Projected Incidence and Cost of Tractor Overturn-Related Injuries in the United States

M. L. Myers, H. P. Cole, S. C. Westneat

ABSTRACT. *In 2004, the Agricultural Safety and Health Centers, supported by the National Institute for Occupational Safety and Health, launched an initiative to conduct research on the consequences of and approaches to control of agricultural tractor-related injuries. The most significant cause of fatal injuries is associated with tractor overturns, and a recognized intervention to control these injuries is equipping the tractor with a rollover protective structure (ROPS). The purpose of this study was to determine the incidence of tractor-related fatal and nonfatal injuries and their social costs. Based upon the annual average incidence of 125 tractor-overturn-related fatalities in the U.S. for the period 1992 to 2002, an analysis was conducted of injuries over the 25-year period 1997 to 2021. Using the number of fatalities as an index value, the analysis found that in 1997, there were a total of 2,412 tractor overturns. These overturns were associated with 125 deaths and 573 nonfatal injuries requiring at least outpatient treatment. Compared to ROPS-equipped tractors, 123 (98.6%) deaths and 543 (95%) of nonfatal injuries were associated with non-ROPS tractor overturns. The undiscounted social cost of these injuries totaled $1.5 billion in 2006 dollars for the 25-year period when using cost factors for the agricultural population. When discounted at 3%, this total was $1.1 billion, and when discounted at 5%, it was $0.9 billion. In an alternative analysis, when using cost factors for all occupations including agriculture, the undiscounted social cost totaled $2.9 billion, $2.1 billion when discounted at 3%, and $1.7 billion discounted at 5% for the 25-year period. Non-ROPS tractors as compared to ROPS-equipped tractors account for at least 97% of the costs, no matter the discount rate or cost factors used.*

Keywords. *Cost, Fatalities, Injuries, Overturns, Tractors.*

The industry sector that includes agriculture, forestry, fishing, and hunting had the highest rate of fatal occupational injuries of all sectors, at 32.5 fatalities per 100,000 employees (714 deaths) in 2005. For the same year, this compares to the next highest rate of 25.6 fatalities per 100,000 employees in mining (159 deaths) and 4.0 fatalities per 100,000 employees (5,702 deaths) for all sectors, as shown in figure 1. Self-employed workers were covered as employees in the calculations. The agriculture,

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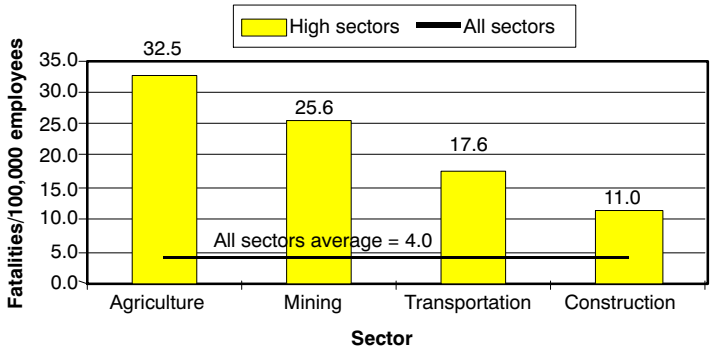

Figure 1. Rate of U.S. occupational fatalities by the highest industrial sectors, 2005 (source: BLS, 2005).

forestry, fishing, and hunting sector accounted for 12.5% all occupational fatalities in 2005 (BLS, 2005).

Consistently, the largest source of fatal occupational traumatic injury has been farm tractors (Hard et al., 2001). In 1971, James F. Arndt of John Deere estimated that 30,000 farmers had been killed in tractor-related incidents in the previous 50 years. The leading cause of these fatalities was tractor overturns. During the 10-year period of the mid-1950s to the mid-1960s, about 500 overturn-related fatalities occurred annually (Jackson, 1985). As rollover protective structures (ROPS) came into use on tractors, a proven intervention to virtually eliminate these deaths, the number of fatalities was reduced (Myers, 2000). During the period 1985 to 1995, National Safety Council data indicated that about 200 fatal injuries occurred annually related to tractor overturns (NSC, 1997).

