A COST-BENEFIT ANALYSIS OF UNITED STATES MOTOR CARRIER SAFETY PROGRAMS

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ABSTRACT

This paper contains a cost-benefit analysis of two federal programs to improve truck safety. One program involves visits by federal inspectors to the operating bases of firms to investigate safety management practices. A rating system is used to determine whether further visits are necessary, and whether enforcement and educational action are needed. The other program is a system of roadside inspections to check for compliance with federal safety laws. Vehicles and/or drivers that fail to comply are placed out-of-service until the problem is rectified.

We conclude that two thousand motor carriers a year are targeted for enforcement and education action as a result of the audit program. As a result of these actions, these firms improve their accident rate by 43%. The benefits of reduced accidents from this program exceed the costs of both the government and the firms by a ratio of over 4:1.

The same is not true of the roadside inspection program. Over 1.1 million interstate trucks a year are subjected to 30-minute inspections, and 370,000 are delayed for up to three hours while problems are corrected. Here the benefits exceed the costs by 26% under the most favorable assumptions regarding the number of accidents avoided, and the costs may exceed the benefits for more mid-range assumptions.

In addition to the direct costs and benefits, we find that there is a deterrence effect where firms improve their performance even though they have not been audited or had their vehicle(s) placed out-of-service. The deterrence effect has a credible maximum value of 50% of the direct effects of the programs, with a more plausible value of 25% of the direct effects. When the deterrence effects are considered, the ratio of benefits to costs for the audit program remains at 4:1. The inspection program has a benefit-cost ratio of 1.6:1 under the most favorable assumptions, but it is somewhat questionable whether it shows any net social benefits under more moderate assumptions.

The net social benefits from the safety programs would be even greater if resources were diverted from the roadside inspection program to the audit program. In addition, the roadside program could be considerably more efficient if the government conducted shorter inspections, at less predictable locations that focus more on the condition of the driver. However, we would recommend this only if the penalties for not complying with hours-of-service laws (the primary violation found in inspections) were made more severe.

1. BACKGROUND

The interstate trucking industry has been economically deregulated since 1980. However, the Federal Highway Administration (FHWA) continues to have control over safety standards. Indeed in the past ten years legislation has been enacted that raised minimum safety standards and made more resources available to ensure compliance with safety laws. This paper deals with two compliance programs aimed at interstate carriers. Many states have adopted similar schemes for intrastate motor carriers.

The first program involves an overhaul of the system of audits of the safety practices of firms. Starting October 1 1986, federally employed inspectors began to conduct audits of compliance with federal safety laws of the 220,000 firms (out of an interstate truck industry estimated to have of more than 250,000 firms) that had not been audited under the previous system. In 1991, 26,000 firms were audited, compared with approximately 10,000 per year under the old regime, and by early 1993 nearly 102,000 firms had been visited by the government.

The second program is a system of roadside inspections. The Motor Carrier Safety Assistance Program (MCSAP), authorized under the 1982 Surface Transportation Assistance Act, provides federal funds to states to cover 80% of the cost of motor carrier enforcement activities. These funds increased the number of roadside inspections, allowed for improved training of enforcement officers, and provided the officers with additional technical support. In 1991, 1.1 million interstate and 0.4 million intrastate carriers were stopped for 30- minute inspections at weigh stations.

This paper investigates whether these two government programs are economically worthwhile. The analysis is in two parts. The first part deals with the direct costs and benefits of the programs. These are the program costs to the government and the firms that are inspected or audited, and the measured improvement in the accident performance of firms that are found to be deficient. In general, objective fact and scientific measurement can give reasonable estimates of the magnitudes of the direct costs and benefits. The second part of the analysis deals with the "deterrence" effect. That is the voluntary, and hence more difficult to measure, improvement in safety performance by firms who observe and may respond to the increased enforcement activity, but have not themselves been subject to citations and penalties.

The cost-benefit calculations are annual figures, with all dollar figures expressed in constant 1992 prices. Figures expressed in the text have been rounded, but the unrounded numbers have been used in calculations. As is usual when calculating costs and benefits that occur in the future, adjustment needs to be made to represent time preference. The U.S. Office of Management and Budgets (1992) recommends discounting of future costs and benefits at a real rate of 7% per year.

2. THE FEDERAL SAFETY PROGRAMS

2.1 Safety Audits

Field staff of the FHWA had undertaken a limited program of safety audits for many years. The audit program was increased by the 1984 Motor Carrier Safety Act, which placed a requirement on the federal government to inspect all interstate carriers. As described in the introductory section of this paper the number of annual audits increased substantially beginning in the fall of 1986.

The inspectors visit the operating bases of firms and question managers about safety related procedures and policies such as those governing maintenance, and driver hiring and training. They do not actually inspect any equipment or test drivers. The FHWA views the initial visit to a carrier, termed a "Safety Review" or SR, as mainly educational, and has a policy of not initiating citations for violations found.

The inspectors have a list of 75 questions, grouped under nine headings. They mark a "yes" or "no" answer to each question, but can append comments and supporting documentation. The inspectors ask 13 general questions. The following is a sample question in this category: "Does the individual in charge of safety have authority to terminate drivers?" There is then one question on whether the firm has been certified by the government as having a minimum level of financial responsibility; five on reporting of accidents ("Can the carrier explain the meaning of a reportable accident?"); thirteen on driver qualifications ("Can the carrier list the documents required to be in a driver qualification file?"); five on driving ("Does the carrier have a policy for monitoring speed?"); eight on maintenance ("Can the carrier produce the prior three months inspection reports on a vehicle selected at random?"); and twelve on hours of service ("Can the carrier produce the prior six months' records of duty status for a driver selected at random?"). If the carrier hauls hazardous materials it can also be asked seven questions on driving and parking rules ("Is the carrier aware of the marking of vehicles requirement?"); and eleven more general questions ("Can the carrier explain the accessibility requirements for shipping papers?").

The carrier is then rated as satisfactory, conditional, or unsatisfactory in each of the nine areas, and finally an overall rating is given to the firm. The FHWA has indicated that the rating is determined by violations found as part of the above audit; the roadside inspection record in the past five years; infringements of the law; accident rates; and evidence of improvements made by the carrier (Office of Technology Assessment, 1988). The agency refused to reveal the weights that it applied to the various elements in arriving at the overall rating, until a Freedom of Information Act request in 1992 (Kenworthy, 1992).

If a firm is found to be unacceptable a return visit is made. These visits, termed "Compliance Reviews" or CRs, are much more detailed. They involve 28 staff hours as against the two to three hours for the initial audit. In addition to reexamining the firm on the above questions, inspectors also determine whether legal enforcement action is necessary, and can collect evidence to support any citations.

There are penalties for failure to comply with federal regulations. Firms can be fined and, in extreme circumstances, banned from offering service. There are also economic penalties. Some large shippers, such as Chrysler Corporation and the Department of Defense, have policies of only contracting with motor carriers that have been rated satisfactory in their federal safety audit. In addition, the Motor Carrier Safety Act of 1990 bars unsatisfactory firms from hauling hazardous materials.

2.2 Roadside Inspections

Because of the funding available under the MCSAP program, the number of roadside inspections increased from almost zero in 1982 to 1.5 million per year in 1991. In addition, there was a concerted effort to establish uniform inspection procedures in all states and in the provinces of Canada. The Commercial Vehicle Safety Alliance (CVSA) is the organization responsible for achieving federal / state / provincial cooperation. In addition to producing an inspection manual, CVSA has also set up a scheme whereby a vehicle inspected in one jurisdiction and found to be satisfactory is given a decal that obviates reinspection for three months. Most inspections are conducted at 650 existing weigh stations nationwide where all vehicles are required to stop when stations are open. Both interstate and intrastate carriers are subject to these inspections. The Federal Highway Administration states that 1,165,000 of the 1,574,188 inspections conducted in 1991 were of interstate carriers.

Roadside inspections deal with drivers as well as vehicles. The North American Standard Inspection, also called a level I inspection, has an inspector walk around and look under the vehicle and check brakes, lighting, tires, coupling devices, steering, windshield wipers, and load securement. Inspectors also check whether drivers possess correct licenses, have adhered to hours-of-service rules, and are not under the influence of alcohol or drugs. Level I inspections account for 65% of all inspections. There is also a level II inspection. It is a curtailed version of the level I inspection. This type of inspection is conducted in locations that are not suitable for under-vehicle examination. They account for 28% of inspections. Finally 6.5% of inspections are level III, where only the driver is inspected.

If serious faults are found, the vehicle and/or the driver can be placed out-of-service. In general, vehicle faults have to be corrected at the site of the inspection, or in certain cases at approved repair facilities within 25 miles of the inspection site. Drivers are also kept out-of-service at the inspection site until they are no longer impaired or are back in compliance with hours-of-service regulations. They may have to be replaced by other drivers.

3. PROGRAM DIRECT BENEFITS AND COSTS

3.1 Evidence of Accident Reduction from Safety Audits

Based on data from the FHWA (1992a), 40% of trucking firms have received at least an initial Safety Review (SR) audit. Of all the firms inspected, 55% were rated satisfactory, 39% conditional and 6% unsatisfactory. The FHWA made available a tape of audit results. Analysis of this dataset, of approximately 85,000 firms, produced the statistics shown in table 1. The typical firm rated unsatisfactory is a quarter the size of the average satisfactory firm, and has an accident rate that is twice as high. The definition of accidents is a measure called “reportable accidents." This federal definition represents the more serious accidents which involve a fatality, a serious injury, or more than $4,400 of property damage. This the time of this analysis the final part of this definition has changed to be whether a tow truck has to attend. This definition excludes the vast majority of accidents in which only minor amounts of property are damaged.

TABLE 1: CHARACTERISTICS OF FIRMS WITH DIFFERENT SAFETY AUDIT RATINGS

Rating	Average Annual Fleet Miles	Approximate Median Annual Fleet Miles	Reportable Accidents per Million Miles
Satisfactory	1,123,000	200,000	0.59
Conditional	239,000	50,000	0.69
Unsatisfactory	258,000	50,000	1.29

The accident reduction due to safety audits is based on the following calculations: (1) accident improvement occurs for 91% of firms that receive an unsatisfactory SR rating in a given year; (2) the initial amount of the accident improvement is 43%; (3) the cost increases necessary to improve safety performance reduce the demand for each satisfactory firm by 6.5%; (4) the improvement continues indefinitely, subject to a decay of 0.7 of one percent per year and an annual probability of 5% that the firm will cease operation; and (5) future accidents are discounted at 7% per annum. The following paragraphs provide support for these figures.

