estimates. Additional direct cost categories were intentionally excluded because of their individual limitations. For example, the most recent estimates for administration costs available at the time of model specification dated to work done in the 1980s. Exploration of improving or updating the estimations for legal and administration costs, property damage, travel delay costs, and funeral and coroner costs should be undertaken. Furthermore, medical costs used for this study were a three-year average of workers' compensation claims from a sample of states. A thorough examination of alternative sources is required to improve the accuracy of the costs.

General discussions among cost-outcome researchers have evoked concern about the accuracy and appropriateness of using a cross-sectional cohort to estimate the probability of survival. The Social Security Administration has conducted some preliminary work to address this criticism by calculating probabilities based on a longitudinal study (Miller, personal communication). As these studies progress further, exploration for this application should be undertaken.

Finally, there are two national systems that compile traumatic occupational fatal injury data: NTOF and the BLS Census of Fatal Occupational Injuries (CFOI) program. Research has shown that NTOF and CFOI vary in the characteristics of the decedents (see Biddle and Marsh, 2002), which will likely affect cost estimates. Therefore, this Model should be expanded to calculate the lifetime costs of CFOI fatalities.

V. CONCLUSIONS

This work provides NIOSH and the safety and health community with the ability to derive the cost of occupational fatal injury by the attributes of the deceased worker and by characteristics surrounding the fatal incident on a continuing basis. The coding schemes used by NTOF permit examination of an enormous combination of characteristics and make estimates at a detailed level possible. Furthermore, the model derives the economic burden by using a bottom-up approach—summing the cost of each individual fatality based on the characteristics of the decedent—thereby providing a more accurate means of describing the burden and thus targeting research and prevention efforts.

Despite the limitations of this study, the cost estimates derived have substantial practical value. In general, cost estimates provide additional information about how injuries affect society. They represent income that is not received and medical expenses incurred because of fatal injuries and may be compared to the gross domestic product and other national economic measures. These estimates can be used to improve occupational injury prevention and control program planning, policy analysis, evaluation of safety and health interventions, and advocacy for a safer work environment.

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