According to the U.S. Department of Labor's Census of Fatal Occupational Injuries (CFOI), over the 11-year period 1992 through 2002, 2,914 workers were killed (an average of 265 deaths per year) in tractor-related incidents. Of these incidents, an average of 125 fatalities per year were attributed to overturns (including non-highway and highway), as shown in figure 2, totaling 1,373 deaths for the 11 years.

Past estimates of the costs of injuries depended on a classification of fatal and nonfatal injuries (Myers and Pana-Cryan, 2000; Pana-Cryan and Myers, 2000; Myers et al.,

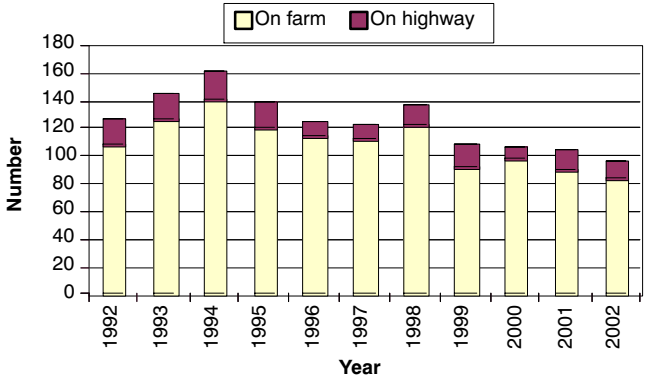

Figure 2. Fatal occupational injuries involving agricultural tractor overturns (source: BLS, 2005).

Table 1. Nationwide direct and indirect costs of fatal and nonfatal injuries for all occupations and for agricultural occupations, adjusted for inflation.

	1997 Dollars		2006 Dollars	
	Fatal ($)	Nonfatal ($)	Fatal ($)	Nonfatal ($)
All occupations (Leigh et al., 2000)				
Direct costs	33,850	8,819	42,793	42,797
Indirect costs	682,589	25,028	862,925	485,067
Total	716,439	33,847	905,718	527,864
Agriculture (Leigh et al., 2001)				
Direct costs	33,853	1,729	42,797	2,186
Indirect costs	363,695	10,551	485,067	13,339
Total	397,548	12,280	527,864	15,524
Agriculture (NIOSH, 2006)			573,632	N/A

2004). An example of these estimates for occupational injuries and separately for agriculture-related injuries nationwide is shown in table 1.

The cost factors shown in table 1 have been used in the cost of illness (injury) approach. Direct costs include lifetime medical, insurance administrative, property damage, police and fire service, injuries to third parties, and funeral and burial expenses. Indirect costs include lost earnings, household production, fringe benefits, and time-loss.

In 2001, investigators at the University of Kentucky conducted a random sample survey of 6,063 Kentucky farms (Cole et al., 2006a; Myers et al., 2006). The nonfatal injuries in table 2 include injuries that required at a minimum outpatient care; they do not include minor injuries for which medical care was not provided. The sample represented 7.98% of Kentucky farms and was drawn from the Kentucky Agricultural Statistics Service's 1997 Census of Agriculture list of Kentucky farms. Data collected included the number of overturns and whether an injury occurred as a result, and detailed the severity of the injury, e.g., fatal. As shown in table 2, data were segmented by ROPS-equipped tractors and tractors that had no ROPS (non-ROPS).

As can be seen in table 2, the more serious event (fatality) was smaller by an order of magnitude than the next event (nonfatal injury) and so on (minor or no injury). This proportion was described as a triangle by Herbert W. Heinrich of Travelers Insurance in 1926, with the least number of fatal injuries at the point of the triangle (Aldrich, 1997; Cole et al., 2006b). Heinrich's triangle is illustrated in figure 3.