Within the FHWA database, 5,961 firms were identified who were assigned an unsatisfactory rating in the initial SR audit and subsequently received a follow-up CR audit. Ninety-one percent of the firms received an improved rating on the CR audit, with 65% improving to satisfactory. Analysis of the FHWA data indicates that in the year from November 1990 to November 1991, 12% of firms with new SRs were rated unsatisfactory. With an average of 18,000 SRs a year, this means there are 2,160 firms assigned unsatisfactory ratings. Of these 2,160 firms 91%, or 1,966, improve their performance.

For the firms that improved their audit rating, the average accident rate reduction was 42.69%. The magnitude of the reduction is supported by an earlier paper by the current authors (Moses and Savage, 1992). A regression model was estimated which linked performance on individual safety audit questions and the accident rates of firms. The SR and CR scores on the questions for 233 firms were substituted into the model, and a 30% reduction in accidents was predicted.

The average improving firm operates about 250,000 fleet miles a year. Therefore such a firm can expect to have had one reportable accident every three years prior to the SR. One might reasonably suggest that our finding of a reduction in accident rate is merely reflecting reversion to the mean if firms are selected for an SR because an accident had occurred. It is certainly true that accident involvement is a criteria for selection for a SR, but this is not always the case. In another study, we isolated 518 firms who in the 1991-93 period had both an unsatisfactory SR rating and poor roadside inspection performance. Of these 518 firms, 442 had not had a reportable accident in the year prior to their SR (Moses and Savage, 1995). In addition, the FHWA rating algorithm cannot assign an unsatisfactory rating to a small firm solely on basis of a poor accident rate. The firm has to have poor safety management practices as well.

The observed 42.69% accident rate reduction implies that the reportable accident rate drops from the 1.29 accidents per million miles typical for unsatisfactory firms to 0.74. The accident improvement should also carry over to the far more numerous category of accidents which involve only relatively minor property damage. The FHWA no longer collects information on this wider definition of accidents that we call "total" accidents. Appendix A describes how we estimate that total accidents are 4.94 more numerous than reportable accidents. Therefore the total accident rate for the improving firms falls from 6.37 to 3.65 per million miles. The seemingly large increase in the number of accidents avoided when the definition is widened to total accidents is not crucial to the benefits of the safety programs. The additional accidents are primarily property damage accidents, whose economic cost is minuscule compared with the cost of accidents in which a fatality or serious injury occurs.

Table 1 suggests that the 1,966 firms who improve average 258,000 miles a year, a total of 507.2 million miles. However this improvement in accident rates requires expenditures by trucking firms. In section 3.7 we estimate that the effective price to customers will rise by 5%, and given a price elasticity of -1.3 (Oum, Waters and Yong, 1992), the mileages of these firms should fall by 33 million to 474 million miles. The number of accidents avoided in the first year after the improvement is composed of two parts. The first is 474 million miles multiplied by the improvement in accident rate from 6.37 to 3.65 total accidents per million miles. The second is the saving in accidents because 33 million miles are no longer operated at the pre-improvement accident rate of 6.37 per million miles. In the first year, 1,500 total accidents are avoided.

The improved performance should continue into the future. However, two adjustments need to be made. The first is made because there is a high incidence of failure among trucking firms. The improvement in accidents will only continue as long as the firm is in business. Annual trucking failure rates are about 150 per 10,000 firms, according to Dun and Bradstreet data (Dempsey, 1992). Since most of the firms rated unsatisfactory are small, the failure rate is much higher. A figure of 500 per 10,000 firms, or 5%, is reasonable.

The second correction is somewhat more controversial. It involves the issue of how long a firm that has shown an improvement continues the management practices that produced the improvement. It is certainly possible for an improvement to decay over time after the CR inspection. Within the federal database 10,274 firms, about 12%, were identified who over approximately a five-year period had been initially assigned a satisfactory or conditional rating, and subsequently the government had cause to conduct a CR. The average accident rate for these firms increased by 24% between the first and second audits, representing an annual increase of 4.4% for these firms, or 0.005% for the population of firms as a whole. That is to say the typical improving firm initially reduces its accident rate from 6.37 to 3.652 per million miles. After one year the accident rate creeps up to 3.671. Therefore, the initial improvement in the number of accidents decays by an average of 0.007 per annum.

The effect of the audit program on accidents can therefore be calculated as:

$$\sum_{n=1}^{\infty} \frac{1500 * (0.95 * 0.993)^n}{1.07^n}$$

which represents an initial accident reduction of 1,500 accidents per year, a 5% annual chance that the firm will go bankrupt, a 0.7% annual decay in improvement, and a 7% discount rate. It is therefore expected that 11,168 accidents are avoided because of safety audit activities in a given year.

3.2 Evidence on Accident Reduction from Roadside Inspections

The methodology for calculating accident reduction from roadside inspections involves a two-step process. The first calculates the number of vehicles and drivers placed out-of-service as a result of roadside inspections. The second step calculates the number of accidents that might be avoided as a result of vehicle faults being corrected, or changes in driver behavior.

TABLE 2: INSPECTIONS AND VEHICLES AND DRIVERS PLACED OUT OF SERVICE (OOS) BY FIRM SIZE CATEGORY (Figures in thousands)

Firm Size Range (Annual Miles)	Estimated Inspections		Vehicles OOS		Drivers OOS
	Vehicle	Driver	Brakes	Other	
- 40k	120	128	15	18	10
40k-100k	138	148	22	26	11
100k-210k	112	119	20	24	9
210k-370k	94	100	18	21	7
370k-850k	83	89	16	19	7
850k-50m	456	488	68	82	43
50m+	86	92	8	10	6

The FHWA estimates that 1,088,900 level I and II inspections were given to interstate carrier vehicles and their drivers in 1991, with a further 77,000 driver only level III inspections. The FHWA made available to the authors a tape that contains the inspection frequency and performance during 1991 and 1992 of 35,000 motor carriers. Based on the estimated mileages by firms shown in appendix A, and the information on the FHWA tape concerning frequency the number of inspections by firm size class were estimated. These data are shown in the second and third columns of table 2. The number of vehicles and drivers placed out-of-service was then calculated using out-of-service rates obtained from the FHWA tape. The final three columns of table 2 show the estimated number of drivers and vehicles placed out-of-service, the latter being sub-divided into brake and other faults. FHWA (1992a) indicates that brake problems account for 45.6% of the vehicles placed out-of-service.

Two types of information are required to transform these data on out-of-service vehicles and drivers into accidents avoided: (1) knowledge of the proportion of accidents that can be attributed to factors that a roadside inspection can address; (2) an opinion on how long the "benefits" of an inspection last. Because of disagreements in the engineering literature, we have calculated both an upper bound and mid-range estimates of these effects. A summary of the figures we have used are shown in table 3. The following paragraphs elaborate on the literature that we have drawn on.

Truck accidents can have many causes, including mechanical failures, driver inattention, and environmental and other road hazards. A survey of the vehicle safety literature by Gillespie and Kostyniuk (1991) reports that mechanical failures are the cause of 6% to 13% of truck accidents. However, there is a school of thought that argues that the influence of mechanical problems is much larger. Two NHTSA reports (Clarke et al., 1987, 1991) calculate that braking deficiencies could be involved in up to 35% of accidents. In addition, brake related accidents usually lead to loss of vehicle control and thus account for more than a proportional number of fatal and serious injury accidents. The 35% figure should be compared with figures of about 4% for accidents caused by brake defects reported in Gillespie and Kostyniuk's literature review.

TABLE 3: SUMMARY OF CALCULATIONS USED TO ESTIMATE ACCIDENT REDUCTION FROM ROADSIDE INSPECTIONS

Violation Type		% of Out of Service Actions[1]	Relative Accident Risk	% Accident Reduction / Duration (months)	
				Upper Bound	Mid-Range
Vehicle	Brakes	36.4%	+31.6%	11% / 3	6% / 3
	Other	43.4%	+31.6%	2% / 3	2% /3
Driver	Impairment	0.5%	+75.0%	43% / 12	43% / 12
	Other	19.7%	+31.6%	4.3% / 6	3% / 3

In calculating the 35%, the NHTSA authors include all accidents where a truck rear-ends another vehicle or had inadequate stopping distance. Yet Clarke et al. (1987) also indicate that in the state of Washington, 5% of truck accidents were ascribed by police officers to the truck driver following another vehicle "too closely," and 13% to driving at greater than appropriate or legal speed. We are sympathetic to the argument that the existing methods of investigating truck accidents tend to understate the causal influence of mechanical problems, but cannot ascribe to braking difficulties those accidents caused by inappropriate speed and poor driver highway discipline. Further support for our position comes from Stein and Jones (1987) who found that 41% of tractor-trailers involved in accidents in Oregon had vehicle defects sufficient for them to be placed out-of-service at an inspection, yet the Oregon Public Utilities Commission (1985) found that only 13% of accidents could be attributed to vehicle defects.

Recognizing the contentious nature of the literature, our upper bound figure will be based on the top end of the more traditional literature. 11% of accidents will be ascribed to brake-related causes and 2% to other vehicle defect problems. Our mid-range estimate is based on the median values of the existing literature with brakes representing 6% of accidents and other mechanical causes 2%.

When an out-of-service fault is found and subsequently corrected, the "benefit" of the inspection may extend for some period because, even with no maintenance, it takes time for the vehicle fault to reappear and become "critical." The CVSA has judged this period to be about three months. This is the period of time that they are willing to exempt a vehicle from further inspection after it has passed a roadside inspection. Gillespie and Kostyniuk (1991) provide engineering evidence to support the three month period. They calculate that an out-of-service fault is certain to develop within six months from the point of last maintenance for a straight (i.e., nonarticulated) truck and under four months for a tractor-trailer combination. The latter type of vehicle is the one that most commonly passes through inspection stations. A figure of three months is used as the period of average benefit from an inspection for both brake and other vehicle violations.

While one can make engineering judgments about the reappearance of mechanical problems, the same cannot be said with respect to drivers. The majority of drivers are placed out-of-service because they exceed permitted hours. Federal law stipulates that drivers who violate hours-of-service rules are placed out-of-service until they are back in compliance. This surely reduces the probability of fatigue-related accidents during the subsequent twenty-four hours. However, the longer term effects are more debatable. It is at the inspectors' discretion whether a traffic ticket is issued when the driver is placed out-of-service. Even if a ticket is issued, convictions for violations of hours rules do not automatically count towards revocation of Commercial Drivers Licenses.

Some large companies do take action against drivers who violate hours rules. A week's suspension without pay is a typical penalty, which should be a serious deterrent. However, FHWA officials comment that for many companies, hours offenses are more symptomatic of unscrupulous dispatchers who put pressure on drivers.

There is some empirical evidence from California. With a sophisticated system of control groups and a sample size of over 200,000 auto drivers, state experts calculated that issuing a warning letter to drivers led to a 4.27% reduction in accidents, with the effect lasting for six months (Marsh, 1990). These figures are used in our base case. However, we regard these figures as the upper bound. The true effect on driver behavior of the roadside inspection program could be much lower. The warning letter issued by the state of California is a serious document with possibly serious repercussions. For many truck drivers, the consequences of hours violations are not severe, and the probability of detection of recidivism is minuscule. The mid-range assumption will be a 3% reduction with a three-month duration.

A different calculation is made for the 2,500 drivers each year are found impaired by drugs or alcohol during roadside inspections. There is an automatic one year revocation of the Commercial Drivers' License for these offenses. We will assume that these drivers are replaced by an unimpaired driver. Hurst, Harte and Frith (1994) calculate that impaired drivers have a 75% higher probability of an accident than unimpaired drivers.

The above discussion has been in terms of percentage reduction in accident rates for a certain time period. Information on typical vehicle mileages and initial accident rates is necessary. Accidents rates per mile can be obtained from the calculations described in appendix A. These are average accident rates for each size class. Obviously, vehicles and drivers found in violation of federal regulations should be much more accident prone. It is difficult to make a precise adjustment for this tendency. It is known that firms inspected frequently have accidents rates 40% above infrequently inspected firms, and that these high-accident-rate firms account for 79% of inspections. Accidents rates for each size class were adjusted up by 31.6% to reflect the more accident-prone vehicles and drivers. This percentage is obtained by taking the average accident rates of the two groups of firms, both frequently and infrequently inspected, and weighting them by the proportion of inspections accounted for by them. The resulting adjusted accident rates are shown in the third column of table 4. It is worth noting that these accident rates may be too high. Vehicles subject to roadside inspections are those which accumulate high mileages on rural limited-access highways. It is generally recognized that such highways have lower accident rates than urban highways and rural undivided highways. However, the traffic on them functions at higher speeds so that the accidents that do occur on them are more serious.

TABLE 4: ESTIMATE OF ACCIDENTS AVERTED BY ROADSIDE INSPECTIONS BY FIRM SIZE CATEGORY

Firm Size Range (annual miles)	Quarterly Miles	Adjusted Accidents per Million Miles	Estimated Accidents Avoided
- 40k	4,550	9.86	153
40k-100k	6,000	5.49	147
100k-210k	7,000	5.01	141
210k-370k	7,500	4.55	118
370k-850k	9,000	4.17	120
850k-50m	12,500	4.01	771
50m+	11,500	4.20	94

Typical annual vehicle mileages were obtained from the tape made available by the FHWA. The figures range from about 9,000 miles per vehicle for the smallest firms up to about 25,000 miles per vehicle for large firms. However, Gillespie and Kostyniuk (1991) point out that most inspections take place on rural limited-access highways. The types of trucks that operate on these highways are typically truck-trailers rather than straight trucks, and are operated quite intensively. Research at the University of Michigan reported in Gillespie and Kostyniuk suggests that vehicles on rural limited-access highways average 40,000 miles a year compared with the national average of 18,000. The average mileages were doubled to represent the high utilization vehicles subject to roadside inspection. The resulting quarterly figures are shown in the second column of table 4. It is assumed that mileages for drivers are similar.

Calculation can then be made for the accidents avoided in each size class. Taking the smallest size class as an example, there are 14,989 vehicles placed out-of-service for brake problems. Each of these vehicles would have operated 4,500 miles in the next three months. The adjusted accident rate is 9.8561 accidents per million miles, and 11% of the accidents are due to brake problems. This implies 73 accidents being avoided. Similarly 17,881 vehicles are placed out-of-service for other mechanical problems, which account for 2% of accidents. Therefore a total of 16 accidents are avoided. There are 267 drivers who have their licenses revoked for one year for driving while impaired. These drivers have an accident rate 75% above the usual accident rate for this size class of 7.49 per million miles. If the impaired drivers are replaced by drivers who have typical accident rates, then 27 accidents will be avoided in the next year. Finally 9,697 drivers are placed out-of-service for other reasons. These drivers improve their driving behavior for six months resulting in a reduction in their accident rate by 4.27%, which implies that 37 accidents will be avoided. The total number of accidents avoided for this size category is therefore 153.

If similar calculations are made for all seven size groups, it is estimated that as an upper bound 1,544 accidents are avoided each year as a direct result of the roadside inspection program. Using mid-range assumptions 967 accidents are avoided.

3.3 Cost of Truck Accidents

Appendix B describes the methodology used to calculate that the typical truck accident results in 0.013 fatalities, 0.194 incapacitating injuries, 0.402 nonincapacitating but evident injuries, 0.635 possible injuries, and $11,960 in property damage. Society loses the productivity of those killed and the time away from work for those injured. Victims and their family and friends feel pain and suffering. There are also the direct costs of administering insurance claims as well as the expenses of police, medical personnel, hospitals and coroners. There are frequently external costs to other traffic at an accident site that are the result of delays and rerouting. The valuation of these costs is also discussed in appendix B. In summary we estimate that the typical truck accident costs society $118,211. The breakdown of this cost shown in table 5.

TABLE 5: SOCIETAL COSTS OF A TYPICAL TRUCK ACCIDENT

Type of Cost	Average Occurrence per Accident	Unit Cost $	Expected Cost $
Fatality	0.013	2,835,693	35,823
Incapacitation Injury	0.194	200,885	38,987
Nonincapacitating Injury	0.402	39,378	15,820
Possible Injury	0.635	20,181	12,808
Uninjured Persons	1.000	2,055	2,055
Property Damage	-	11,960	11,960
Delays to other Traffic	-	758	758
TOTAL			118,211

In addition there may be costs to motor carriers associated with disruption of business when an accident occurs. These costs take the form of delays to shipper's cargo, and the need to provide a replacement vehicle to complete the delivery. These costs are discussed later in this section.

3.4 Governmental Program Costs

Government expenditures were obtained from data reported in the federal budget, and put into 1992 prices (Office of Management and Budgets, annual). MCSAP now costs $65 million. These funds pay for 80% of state spending on enforcement activities, which implies expenditure of $81.25 million per year by all levels of government. Inspections are conducted for both interstate and intrastate carriers. The FHWA indicates that 74% of roadside inspections are of interstate carriers. Since all parts of our analysis, and calculation of costs and benefits, are concerned with interstate carriers, the program costs have been factored down to $60.125 million.

The federal Office of Motor Carriers expanded its staff from 270 to 640 as a result of the audit program. Its operational budget increased from just under $14 million prior to the program to $44 million in 1992. Therefore, taking both programs together there is an increase in resources of $90 million a year.

The standard cost-benefit-analysis literature assumes that public expenditures have a shadow value attached to them. This results from the deadweight loss associated with raising tax revenues. Most of the funds for the motor carrier safety program are raised from federal income taxes. Empirical studies suggest that income taxes cause 21¢ deadweight loss for each dollar raised (Dodgson and Topham, 1987).

3.5 Inspection Costs to Motor Carriers

Motor carriers have to bear the time costs involved in safety audits and roadside inspections. In 1991 there were 18,000 initial SR audits and 8,000 CR audits. A typical SR takes two to three hours to complete and a CR takes 28 hours (Office of Technology Assessment, 1988). Senior management of the carrier has to be present to answer questions and show the inspector written records. It is unlikely that any trucking firm would hire additional managers to meet with FHWA inspectors. Existing managers are most likely diverted from other work for their companies, which must be valued at their wage rate, including fringe benefits. The average manager or supervisor earned $43,340 in 1990 (ATA, 1990). Fringe benefits (pension, health, etc.) were 29.2% of earnings. So the average earnings package was $56,000 in 1990 prices or $60,000 in 1992 prices. If, as seems likely, only one manager who works 48 weeks a year and 40 hours a week meets with an FHWA inspector, the implied cost of an SR is $90 and $875 for a CR. The annual total cost to the motor carrier industry of the audit program is then estimated to be $8.6 million.

The typical roadside inspection delays the vehicle by 31.5 minutes (FHWA, 1992b). The fact that the vehicle would have had to stop for weighing anyway means that the considerable time costs of decelerating from mainline speeds, accessing and exiting from the inspection station and accelerating to existing speeds should not be included in the cost-benefit analysis. The 31.5

minute delay is roughly equivalent to a 20 mile drive since most inspections occur at weigh stations on major highways. Given 1.165 million inspections in 1991, this represents a delay equivalent to 23.3 million miles. A dollar value can be attached to this mileage figure by: (1) disaggregating this delay into the seven size categories described in section 3.2; and (2) applying average cost figures derived in appendix C. This appendix suggests that firms in the five smallest size categories have an average cost of $1.30 a mile, those in the sixth category $2.65 a mile, and the largest firms average $2.75 a mile. Consequently, we estimate that the time required for inspections costs the industry $36.4 million a year.

Some reviewers have commented that the cost of inspections should not be valued at average total cost. They argue that the only true cost is the unproductive use of the time of the driver. Even fuel costs are avoided because the vehicle's engine is turned off. We disagree with this view. There has to be some increase in national fleet size to compensate for the 600,000 annual vehicle-hours of delay to interstate carriers.

Firms that have their vehicles or drivers placed out-of-service have to bear the cost of a trip being delayed until vehicle repairs are made; or the driver is no longer impaired, is relieved, or is back in compliance with hours-of-service regulations. FHWA data indicate that 367,341 interstate vehicles and 93,341 drivers were placed out-of-service in 1991. The FHWA does have data on the reasons why drivers or vehicles are placed out-of-service, but it does not keep records on the time taken to eliminate problems. The latter were obtained by interviewing FHWA officials and managers of trucking companies.

The number of out-of-service actions was categorized into four violation types, and the seven firm-size categories used throughout this paper. The four violation categories were driver, vehicle brakes, vehicle lighting, and other vehicle defects. Forty-five percent of vehicle violations are brake related and 20% are due to lighting problems (FHWA, 1992a). Where a vehicle out-of-service action occurs simultaneously with the driver being placed out-of-service, it is categorized as a driver violation because it is the driver's return to compliance that usually determines delay time.

The number of cases where a driver and vehicle were both placed out-of-service had to be estimated. FHWA data indicate that of a total of 93,341 driver out-of-service actions, 15,000 occurred in level III inspections where the vehicle was not examined. The remaining 78,341 driver out-of-service actions plus the vehicle out-of-service actions occurred in the 1,088,856 level I and II inspections. Under the reasonable assumption of independence, vehicle out-of-service rate and the driver out-of-service rate can be multiplied. Such multiplication yields a figure of 26,430 inspections that result in the driver and vehicle being placed out-of-service simultaneously.

Most driver out-of-service actions involve violations of the limits on driving hours. In general, drivers placed out-of-service are forced to take an eight hour rest before continuing their journey. The extent of the network effect on the trucking firm depends on whether the driver's original schedule included rest during that period. There is no definitive information on planned duty versus the time at which the driver is placed out-of-service. The location of inspection stations on rural-limited access highways contributes to the general feeling that drivers are not generally "close to home" when placed out-of-service. Discussions with industry suggest the consequent loss of productivity to the trucking firm averages 4 hours.