The proportion across rows may be biased between ROPS-equipped and non-ROPS tractors because tractors from the period of time before ROPS technology was available were included in the numbers. In Sweden, where ROPS were mandatory and with 98% compliance in 1990, tractor overturn-related fatalities were reduced 56-fold, from 17 to 0.3 deaths per 100,000 tractors annually between 1960 (pre-ROPS period) and 1990 (Springfeldt, 1998). Based on the Swedish (Springfeldt et al., 1998) and Kentucky data

Table 2. Tractor overturn injury event proportions in Kentucky from an 8% sample of farms, *n* = 6,063 (source: Cole et al., 2006a).

	ROPS-equipped		Non-ROPS		Total	
Event	Number	Percentage	Number	Percentage	Number	Percentage
Fatal injury	1	1.12	24	5.42	25	4.70
Nonfatal injury	15	16.85	107	24.15	122	22.93
Minor or no injury	73	82.02	312	70.43	385	72.37
Total overturns	89	100.00	443	100.00	532	100.00

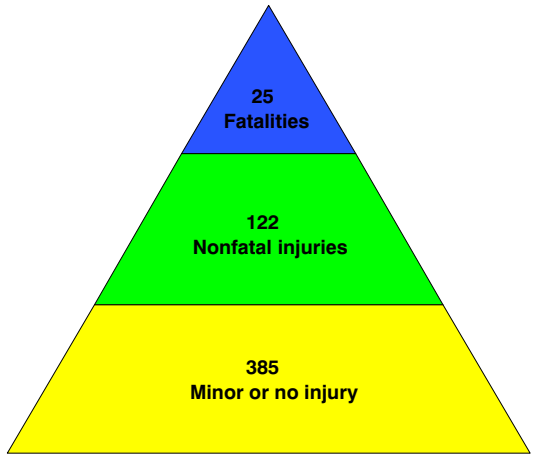

Figure 3. Heinrich triangle of injuries associated with tractor overturns.

(Myers et al., 2005), the proportion of deaths from ROPS-equipped to non-ROPS tractors was 1 to 83. This proportion was based on the probability of death associated with, respectively, ROPS-equipped and non-ROPS tractor overturns.

The NIOSH Agricultural Safety and Health Centers launched an agricultural tractor safety initiative in 2004 (Swenson, 2004). One of the recommendations was to "identify 'full costs' of injuries/fatalities to farmers, ranchers, employers, employees, families, and communities." In 2005, NIOSH funded projects as part of a tractor safety initiative for a two-year period, 2006 to 2007. One of the projects was entitled "Costs of Tractor Operator Injuries from Overturns and Highway Collisions." One purpose of this project was to determine the incidence of farm tractor overturn injuries and to calculate the social cost of these events. The purpose of this article is to report estimates of the incidents of overturn-related injuries and the cost of fatal and nonfatal injuries related to tractor overturns.

Method

The fundamental method is to determine the social cost of tractor overturns to the nation by multiplying the annual number of nonfatal and fatal injuries associated with tractor overturns nationwide by the direct and indirect costs of these injuries. The analysis is indexed to the national average number of fatalities per year associated with tractor overturns for the years 1992 to 2002, with the median year 1997 used as the base year for the analysis.

A Kentucky study conducted in 1997 collected the tractor-related data used to determine the number of nonfatal injuries for this analysis (Cole et al., 2006a; Myers et al., 2006). These data are used to derive a Heinrich proportion of fatalities to nonfatal injuries to minor or no injuries associated with tractor overturns. This proportion is mapped against the average number of fatalities nationwide in order to estimate the annual number of nonfatal injuries in the nation for the base year 1997.

Two corrections are made to the first step in generalizing the proportions of fatal to nonfatal injuries in the nation. A second step adjusts the proportion between ROPS-equipped and non-ROPS tractors for the probability-based relationship regarding the potential for death given a tractor overturn (a ratio of 1:83). In addition, since the

proportions are different for ROPS-equipped and non-ROPS tractors, a third step is performed to correct for the difference between the percentage of ROPS-equipped tractors in Kentucky and the nation in 1997. In that year, the nation had a 33% higher proportion of ROPS-equipped tractors than did Kentucky.