There were 340,911 occasions in 1991 when a vehicle was placed out-of-service but its driver was not. FHWA (1992a) information indicates 45.6% of these actions involve brake defects. Discussions with the FHWA and industry managers suggest that 70% of brake out-of-service actions result from alignment problems. Most firms allow their experienced drivers to adjust brakes themselves, and 30 minutes is usually sufficient to perform this task. The remaining 30% of brake problems require the services of a mechanic and a typical delay of three hours. Therefore brake out-of-service actions cause an average delay of 1.25 hours.

The next largest category of vehicle problems covers lighting defects. They represent 19.1% of vehicle-only, out-of-service actions. Industry contacts suggest that in about 60% of lighting cases the driver can replace defective bulbs in 30 minutes. The other 40% of cases are usually due to wiring problems and necessitate the attendance of a mechanic and a typical delay of three hours. Lighting out-of-service action therefore requires a delay of 1.5 hours.

The remaining vehicle out-of-service actions are more serious problems that involve wheels, tires, suspension, and steering. In these cases, there is the possibility of an extended delay, particularly if the vehicle has to be towed to a repair site by a wrecker, or a company mechanic has to travel a considerable distance to the scene. Industry representatives explain that independent mechanics have set up businesses close to weigh station to cater to companies whose vehicles have been placed out-of-service. They also estimate that a serious vehicle problem is corrected in two hours of work plus a delay of one hour waiting for the mechanic to arrive, an overall delay of three hours.

All told there is a total delay time of almost 1.1 million hours to correct out-of-service problems. If, as seems reasonable, vehicles would cover 40 miles in an hour, and the costs per mile for the various size categories are applied, these delays are estimated to cost the industry $65.5 million a year. This estimate excludes the costs of the repairs themselves in terms of labor and parts.

Assuming for now a long-run, constant supply-price industry, the costs of the safety programs are passed on to shippers. The sum of the cost increases explained above is $8.6 million for the audits and $101.9 million for the inspections. With an estimated industry mileage of 77.658 billion miles, the costs of inspections represent an increased cost of 0.13¢ a mile, or 0.08% with an average industry cost per mile of $1.71. Given an elasticity of demand of -1.3 (Oum, Waters, and Yong (1992)), this represents a deadweight loss of about $0.1 million. The deadweight loss for the audits is negligible.

There is an offsetting benefit to the out-of-service delays. This accrues to the 1,544 drivers and/or vehicles placed out-of-service who would have been involved in an accident in the upper-bound case. The companies bear the lost productivity while the violation is rectified, but they do not suffer the productivity delay that would occur at the scene of a subsequent accident. A benefit is assumed to be equal to a delay of 3 hours for each of these vehicles and/or drivers. As with out-of-service time, each hour is equivalent to 40 miles, and a mileage cost appropriate to the different sizes of firm applied. This results in an upper-bound annual benefit of $0.29 million, with a mid-range estimate of $0.18 million.

3.6 Accident Reductions due to Inspection Costs

The calculations in the preceding paragraph suggest that if the costs of audits and inspections are passed on in price, then industry output will fall. Reductions in mileage will affect the number of accidents. In section 3.5 it is estimated that the cost to motor carrier firms in managerial time costs for meeting with federal inspectors and answering their questions during SR and CR audits is $8.6 million a year. Appendices A and C contain calculations that suggest a total, interstate, industry annual mileage of 77.658 billion at an average cost of $1.71 a mile. Inspections increase average costs by 0.011¢ per mile or about 0.007 of one percent. With a price elasticity of -1.3 (Oum, Waters and Yong, 1992), industry mileage declines by 6.5 million if costs are passed on in prices to shippers. Based on the estimate in appendix A that the industry average accident rate is 3.37 per million miles, 22 accidents are avoided because of the cost and price increases associated with conducting the audits in a given year.

In section 3.5, it is estimated that the cost to motor carriers of undergoing thirty-minute roadside inspections is $36.4 million a year. Using a similar methodology to the preceding paragraph, industry miles decline by 27.7 million, and 93 accidents are avoided.

Also in section 3.5, it is estimated that firms placed out-of-service suffer a net time delay equivalent to $65.3 million a year after allowance is made for the delays that might have occurred as a result of an accident. Using the same methodology, these costs should reduce industry mileage by 49.6 million if costs are passed on in prices. Given the assumption that firms placed out-of-service have an accident rate 31.6% above the industry average of 3.37 per million miles, the mileage reduction implies that 220 additional accidents are avoided.

3.7 Cost of Improved Operating Quality

Earlier calculations in the paper concluded that 1,966 firms a year improve their accident performance as a result of the audit program. Clearly these firms experience an increase in unit costs. It is illogical to argue otherwise; for if costs stayed the same or decreased firms would have already chosen of their own free will to improve accident performance. Cost goes up because of increased expenditures by the firms on such things as better training of employees, improved maintenance practices, or the acquisition of higher quality staff or equipment. These increases in costs are, of course, partially offset by some cost reductions. The insurance premiums of the firms may be reduced, vehicles sustain less damage, there will be fewer business interruptions associated with accidents, or the costs associated with hiring replacement drivers for those disabled or killed.

We are not aware of studies that quantify an elasticity of cost with respect to accidents and their prevention. However, these is some evidence from Allen and Liu (1995) who used shippers' perceptions of the quality of trucking firms, as reported in an annual survey in a trade journal, on cost functions. They found that the difference in cost between a group of low quality and a group of high quality firms was 6% to 7%.

TABLE 6: DISTRIBUTION OF FIRMS RECEIVING AN UNSATISFACTORY RATING ON A SAFETY REVIEW

	% Firms	Average Miles	Cost $/Mile
Private Carrier	68.3%	146,000	1.33
General Freight For-Hire	6.4%	931,750	1.99
Specialized For-Hire	25.1%	312,250	1.02

Data: SR Audits November 1990 - November 1991

Firms that receive unsatisfactory SR ratings are generally quite small. They are distributed between private carriers, general freight and specialized carriers as shown in table 6. This table is derived from an analysis of data on SRs that were conducted between November 1990 and November 1991. The final column of the table presents estimates of costs per mile based on calculations for "small" firms described in appendix C. Taking the figures on the distribution of types, and their respective average annual miles, an average cost of $1.39 per mile is obtained for the firms that are assumed to improve as a result of being classified unsatisfactory on an SR. Given that these firms had a poorer accident record and hence lower costs before the audit, and that firms have a 6% cost increase when they reduce their accident rates, their previous cost was $1.311 a mile. The audit increases the costs of these firms by about 8¢ a mile.

Cost-benefit analysis is also concerned with the effect this cost increase has on the consumer surplus of shippers. Shippers who have used the carriers that attempt to improve their safety performance could elect to stay with them. These shippers lose the usual consumer surplus that follows an increase in price, perhaps reduced a bit because the higher quality of service they are consuming turns out to have some value for them. Other shippers may find they cannot afford higher price transportation service and drop out of the market.

Some strong assumptions are required if the effects described in the preceding paragraph are to be estimated. The first assumption concerns price. The simplest market structure to describe the trucking industry would be a series of hedonic perfectly competitive markets. At each quality level there is a sufficiently large number of competitors that price is driven to cost. In this model a cost increase of 8¢ a mile due to safety improvements results in an 8¢ increase in price. However, there are other models of quality differentiation, such as the traditional Chamberlin model (1933) and the more recent models based on Shaked and Sutton (1982), where price exceeds marginal costs. The effect of forcing some firms to upgrade their quality may be to upset the market equilibria in higher quality markets. Such an upset influences prices in a manner that cannot be determined easily and can affect all shippers in the market. We assume that prices and costs are closely related in this industry.

There is a qualification to this statement. Firms that improve safety performance may not be able to raise price immediately. They may have to operate for some time before they gain the reputation of offering higher quality and can thereby charge an increased price. While the firm adjusts to higher quality it will earn less than normal profits. The length of the adjustment process does not affect the costs and benefits of the program. Firms will choose to restrict output when their costs rise, and will deny service to some shippers who desire service at the preexisting price. Providing that it is the shippers who value the service least who are denied service, the welfare consequences are identical to a situation where price responds instantaneously to the cost change.

The second assumption concerns the value that shippers place on the higher quality service they receive if they continue to patronize the firms that have invested to improve safety. Data on demand elasticities with respect to safety do not exist. As a substitute it is assumed that shippers gain the equivalent of the damage to their cargo that is avoided as a result of the accident improvement. This benefit may be in the form of reduced inventory carrying costs. A typical accident causes $12,000 of damage to cargo, vehicles, and roadside property. We assume that $5,000 of this damage occurs to the cargo. Safety improvements have already been calculated to reduce total accidents by 2.72 accidents per million miles. Shippers therefore gain 1.4¢ per mile.

The final assumption concerns the continued existence of low quality transportation in the market. It has already been made clear that the audit program will not cover all firms this century. Therefore a customer of a firm that improves its quality as a result of an SR need not stay with that firm. There will be plenty of unaudited firms that can offer the lower quality service that the shipper desires. These shippers will not suffer reduced welfare, save for the search costs of finding a new trucking line. If one takes this line of argument to the extreme, there would be no costs to shippers as a result of improved performance by some firms. The shippers who used these firms transfer their business to other, low-quality firms. The service-improved firms will compete with the existing higher-quality firms for a fixed pool of customers, and firms may have to leave the market. However, given that over the long run lower-quality service will become scarce because of the safety programs, we choose to adopt the view that shippers accept higher quality.

Welfare effects can now be calculated. As has already been indicated, 1,966 firms a year improve. They each operate 258,000 miles a year, a total of 507.2 million miles. Cost, and hence price, has increased by 8¢ a mile to reflect the increased expenditures on safety. This represents a move along the demand curve. However, the demand curve will also shift upwards as shippers are now consuming a higher quality product. This effect will be qualified by the 1.4¢ figure discussed in a previous paragraph.

The net cost to the shipper therefore increases by only 6.4¢, or 5%. If there is a price elasticity of -1.3 (Oum, Waters and Yong, 1992), output of these carriers will fall to 474 million miles. The welfare change is equivalent to a loss representing the cost increase of 8¢ for each of the 474 million miles now operated, a gain of 1.4¢ for each of these miles representing the upward shift in the demand curve, and a deadweight loss under the original demand curve for the miles no longer operated. These total $38 million, $6.6 million and $1 million respectively.

These welfare changes continue into the future in a manner that resembles the calculations made earlier about accident avoidance. Future benefits and costs are discounted at 7% per year, and adjustment is made for the probability of firm failure and the decay in accident improvement.

4. ESTIMATE OF DIRECT BENEFITS AND COSTS

Table 7 contains estimates of the direct benefits and costs of the audit and inspection programs. The audit program has a large benefit, namely $1 billion, with the benefits exceeding the costs by a factor of 4:1. Under the most favorable assumptions, the benefits of the inspection program only exceed the costs by 26%. The effect of more moderate assumptions implies that the inspection program is not worthwhile. It is worth noting that in this case, a third of the accidents avoided are due to reduced industry mileage resulting from the costs of the inspections rather than as a result of repairs made to vehicles or improved driver behavior.

TABLE 7: DIRECT COSTS AND BENEFITS

Estimates in 1992 $ millions	AUDITS	INSPECTIONS	
		Upper bound	Mid- range
BENEFITS			
Fatalities Avoided	400.9	66.5	45.9
Injuries Avoided	779.6	129.4	89.2
Property Damage Avoided	133.8	22.2	15.3
Traffic Delays Avoided	8.5	1.4	1.0
Business Disruption Avoided	*	0.3	0.2
Higher Quality Service	48.1	-	-
Total Benefits	1370.9	219.8	151.5
COSTS			
Government Costs	30.0	60.1	60.1
Shadow Value of Public Funds	6.3	12.6	12.6
Motor Carrier Inspection Costs	8.6	36.4	36.4
Out-of-Service Time	-	65.5	65.5
Higher Operating Costs	278.1	-	-
Deadweight Loss	7.9	0.1	0.1
Total Costs	330.9	174.7	174.7
BENEFITS - COSTS	1040.0	45.1	-23.2
BENEFIT / COST RATIO	4.14	1.26	0.87

* included as a mitigating factor in "Higher Operating Costs"

Sensitivity analyses were conducted for the audit program. The major area of uncertainty is the level of cost increase needed to bring about the safety improvements. In table 7, it was assumed to be 6%. The effects of 4% and 8% cost increases were examined. The benefit-cost ratio for the audit program which is 4.1:1 in the base case rises to 5.5:1 if the cost increase is only 4%, and falls to 3.4:1 if the cost increase is 8%. Some reviewers have argued that there is no evidence that safety improvements by firms after CR audits are sustained over the long run. The program is only seven years old which is too soon to observe any lasting effect. Calculations were made with a cut-off of six years for the continuing costs and benefits of the audit program, and an assumption that the level of benefits in year one declined linearly over the period. Under these assumptions the total benefits for the audit program are $654.7 million with total costs of $179.1 million, a benefit-cost ratio of 3.66. These results suggest that the safety audit program passes the test of social worth whatever assumptions are made.

5. ESTIMATION OF A DETERRENCE EFFECT

It is quite possible that the benefits of the two safety programs extend far beyond those firms that are given an unsatisfactory SR rating or have many of their vehicles or drivers placed out-of-service in roadside inspections. It is not difficult to find people who will argue that the chance of a safety audit may cause many unaudited firms in the industry to improve their safety performance. The FHWA points out that even those vehicles that are not placed out-of-service in roadside inspections are frequently served citations for more minor infractions. These firms may also be motivated to improve their safety performance. In addition, the visibility of the inspection program may have a deterrence effect on the entire industry.

Estimation of the magnitude of the deterrence effect is problematic when compared with estimating the direct effects. The analysis of the direct effects is facilitated by objective databases on improvements in accident rates from SR to CR audits, and out-of-service violations classified by type of vehicle or driver defect. The deterrence effect is found by an analysis of industry wide time-series data, using three measures of safety performance: safety audit ratings, roadside inspection results, and fatal accident rates.

5.1 Estimating a Deterrence Effect from Safety Audit Data

If firms are selected for initial SR audits randomly, then one would expect that the existence of a deterrence effect would mean that firms selected for audit later in the program should be "better" than firms selected early on. However, the program is not random. Large carriers of hazardous materials were targeted early in the program. As the program developed inspectors were able to concentrate on smaller firms who typically have higher accident rates.

Therefore to make a fair comparison, analysis was confined to the 6,074 large firms operating over 850,000 miles a year in the FHWA database. Table 8 shows the SR audit ratings and accident rate for these firms categorized by the year in which the audit took place. There is clearly some evidence that firms audited in 1990 and 1991 were less likely to be assessed an unsatisfactory rating. However, there does not appear to be a definite trend in accident rates over time.

TABLE 8: SAFETY REVIEW AUDIT RESULTS BY YEAR FOR FIRMS OPERATING MORE THAN 850,000 MILES ANNUALLY

Year	# of Firms	Rating (%)			Accidents per Million Miles
		S	C	U	
1986	240	66	17	9	0.91
1987	1856	66	20	9	0.41
1988	1597	58	24	11	0.63
1989	925	67	21	10	0.60
1990	892	77	18	5	0.53
1991	563	76	21	3	0.62

5.2 <u>Estimating a Deterrence Effect from Roadside Inspection Data</u>

One would imagine that if there is a deterrence effect, the performance of firms in roadside inspections should improve over time. A FHWA tape of inspection results was used to investigate this issue. The data covered the calendar years 1989 through 1992. The data was split into two periods, 1989/90 and 1991/2. 13,997 firms received roadside inspections in both periods.

TABLE 9: COMPARISON OF VEHICLE OUT-OF-SERVICE VIOLATIONS PER INSPECTION IN 1989/90 AND 1991/2 BY FIRM SIZE CATEGORY

Firm Size Range (Annual Miles)	Out-of-Service Violation Rate		
	1989/90	1991/92	% Change
- 40k	0.687	0.599	-13%
40k-100k	0.786	0.690	-12%
100k-210k	0.868	0.782	-10%
210k-370k	0.906	0.807	-11%
370k-850k	0.891	0.819	- 8%
850k-50m	0.691	0.627	- 9%
50m+	0.476	0.404	-15%

Section 3.2 discussed the apparently different inspection policies adopted towards small and large firms. Therefore the data were disaggregated into the seven size class used throughout this paper. As can be seen in table 9, vehicle violation rates declined by between 10% to 15% between 1989/90 and 1991/2, which is supportive of a deterrence effect.

However, the inspection program expanded greatly between the two periods. There were 317,000 inspections conducted on these firms in 1989/90, and 442,000 in 1991/2, a 40% increase. If one accepts that inspectors have a tendency to select the worst looking vehicles for inspection, the average violation rate should be expected to fall as the number of inspections increases. This is because inspectors can now devote time to tackling the next to worst cohort of vehicles.

5.3 Estimating a Deterrence Effect from Accident Rate Data

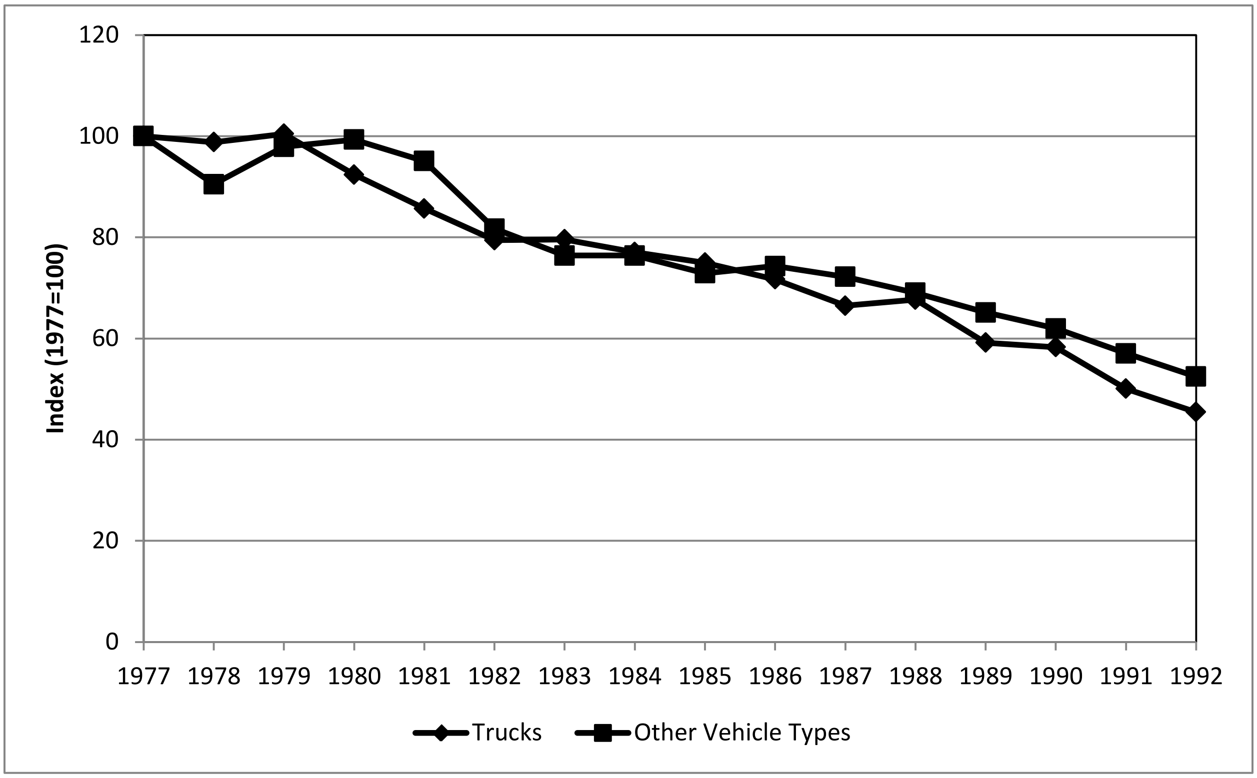
The accident data considered to be the most reliable are contained in the NHTSA's *Fatal Accident Reporting System* (FARS). Table 10 contains time series accident data for combination trucks since 1977. To ensure comparability between accidents and mileages, the FARS data was restricted to combination trucks, with the mileage estimate for the same category from the FHWA's *Highway Statistics*. Both of these measures include intrastate trucking, which is not subject to federal licensing and oversight. However, intrastate trucks are inspected at roadside inspections. In addition, some states have adopted programs similar to the audit program.