A 25-year analytic horizon is used, starting with the base year 1997 and extending to the year 2021. A 1.5% annual replacement rate of ROPS-equipped tractors with non-ROPS tractors consistent with the two NIOSH surveys is assumed to extend over the 25-year period (Myers, 2003).

The current recommended social discount rate is 3% (Biddle, 2004), yet in 1994, the Centers for Disease Control and Prevention recommended a discount rate of 5% (CDC, 1994). Consequently, a sensitivity analysis is applied with different discount rates of 0%, 3%, and 5% over this analytic horizon. To accomplish the discounting calculation, the fatal and nonfatal injuries for the 25-year analytic horizon are discounted to the base year 1997. Then the discounted injuries for the 25-year period are multiplied by cost factors from two sources to offer another sensitivity analysis regarding the value of a farmer's life and health.

The cost factors are shown in table 1 for all occupations (Leigh et al., 2000) and more specifically for agriculture (Leigh et al., 2001). Myers (2000) provides a description of these factors, their limitations, and their definitions. The cost analysis follows several points:

- The perspective is social in which all costs are included irrespective of who incurs the costs.
- The cost of injury approach is used, which excludes the cost of pain and suffering.
- The agricultural population is used to calculate the cost of injuries, which is less than that for all occupations.
- All occupations are used to calculate the cost of injuries as a sensitivity analysis to compare costs against the results for the agricultural population. Using all populations is warranted in part since, in Kentucky at least, 59% of principal farm operators have off-farm jobs and are thus employed outside of agriculture.
- No age adjustments are made within this analysis, since some ethical principles consider all human life of equal value no matter the age (Nord, 1999).
- U.S. dollars are used to measure the cost.
- Three rates (0%, 3%, and 5%) are used to discount the cost of future injuries associated with tractor overturns, e.g., today's dollar is valued more than next year's dollar.

Results

In the base year 1997 for this analysis, 2,412 tractor overturns nationally resulted in 125 fatalities, 573 nonfatal injuries that resulted in at least outpatient treatment, and 1,714 incidents of no or minor injuries. These results are shown in the table 3. Of the fatalities, 1.4% are related to overturns of ROPS-equipped tractors, and 98.6% are associated with overturns of non-ROPS tractors. Of the nonfatal injuries, 4.8% are related to overturns of ROPS-equipped tractors, and 95.2% are associated with overturns of non-ROPS tractors.

The fatal and nonfatal injuries as extended over the 25-year period from 1997 to 2021 are shown in figure 4. Over this period, tractor overturns result in 2,640 fatal and 12,286 nonfatal injuries. Fatal injuries related to overturns of ROPS-equipped tractors account for 59 deaths (2%), and 2,581 deaths (98%) are associated with overturns of non-ROPS

Table 3. Annual frequency of injuries associated with tractor overturns indexed against total fatalities and corrected for the probability of death and the national percentage of ROPS, 1997.

	Step 1: U.S., using Kentucky proportions			Step 2: U.S., adjusted for death probability[a]			Step 3: U.S., adjusted for percentage of ROPS[b]		
Events	ROPS	Non-ROPS	Total	ROPS	Non-ROPS	Total	ROPS	Non-ROPS	Total
Fatal	5	120	125	1.5	123.5	125	2.0	123.0	125
Nonfatal	75	535	610	22.2	550.7	573	29.5	543.4	573
No or minor injury	365	1,560	1,925	108.1	1,605.8	1,714	143.7	1,570.1	1,714
Total overturns	445	2,215	2,660	131.8	2,280.0	2,412	175.2	2,236.5	2,412

[a] The ratio of the probability of an overturn-related death involving a ROPS-equipped tractor to that involving a non-ROPS tractor (1 to 83).

[b] Adjusted for the difference in ROPS-equipped tractors, as a percentage, between Kentucky (29.5%) and the U.S. (44%) in 1997.