TABLE 10: TIME SERIES ANALYSIS OF COMBINATION TRUCK FATAL ACCIDENT RATES

Year	Combination Trucks			Other Vehicle Rate	Additional Enforcement ($000)	Estimated Rate Reduction	
	Accidents	Miles (billions)	Rate			Method I	Method II
1977	3,734	55.682	67.1	28.4	0		
1978	4,176	62.992	66.3	25.7	0		
1979	4,514	66.992	67.4	27.8	0		
1980	4,261	68.678	62.0	28.2	0		
1981	3,974	69.134	57.5	27.0	0		
1982	3,553	66.668	53.3	23.2	0		
1983	3,727	69.754	53.4	21.7	0		
1984	3,997	77.367	51.7	21.7	0		
1985	4,002	79.600	50.3	20.7	7981	- 0.7%	- 1.0%
1986	3,940	81.833	48.1	21.1	15174	- 1.3%	- 2.0%
1987	3,847	86.334	44.6	20.5	69267	- 5.9%	- 8.6%
1988	4,092	90.158	45.4	19.6	75157	- 6.4%	- 9.4%
1989	3,787	95.349	39.7	18.5	87011	- 7.3%	-10.8%
1990	3,771	96.367	39.1	17.6	86358	- 7.3%	-10.8%
1991	3,262	96.949	33.6	16.2	92317	- 7.7%	-11.5%
1992	3,025	99.032	30.5	14.9	98524	- 8.2%	-12.2%

A number of variables were considered to represent the audit and inspection program. Data were obtained on the number of roadside inspections in each year and the cumulative number of firms that had been given an SR audit by year's end. The cumulative figures are used because the effects of audits extend over many years. The two sets of data are extremely collinear. This collinearity means that it is impossible, using regression techniques, to separate the contribution of the audit and roadside inspection programs to industry accident reduction. Therefore the combined expenditures on both programs were used. Expenditure figures were obtained from the federal budget (Office of Management and Budgets, annual) for expenditures on MCSAP and FHWA motor carrier safety operations. The MCSAP figures were multiplied by 1.25 to reflect state matching payments, and the combined expenditures put into 1992 prices. Taking 1984 as the base level of expenditure, the sixth column of table 10 shows the additional expenditures used to support the audit and roadside inspection programs.

FIGURE 1: FATAL ACCIDENT RATES



It is clear from the fourth column of table 10, and the graph in figure 1, that combination-truck accident rates declined continually even after economic deregulation and before both of the safety programs came into full effect in 1986. Of course, much of this improvement is explained by improvements in automotive engineering and increased seatbelt use, both of which make accidents more "survivable." Two methods were used to deal with the time trend. The first method was to fit a linear time trend to the logarithm of truck accidents for the years 1977 to 1985. By limiting the analysis to the earlier period, any change in accident rates due to increased enforcement since 1986 does not affect the estimated time trend. The regression result was used to estimate truck accident rates, absent a trend, for the entire period 1977 to 1992. The logarithm of the detrended truck-accident rates was then regressed against the enforcement variable. A statistically significant negative relationship was found with a t-statistic of 2.73.

The regression had an r^2 of 0.35. Substitution of the data into the regression permitted calculation of the percentage decline in accident rates shown in the next to last column of table 10 under the heading "method I." Using this methodology, it is estimated that in 1992 the effect of the enforcement programs was to reduce the accident rate by 8.2%.

A second method to control for the time trend in accident rates is to use data for other vehicle classes as a proxy for more general changes in highway safety. The accident rate for all vehicle classes, excluding combination trucks, is shown in the fifth column of table 10. In figure 1, indices of both combination truck and other vehicle accident rates are shown with the rate in 1977 set equal to 100. Accident rates declined by almost 50% for all vehicle classes in the past 15 years. However, there appears to be evidence that truck accidents declined at a faster rate since the mid-1980s. The logarithm of the accident rate of the other vehicle classes, and the variable representing the change in enforcement expenditures were regressed on the logarithm of the truck accident rate. The regression had an r^2 of 0.96. The change in enforcement expenditures was significantly negatively related to the truck accident rate with a t statistic of 2.11. Substitution produced the percentage reduction in accidents shown in the final column of table 10 under the heading "method II." In 1992 the enforcement programs are estimated to have caused a 12.2% decline in accidents, a figure that is about 50% larger than that estimated using method I.

The data are for fatal accidents. Even if fatal accidents fell by 8% to 12% one cannot assume that these accidents no longer occur. If roadside inspections lead to less defective brakes, then what would have been a fatal accident might be reduced to an injury or property-damage-only accident. Therefore the reduction in total accidents may be less.

5.4 Evaluation of the Magnitude of a Deterrence Effect

The regression analysis indicates that truck accidents declined over the period of the safety programs by 8% to 12% more than would be expected given long-standing time trends. Some of this decline has already been accounted for by the direct effects of the programs, estimated in sections 3.1, 3.2 and 3.6. In the first year of the program 3,294 would be prevented by the program. This comprises 1,500 x 0.95 x 0.993 = 1,415 from the audit program, 1,544 in the upper bound case from the roadside inspections, and 335 from the reduced mileage due to the passing on of inspection and delay costs to the programs to shippers. In the second year of the program, the firms audited the previous year avoid 1,500 x $(0.95 \times 0.993)^2$ = 1,335 accidents, and the firms audited in the second year avoid 1,415 accidents. Accident reduction from the roadside inspections and the reduced mileage due to inspection costs remain the same. A total of 4,629 accidents are avoided in the second year. In appendix A it is estimated that there are 261,933 interstate truck accidents of all severities a year. From this base of 261,933 accidents, the calculations of the direct effects imply that accident rates should have fallen by 1.3%, 1.8%, 2.2%, 2.7%, 3.1%, 3.5%, and 3.9% in each year that followed the introduction of the programs.

Thus in 1992, the seventh year of the program, the direct effects of the programs are estimated to reduce accident rates by 3.9%. In comparison, time series analysis suggests that accidents have fallen by 8% to 12%. Is the difference between these two figures a credible estimate of the deterrence effect?

The two programs increased continually over the 1987 to 1992 period. Therefore other, unidentified or unmeasured effects on truck safety which have taken place in recent years may inflate the regression estimates of the previous section. Since the mid-1980s there has been an unprecedented series of legislative acts concerned with truck safety. In addition to the two programs under investigation, these acts changed vehicle standards, introduced new rules for the carriage of hazardous materials, and implemented the national Commercial Drivers License. The license was phased in over the period 1987 to 1992. It imposed uniform testing standards across states and prevented drivers from having multiple licenses as a way of avoiding the consequences of revocation in one jurisdiction. Many states had to raise driver testing standards considerably.

A fruitful way to evaluate the magnitude of the deterrence effect is to apply economic reasoning. It is possible to express different magnitudes of the deterrence effect in terms of the number of firms who would have to voluntarily improve safety performance. It is also possible to estimate the economic consequences for firms that do not comply with safety regulations.

How many firms would have to voluntarily improve for the deterrence effect to be a quarter as large, half as large, the same size, or twice the direct effects of the program? We assume that the firms who voluntarily improve are similar to those found unsatisfactory on an SR audit, and that the magnitude of improvement is also similar. Based on the methodology used earlier, each firm that improves reduces the industry annual accident total by 0.774 accidents.

In 1992, the direct effect of the programs was to reduce annual accidents by 10,169. If the deterrence effect is the same size as the direct effect, 13,125 firms would have had to voluntarily improve sometime over the period 1986 to 1992. In table 11, the number of firms who would have to voluntarily improve for different magnitudes of the deterrence effect are shown. These numbers are also shown as a percentage of the firms that have not received an SR audit.

TABLE 11: NUMBER OF FIRMS REQUIRED TO IMPROVE FOR DIFFERENT MAGNITUDES OF THE DETERRENCE EFFECT

Deterrence Effect as Percentage of Direct Effect	Firms Required to Voluntarily Improve	As a Proportion of Currently Unaudited Firms
25%	3,318	2.1%
50%	6,635	4.3%
100%	13,270	8.5%
200%	26,540	17.0%

A deterrence effect similar in size to the direct effect or twice the direct effect is not credible based on evidence that is available on the safety record of newly audited firms. Over the history of the SR program only 6% of firms have been rated unsatisfactory, and even the most recent audits which are concentrated on smaller firms find 12% to be unsatisfactory.

The credibility of the different magnitudes can also be evaluated by the economic choices open to a small trucking firm which has a poor safety record but has not been audited and has not been subject to many roadside inspections. Choice A is to improve quality and avoid the possibility of enforcement action. Choice B is to leave its operating practices unchanged, and risk enforcement actions.

If the firm decides to make choice A, to voluntarily improve, it will incur subnormal profits for one year until its improved reputation permits an increase in price to match the 6% increase in costs necessary to buy better trucks, provide better maintenance, hire better drivers, or undertake better training of existing drivers. These additional costs were estimated to be 8¢ per mile. The total subnormal profit equals 8¢ multiplied by the mileage operated. Currently, annual average mileage per truck is about 15,000, or a firm total of 15,000T where T is the number of trucks owned. The cost of choice A is therefore $1,200 per truck.

If this firm decides against improvement, the probability that it will be audited or inspected in the coming years can be calculated, and the financial consequences of enforcement action in the event of an audit or inspection can be computed. An unaudited firm has a probability of 0.115 of being inspected each of the next nine years, by which time it is certain to be audited. Sixty percent of the interstate trucking industry of 260,000 firms remains to be audited, and approximately 18,000 new SR audits are conducted each year. If an audit takes place and the firm is given an unsatisfactory rating the firm is faced with costs. The management time cost to the firm of an SR was estimated as $90, and $875 for the subsequent CR. In addition, the firm will have to improve its quality and incur costs similar to choice A. The expected costs of an audit are $(111 + 138T) each year for the next nine years. Future costs are discounted at an annual rate of 7%, and allowance is made for a 5% annual probability that the firm will cease trading. The discounted present cost of the audits is $(650 + 810T).

Analysis of the FHWA data tape on roadside inspections indicates that a truck can expect to receive a roadside inspection once every five years. The firm can expect to receive 0.2T inspections a year if it does not improve. If this poorly performing firm is certain to have its vehicle and/or driver placed out-of-service if an inspection occurs, it will incur a delay of 4.5 hours; 30 minutes for the inspection and four hours while the out-of-service fault is rectified. Based on the earlier methodology, this delay is estimated to be equivalent to operating 180 miles at a cost of $1.31 a mile. The expected annual costs to the firm are 47.2T. The probability of a firm incurring this cost in any year is unity minus the cumulative probability that the firm has been subject to an audit. Discounting future costs in a similar fashion to the audits produces a discounted present inspection cost of $174T.

Therefore, over a nine-year horizon, a firm will incur a loss of $1,200T if it voluntarily improves now, and a discounted present value loss of $(650 + 984T) if it waits until it is audited before improving. It is irrational for firms with four or more trucks to voluntarily improve. While only 30% of firms have more than four trucks, these firms operate 90% of industry mileage. The choice in favor of waiting would be decisive for all firm sizes if they are able to recoup inspection costs in higher prices charged to shippers.

One can also question whether smaller firms will voluntarily improve. The above analysis considered the economist's definition of profitability. Cash flow issues also have to be considered. For a firm to improve its quality, it has to have the financial wherewithal "up front" or borrowing capacity to send drivers to training courses, enter into leases for new equipment, or upgrade its workshop facilities. These are major expenses for poorly capitalized firms that can easily earn normal profit by continuing to serve the pool of shippers who demand lower quality service. Such firms are unlikely to improve quality, unless forced to by government sanctions.