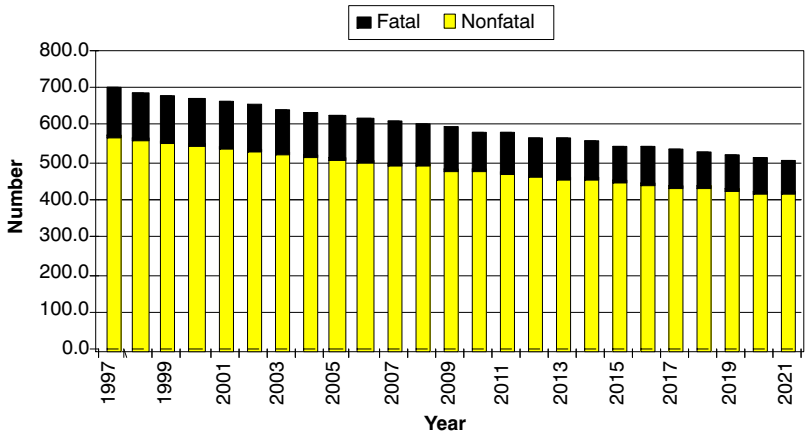

Figure 4. Number of fatal (2,640) and nonfatal (12,286) injuries associated with tractor overturns over a 25-year period based on the decline in non-ROPS tractors, 1977-2001.

tractors. Nonfatal injuries related to overturns of ROPS-equipped tractors total 888 (7%), and 11,398 nonfatal injuries (93%) are associated with overturns of non-ROPS tractors.

Table 4 shows the social costs of injuries related to tractor overturns for the 25-year period 1997 to 2021. The costs are adjusted for inflation from the base year 1997 to the year 2006 using the consumer price index. In all cases, the indirect costs exceed the direct costs for the injuries. The costs of non-ROPS tractors vis-à-vis ROPS-equipped tractors account for 97% or more of the total social costs. This high proportion of costs regarding non-ROPS tractors held true for all factors, including all three discount rates, for the two population-based costs of all occupations and agriculture, and by the total of direct and indirect costs.

Figure 5 summarizes the costs shown in table 4, which shows that the results are sensitive to discount rates and to whether all occupations or the agricultural population is selected for the analysis. The 3% discount rate reduces the total cost of $2.9 billion by 28% to $2.1 billion for all occupations, and reduces the total cost of the agricultural population from $1.5 billion by 27% to $1.1 billion. Similarly, the 5% discount rate reduces the costs, respectively, by 43% and 40%. As discussed above, non-ROPS tractors account for at least 97% of these costs.

Table 4. Cost of fatal and nonfatal injuries associated with tractor overturns in the U.S. based for the years 1997–2021, at three different discount rates, 2006 dollars in millions.

	ROPS-Equipped Tractors		Non-ROPS Tractors		Total Cost
	Fatal	Nonfatal	Fatal	Nonfatal	(% non-ROPS)
0% Discount Rate					
All occupations[a]					
Direct	$9.9	$2.5	$126.7	$110.1	$249.1 (95%)
Indirect	$28.0	$50.9	$359.5	$2,219.7	$2,658.1 (97%)
Total	$37.9	$53.4	$486.1	$2,329.8	$2,907.2 (97%)
Agriculture[b]					
Direct	$1.9	$2.5	$24.8	$110.1	$139.4 (97%)
Indirect	$11.8	$27.1	$151.5	$1,182.7	$1,373.2 (97%)
Total	$13.7	$29.6	$176.4	$1,292.8	$1,512.5 (97%)
3% Discount Rate					
All occupations[a]					
Direct	$6.8	$1.8	$92.2	$80.1	$180.8 (95%)
Indirect	$19.4	$35.3	$261.5	$1,615.0	$1,931.3 (97%)
Total	$26.3	$37.1	$353.7	$1,695.1	$2,112.2 (97%)
Agriculture[b]					
Direct	$1.3	$1.8	$18.1	$80.1	$101.3 (97%)
Indirect	$8.2	$19.8	$110.3	$860.5	$997.8 (97%)
Total	$9.5	$20.6	$128.3	$940.6	$1,099.1 (97%)
5% Discount Rate					
All occupations[a]					
Direct	$5.5	$1.4	$76.1	$66.1	$149.1 (95%)
Indirect	$15.6	$28.3	$216.0	$1,333.8	$1,593.7 (97%)
Total	$21.0	$29.7	$292.1	$1,400.0	$1,742.8 (97%)
Agriculture[b]					
Direct	$1.1	$1.4	$14.9	$66.2	$83.6 (97%)
Indirect	$6.6	$15.1	$91.1	$710.7	$823.4 (97%)
Total	$7.6	$16.5	$106.0	$776.8	$906.9 (97%)