In summary, evidence from the number of firms found to be unsatisfactory in recent SR audits suggests a credible upper bound to the deterrence effect as half the direct effect. Consideration of the financial consequences of noncompliance suggests an even smaller figure. We believe that a more likely magnitude for the deterrence effect is a quarter of the direct effect.

If the deterrence effect is 25% of the direct effects then 1992 truck accidents accident are reduced by 5% due to the safety programs: 4% due to the direct effects; and 1% due to the deterrence effect. Accident rates are estimated to have fallen by 8-12% depending on the methodology used to correct for long-standing time trends. Our position is that the residual 3-7% accident reduction is attributable to the implementation of the Commercial Drivers License and other safety programs, and significant safety advances in truck engineering.

6. VALUING THE DETERRENCE EFFECT

The deterrence effect means that some firms voluntarily decide to improve the quality and safety of the service they offer. Therefore the calculation of costs and benefits should be very similar to the framework used for the firms who improve as a result of safety audits. Costs rise by a certain percentage as quality increases. Output is reduced, and there is a deadweight loss to some shippers.

Due to uncertainty over the size of the deterrence effect, benefit-cost ratios have been calculated based on a deterrence effect of zero, a quarter of the direct effects and half of the direct effects. The methodology used will be illustrated for a deterrence effect of a quarter of the direct effect.

In section 3, the direct effect of enforcement efforts in a given year were calculated to reduce accidents by 13,027 when accidents avoided in future years from firms improving due to the audit program are discounted at 7% per annum. This figure is arrived at in the following way: 11,148 from firms improving due to the audits, 1,544 from the upper-bound direct effects of the roadside inspections, and 335 from the additional costs imposed on the industry due to the costs of undertaking audits or inspections. In the case under consideration, the deterrence effect will be 3,257 accidents. The deterrence effect accidents are 29.2% of the 11,148 accidents avoided due to audits. The benefits and costs of the deterrence effect can therefore be found by multiplying the benefits and costs of the audit program, excepting the government and inspection costs, by 0.292.

In the preceding section, it was estimated that the expected annual costs of the audit program and the inspection program were $(111 + 138T) and $47.2 respectively, where T is the number of trucks a firm owns. The expected consequences of the audit program are about three times those of the inspection program. It would therefore be reasonable to assign 75% of the estimated deterrence effect to the audit program, and 25% to the roadside inspection program.

7. ESTIMATES OF COSTS AND BENEFITS FOR BOTH DIRECT AND DETERRENCE EFFECTS

Table 12 shows the benefits and costs of the two programs under a variety of assumptions concerning the size of the direct effect of the roadside inspection program, and different magnitudes of the deterrence effect. Prior to a discussion of the results of the table, three comments are of interest. First, the government may claim that the net social benefits implied in the table represent an impressive return on the $90 million of public money expended each year, but this does not take into account that 85% of costs of the programs are borne by trucking firms and their customers.

TABLE 12 COSTS AND BENEFITS OF SAFETY PROGRAMS FOR DIFFERENCE MAGNITUDES OF THE DETERRENCE EFFECT

	Upper Bound Accident Reduction from Inspections		Mid-Range Accident Reduction from Inspections	
	Audits	Inspections	Audits	Inspections
NO DETERRENCE EFFECT				
Benefits	$1,371m	$ 220m	$1,371m	$ 152m
Costs	$ 331m	$ 175m	$ 331m	$ 175m
Ratio	4.14	1.26	4.14	0.87
DETERRENCE EFFECT IS QUARTER OF DIRECT EFFECT				
Benefits	$1,671m	$ 320m	$1,657m	$ 247m
Costs	$ 394m	$ 196m	$ 391m	$ 195m
Ratio	4.24	1.63	4.24	1.27
DETERRENCE EFFECT IS HALF OF DIRECT EFFECT				
Benefits	$1,970m	$ 420m	$1,944m	$ 343m
Costs	$ 456m	$ 216m	$ 451m	$ 215m
Ratio	4.32	1.94	4.31	1.60

Second, Congress presumably had the primary objective of avoiding human suffering when promulgating the legislation that created these programs. This objective has been met for the audit program, given that 60% of the benefit of the program comes from avoiding fatalities and incapacitating injuries.

Third, about a fifth of the accidents avoided result from reduced industry mileage caused by the increased costs to the industry.

The audit program shows a consistent benefit-cost ratio of approximately 4.2:1. The reason for this consistency is that the government costs of this program are modest: Thus, even if additional firms improve due to a deterrence effect, there is not much gain from spreading the costs of the audits over a larger number of improving firms. The roadside inspection program is reasonably expensive both to the government and motor carriers. Therefore if firms improve voluntarily without the costs of inspection, the benefit-cost ratio of the program increases significantly.

The audit program has a larger benefit-cost ratio than the inspection program over the whole range of reasonable assumptions concerning accidents avoided and the magnitude of the deterrence effect. Serious questions can be raised as to the whether the roadside inspection program makes a positive contribution to society at all. If mid-range estimates of accident avoided are used, the deterrence effect has to be at least a quarter of the size of the direct effect for the program to be worthwhile.

8. POLICY IMPLICATIONS

To summarize, the benefits of the safety audits arise from approximately 2,000 firms that received an unsatisfactory rating on a Safety Review audit and then improved their accident performance by 43%. The benefits of the roadside inspection program are that vehicles placed out-of-service are defect free for three months and a proportion of the drivers placed out-of-service are not recidivists for six months. The favorable evidence from the literature is that the accident rate of vehicles placed out-of-service is reduced by 13%, and the accident rate for drivers placed out-of-service falls by 4.27%. Mid-range estimates of accident reduction are 8% for vehicles and 3% for a period of three months for drivers.

There is also a deterrence effect. Its value can credibly be taken to be a maximum of 50% of direct effects. A more plausible value is 25% of the direct effects. Calculation of costs and benefits suggests that the audit program has a benefit-cost ratio of 4.2:1 under a wide variety of assumptions. The inspection program has a benefit-cost ratio of 1.5:1 under the most favorable assumptions, but it is somewhat questionable whether it shows any net social benefits under more moderate assumptions.

The most immediate conclusion is that net benefits would be larger if there were a reallocation of resources from roadside inspections to SR/CR audits. With 150,000 trucking firms still unaudited, there is no immediate prospect of diminishing returns from expanding the audit program. Increasingly the audit program is visiting the smallest and worst performing firms. One should not ignore the fact that the CR audit is the most powerful tool that the FHWA has for reforming firms, in that it is used to support legal actions and in the extreme can lead to the removal of operating authority.

The weakness of the roadside inspection program is apparent. The program is relatively expensive to the government, when compared with the audit program. There are substantial costs to motor carriers, and therefore to consumers, from the delays that occur. The inspections alone incur 600,000 vehicle-hours of delay a year. The very large number of vehicles placed out-of-service results in another 1.1 million vehicle-hours of lost productivity.

It is hard to argue against the necessity for the latter delays because it is morally difficult to accept known deficient vehicles and drivers on the highway. However, one can take issue with the inspection procedures. The 30 minute duration of the inspection results from the full mechanical inspection of the vehicle. Everyone in the safety business knows that, excluding brakes, mechanical failures account for a very small percentage of accidents.

The FHWA would do well to concentrate on inspections of drivers and detecting brake deficiencies. We are encouraged to hear about field trials of new technologies which may shorten inspections. Eight states are now starting to use roller dynamometers. They are able to test the brakes of a combination truck in ten minutes, and are also portable enough to be used at "surprise" locations. Research is being conducted in Oregon into infrared scanning of brakes while the vehicle is at mainline speeds. Trials have also suggested that the use of audio headsets or handheld terminals by inspectors to record results can reduce inspection time by ten minutes. There are also trials to provide real-time information to inspectors so that they can concentrate their activities on firms with poor accident or audit performance, and firms about which the government has little information. Inspectors will be able to identify those firms with satisfactory audit rating, and refrain from inspecting unless a problem is evident (Lantz, 1995).

It is also tempting to recommend that the FHWA should expand its level III roadside inspection where only driver compliance is investigated. These inspections would be shorter and could be conducted almost anywhere, thereby introducing an element of surprise. The current policy of conducting inspections at weigh stations allows unscrupulous carriers to time and route their vehicles to minimize the chances of inspection. However, most driver violations concern exceeding permitted hours of service. During the course of this research it became apparent to us that the current law has no teeth to deal with this problem. Traffic tickets are not automatically issued, and even if they are there is little likelihood that they will be used in actions to revoke a driver's Commercial Drivers License. We would only recommend expansion of level III inspections if it becomes normal to issue a traffic ticket for hours offenses, subject to inspector discretion in exceptional cases, and that these tickets carry demerit points on the Commercial Drivers License.

In contrast the SR/CR audit program appears to be very worthwhile. This program has the virtue of being relatively inexpensive. However, even this program is not without its critics. Moses and Savage (1992) showed that, with a few exceptions, compliance with the questions asked had little to do with actual accident experience. The exceptions were hours-of-service compliance, and the reporting of accidents. The Congressional Research Service (U.S. Senate, 1989) also commented that there are so few federal inspectors that most trucking firms could reasonably expect that they would not be audited in the next five years. If they are audited and found unacceptable, staff restrictions mean that follow up audits may occur years after the initial audit. In fairness to the program, it should be pointed out that while only 40% of trucking firms have been audited, these firms operate 78% of the industry mileage (see appendix A). As already discussed, there should be considerable net benefits from diverting government resources from the roadside inspection program to the audit program.

The main virtue of the audit program is its effect on a small number of individual firms. The government is seen as taking an interest in the performance of individual firms. It collects accurate information on accident experience, and threatens and cajoles the worst firms to improve. Our earlier work provides suggestions on how the audit process can be made more efficient by focusing on a few questions that have been shown to be strongly related to actual accident experience. Those questions deal with accident reporting and drivers' hours-of-service compliance. This should allow the existing workforce to visit more firms. In addition, in the future the FHWA should target specific types of firms for auditing, such as small, general-freight firms because they have relatively high accident rates.

APPENDIX A: ESTIMATE OF INDUSTRY SIZE AND NUMBER OF ACCIDENTS

The FHWA estimates that, excluding bus companies, there are 257,682 interstate motor carrier firms. As of March 8, 1993, the agency had conducted audits on 101,805 firms. As part of these audits data are collected on annual fleet miles and accident experience in the previous twelve months. The FHWA also has some size data on 98,152 of the unaudited firms because these firms are required to submit a postcard indicating number of drivers and trucks. However, there are 57,715 for which the FHWA has no data.