[a] Leigh et al. (2000), adjusted to 2006 dollars.
[b] Leigh et al. (2001), adjusted to 2006 dollars.

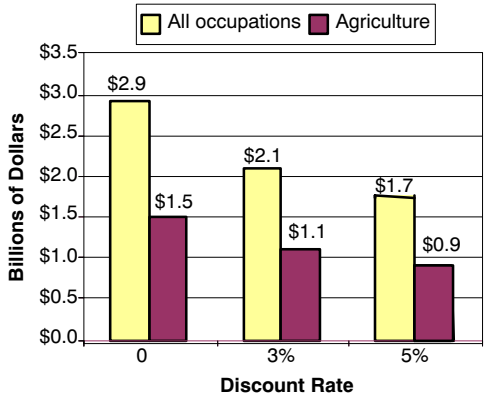

Figure 5. Social costs of tractor overturn injuries and results of sensitivity analysis of three discount rates for two sources of data, all occupations and agriculture, for the 25 year period 1997–2021.

The choice of all occupations as compared to the agricultural population as a basis of cost analysis is dramatic in its effect. The all occupations analysis, undiscounted, places the total cost at $2.9 billion, whereas when the agricultural population is used, the total is reduced by nearly half, to $1.5 billion.

Discussion

Retrofitting tractors with ROPS is shown to be a life saver and injury averter. If the $2.1 billion cost discounted at 3% for all occupations is expended on ROPS retrofits, priced at between $815 to $868 each in 2006 dollars (Myers et al., 2005), then 2.6 to 2.4 million tractors could be retrofitted, which exceeds the number of non-ROPS tractors in the U.S. Lowering the unit price would make these purchases even more attractive for saving lives and averting nonfatal injuries. A note of caution, however: this calculation does not represent a cost-effectiveness analysis, for the cost and effectiveness of implementation programs would need to be investigated. Moreover, a ROPS design is not available for all older tractors.

This analysis did not include the cost of "minor" injuries for which the tractor operator did not seek medical treatment. Farmers typically seek treatment for maladies only when the injury is serious, frequently err on the side of self-sufficiency, and forego professional medical treatment for multiple reasons, including the costs of medical care, lost work time related to travel from remote rural areas to distant health care facilities, and not infrequently the lack of health insurance. A recent study identified 107 farmers who were nonfatally injured during overturns of non-ROPS tractors. Nineteen (17.8%) did not seek or receive professional medical treatment, 24 (22.4%) were treated as outpatients, and 64 (58.8%) were admitted to a hospital. Of the 19 who received no medical care, 11 reported no lost workdays and 7 reported a temporary disability, with a mean of 4.67 work days lost. One additional individual was permanently disabled by a back injury that prevented him from ever resuming farm work. In summary, 8 of the 19 injured who did not receive medical treatment sustained temporarily disabling injuries that resulted in lost workdays ranging from 1 to 28 days lost, and one farmer was permanently disabled (Cole et al., 2006b).

The study does not differentiate the nonfatal injuries by severity. Because of the crushing-type injuries related to tractor overturns, the proportion of critical and severe injuries may be higher than were accounted for in establishing the direct and indirect costs of nonfatal injuries. Indeed, in studies of tangible damages regarding automobile crash-related injuries, a minor injury costs an average of $10,600 whereas a critical injury costs on average $1,096,200 (Blincoe et al., 2002).

The analysis also does not account for the victims that no longer farm because of the seriousness of the injury. The study population in Kentucky included current farmers and not those who have left farming. Thus, missing from the analysis are those victims no longer farming because of their self-selection out of the farming occupation, termed the "healthy worker" effect.

Previous estimates of the indirect costs of injuries include a large population of farm workers who earn lower wages and less income from off-farm jobs than is the case for farm owners and operators. This tends to lower indirect cost estimates for an agricultural injury. In Kentucky, the farmer or farm family members are typically the individuals injured in tractor overturns (table 5). An agricultural injury to a Kentucky farmer usually results in lost wages from off-farm jobs. For example, in 1997 a total of 50,494 of Kentucky's 82,273 farms (61.4%) earned $2.23 billion from off-farm wages and an additional $3.06 billion from farm product sales. Thus, in 1997 about 73% of Kentucky

Table 5. Identity, frequency, and mean age and standard deviation of Kentucky farmers who overturned non-ROPS tractors.[a]

Identity and Frequency			Age (years) Characteristics			
Identity	Frequency	Percent	n[b]	Mean	SD	Range
Farm operator	182	42.13	171	34.7	15.6	8 to 77
Family member	202	46.76	190	42.3	18.7	6 to 82
Other person	48	11.11	44	32.8	13.2	14 to 65
Totals	432	100.00	405	37.9	17.3	6 to 82

[a] Data from the January-February 2001 Kentucky Tractor Overturn Survey of a statewide random sample of 6,063 Kentucky principal farm operators.
[b] Numbers less than total because age at time of overturn was not known for all persons.

farmers' income was from non-agricultural off-farm work (USDA, 1997, 1999). It is estimated that 59% of Kentucky farmers hold off-farm jobs, with many of these being full-time jobs. Thus, the cost estimate regarding the agricultural population used in this study may undercount the cost burden to society of tractor overturn-related injuries.

Estimates of wages lost and indirect costs for fatal and nonfatal injuries to older workers are typically lower because of there are fewer years of productive life lost. Nonetheless, ethical principles argue not to devalue a life because of age. In addition, based on a USDA study from the 1999 Agricultural Economics and Land Ownership Survey, Gale (2002) reported that farm operators age 65 years and older owned 18% of U.S. farm assets, far more than any other age group. By 2002, farmers age 65 years and older owned 18.8% of the nation's farms (USDA, 2002). Gale (2002) also noted that the while the number and proportion of farm operators under age 65 years steadily declined from 1978 to 1997, the number and proportion of farmers age 65 years and older has steadily increased. He notes that older farmers generally are healthier, live longer, and continue farming into old age.

The study assigns costs to society, which includes all costs no matter who pays. It does not examine the distribution of these costs by segmenting payments made by the farmer and his/her family vs. the taxpayer, etc.

Conclusion

We found the cost in lives, nonfatal injuries, and dollars over a 25-year period from tractor overturns to be, respectively, 2,640 deaths, 12,286 nonfatal injuries, and $2.9 billion in 2006 undiscounted dollars for all occupations and $1.5 billion for the agricultural population. When discounted at 3%, these costs are $2.1 billion and $1.1 billion, respectively. Non-ROPS tractors account for at least 97% of the cost no matter the discount rate used or the population-based cost factors used.

This analysis is limited by several factors. The cost does not include minor injuries. As reported earlier, farmers' injuries for which medical care was not received are often categorized as "minor" injuries but in fact are costly. Farmers no longer farming because of a serious injury are excluded, and nonfatal injuries related to tractor overturns may have a higher severity and cost than experienced by all occupations. Furthermore, the difference between the cost of all occupations and of the agricultural population is vast, and the distribution of the costs is neither investigated nor calculated. Moreover, the cost effectiveness of a social investment in ROPS retrofits on older tractors needs to be investigated, for $2.1 billion could purchase 2.5 million ROPS retrofits, averting thousands of fatal and nonfatal injuries nationwide in years to come.

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