An estimate of industry mileage was made by analyzing the fleet sizes and annual fleet miles of the audited firms. A tape of this data was made available by the FHWA. Firms were split into seven size categories corresponding to fleet size divisions used by the FHWA. Mileage ranges were then determined that were associated with these fleet sizes, and average fleet miles for each size class calculated. FHWA data indicates the size classes of the 101,805 audited firms and 98,152 unaudited firms who submitted fleet data. The 57,715 firms for which data are not available are believed to be relatively small. Therefore, these firms were distributed among the four smallest size categories shown in table A1 in a similar fashion to the 98,152 unaudited firms. Using this method, a total of 77.658 billion miles was estimated for the interstate industry.

TABLE A1: DISTRIBUTION OF FIRM SIZES

Band	Annual Fleet Miles Range	# of Vehicles	Average Fleet Miles	# of Firms	% Audited
1	-40k	1	22k	106,943	24
2	40k-100k	2-3	70k	72,166	37
3	100k-210k	4-6	151k	36,673	51
4	210k-370k	7-11	281k	19,583	63
5	370k-850k	12-20	558k	10,163	79
6	850k-50m	21-1500	3.46m	12,068	87
7	50m+	1500+	135m	86	97

To place this estimate in context, the FHWA's annual *Highway Statistics* estimates that in 1991 there were 97 billion miles operated by combination vehicles, and 151 billion by all trucks of over 10,000lbs. These latter numbers include the operations of intrastate carriers as well. We are therefore estimating that the interstate carriers under federal safety jurisdiction account for about half of the entire trucking industry, and probably a substantial proportion of the mileage operated by large combination vehicles.

An estimate can also be made of the total number of reportable accidents for the industry. The reportable accident rates per million miles for seven size classes of audited firms were obtained from the tape made available by the FHWA. They are 1.51, 0.84, 0.77, 0.69, 0.64, 0.61, and 0.64, respectively. One should note that these data were collected by federal inspectors during the audit process and therefore regarded as more reliable than the self-reporting of individual accidents that is used for the publication referred to later in this paragraph. If unaudited firms have accident rates that are similar to those of their audited peers by size group, an estimate of 53,023 reportable truck accidents is obtained. This total should be compared with 35,885 accidents reported to the government in 1990, the latest year for which data are available (FHWA, 1990). The latter number is widely believed to be an underestimate, even by the authors of the report who speculate, in the 1990 edition, that much of the underreporting is by private carriers. Based on our estimates one-third of eligible accidents are not reported to the government.

TABLE A2: PUBLISHED GOVERNMENT STATISTICS ON ANNUAL TRUCK ACCIDENTS

<table>
<tr><th rowspan="2"></th><th colspan="3">General Estimates System</th><th colspan="2">FARS</th><th rowspan="2">OMC
1990</th></tr>
<tr><th>1991</th><th>1990</th><th>1989</th><th>1991</th><th>1990</th></tr>
<tr><td>Property Damage</td><td>305,000</td><td>375,000</td><td>365,000</td><td></td><td></td><td>13,733</td></tr>
<tr><td>Minor/Medium Injury</td><td>20,000</td><td>45,000</td><td>35,000</td><td></td><td></td><td rowspan="2">19,533</td></tr>
<tr><td>Serious Injury</td><td rowspan="2">5,000</td><td rowspan="2">7,000</td><td rowspan="2">7,000</td><td></td><td></td></tr>
<tr><td>Fatal</td><td>4,340</td><td>4,761</td><td>2,619</td></tr>
</table>

The accidents referred to above represent the most serious accidents, those that involve a fatality, a serious injury, or more than $4,400 of property damage. There are clearly many additional accidents that are more minor in nature. The exact number of annual truck accidents in the United States is unclear. Table A2 presents the data that are available for a number of recent years. The first source is the National Highway Traffic Safety Administration's (NHTSA, annual) *General Estimates System* (or GES). This system uses police reports on accidents of all severities for all classes of vehicles collected at 60 sites around the country. These samples are then factored up to give estimated national totals. A truck is defined as a freight vehicle over 10,000 lbs which can be operated by either an interstate or intrastate carrier. The second source is NHTSA's annual *Fatal Accident Reporting System* (or FARS). This is a complete census of road accidents resulting in a fatality. The definition of a truck is the same as in GES. FARS gives very accurate information, but gives a limited picture. From 1992 both GES and FARS data are presented in a single publication called *Traffic Safety Facts*. The final source is the, now defunct, system by which interstate firms notify the FHWA Office of Motor Carriers (OMC) of "reportable" accidents. This source considers a truck to be freight vehicle operated by an interstate carrier. Earlier calculations were that interstate operations comprise only half of the national truck mileage, so it is not surprising that the figures in the final column are much smaller than those in preceding columns. In addition, property damage accidents are defined as being resulting in over $4,400 of damage in the OMC data and of any magnitude in GES.

GES is a sampling system and can therefore be subject to statistical errors. In particular the 1991 GES estimates are hardly believable. If the 1990 OMC is any guide to 1991, then nearly all the injury accidents in GES involved interstate firms who filed accident reports! We are more apt to believe the 1989 and 1990 GES estimates that suggest that property-damage-only accidents exceed injury and fatality accidents by a factor of 7:1. If one applies this ratio to the 1990 OMC figures, the number of property damage accidents of all severities by interstate firms should be 7x(19,533+2,619) which equals 155,064. A total of 177,216 accidents in all, which is 4.94 times the reported accidents of 35,885. This latter ratio is in line with relationships found in the FHWA database during the era prior to November 1990 then the government used to collect data on "total" accidents. Using this ratio and the estimate of 53,023 reportable accidents, a total of 261,933 accidents of all severities by interstate carriers is estimated. This estimate can be compared with the GES estimate of over 400,000 annual truck accidents by both intrastate and interstate carriers.

APPENDIX B: COST OF TRUCK ACCIDENTS

B.1 Characteristics of a Typical Truck Accident

In appendix A it was estimated that interstate firms have 53,023 reportable accidents, about 1.48 times the 35,885 accidents that were actually self-reported in 1990. The latter 35,885 accidents resulted in 3,309 fatalities and 34,348 injuries. Injuries are defined as persons who receive immediate medical treatment away from the scene of the accident. Comparing OMC with FARS it seems likely that all the fatal accidents are reported, given that the latter contains intrastate carriers as well. However, injury accidents will be treated as underreported. Injuries are inflated by 1.48 to produce an estimate of 50,835 injuries.

TABLE B1: ANNUAL MOTOR VEHICLE FATALITIES & INJURIES

K	Killed	47,093
A	Incapacitating Injury	558,467
B	Non-incapacitating but evident Injury	1,154,001
C	Possible Injury	1,828,531
O	Uninjured	13,791,181

In addition to the fatality and serious injury accidents, there will be other accidents in which there is property damage or minor injuries that can be treated at the scene. There is no precise figure on the number of more minor injuries sustained in truck accidents. NHTSA's *National Accident Sampling System* (NASS) does give a breakdown of severities for road accidents in general. It uses the "KABCO" system of injury classification used by police officers (National Safety Council, 1989). The annual data for accidents involving all classes of vehicles is shown in table B1 (Miller et al., 1991). Incapacitating injuries are defined as those where the person cannot immediately continue with whatever they were doing (driving, walking, etc.). It is close to the definition of an injury used by the OMC. The NASS data suggest a ratio of B and C injuries to A of 1:2.07:3.27. Earlier, 50,835 KABCO A injuries were estimated which would imply 105,229 KABCO B and 166,231 KABCO C injuries. The above ratio of injuries is based on accident reports received by NHTSA. There is considerable evidence that many minor road accidents go unreported, and these may include, especially, KABCO C injuries.

Based on an estimate of 261,933 truck accidents, it can be calculated that the typical truck accident will result in 0.013 fatalities, 0.194 incapacitating injuries (KABCO A), 0.402 non-incapacitating but evident injuries (KABCO B), and 0.635 possible injuries (KABCO C).

B.2 <u>The Value of Fatalities and Injuries</u>

There has been an extensive literature estimating the valuation of injuries and fatalities. There was a landmark NHTSA report in 1983, followed by a FHWA sponsored report by Miller et al. (1991), and another NHTSA report by Blincoe and Faigin (1992). The following discussion is based on the work of Miller et al.

The costs of injuries and fatalities fall into three categories: direct costs, lost productivity, and pain and suffering.

Direct costs include the attendance of medical, fire and police personnel; hospital and medical costs; vocational rehabilitation; workplace costs associated with hiring temporary or replacement workers; and the administrative and legal costs of settling insurance claims.

Lost productivity is estimated by the wages the victim that would have been paid during their absence from work. In a perfect labor market the wage should equate with the marginal productivity of that person. In recent years, the definition of productivity has been widened to include work within the household.

Pain and suffering from a fatality represents the more intangible costs that constitute the economic concept of the "value of life." These cost can be very large, exceeding the productivity loss and direct costs by a factor of four. They are also somewhat controversial provoking an extensive empirical literature over the past twenty years. (See Jones-Lee, 1989, for a survey; and Jones-Lee, Hammerton and Philips, 1985, for a large and well organized empirical investigation of values for road accidents.) There would appear to be some consensus in recent years with a value of life in the range of $2.5 million.

A relatively new area of investigation is the value of *pain and suffering associated with injuries*. Jones-Lee et al. (1985) asked respondents to their survey to rate the seriousness of eight different injuries in comparison with death. Many serious injuries were felt to be as bad as, if not worse than, death. Miller et al. (1991) take the position that the value of pain and suffering of an injury can be inferred by factoring down the pain and suffering of a fatality based on the years of incapacitation. For example, a typical road fatality would have had a work career of another 19.39 years. A typical KABCO A injury leads to 1.39 years of incapacitation. The value of pain and suffering for a KABCO A injury is assumed by Miller et al. to be 7% of that of a fatality.

There is currently work being funded by the British Department of Transport from Jones-Lee and his associates which reports on empirical valuation of injury (O'Reilly et al., 1994). The most serious injury considered, called a type R in Britain and equivalent to a moderately severe KABCO A injury, is estimated to be valued at 23% to 87% of the value of life. The range of values reflects a variety of experimental survey technique used by the authors. The British type W corresponding to the least serious KABCO A or the most serious KABCO B injury is valued at 2% to 21% times the value of life by O'Reilly et al.'s respondents. This report follows the methodology of Miller et al. while noting that within the next five years professional opinion may evolve to placing a higher value on injuries.

TABLE B2: VALUES OF LIFE AND INJURY ($)

		Direct Cost	Lost Productivity	Pain and Suffering	Total Value
K	Killed	152,282	616,655	2,066,755	2,835,693
A	Incapacitating Injury	24,416	17,751	158,718	200,885
B	Non-incapacitating but Evident Injury	7,796	4,493	27,090	39,378
C	Possible Injury	4,798	2,731	11,765	20,181
O	Uninjured	1,596	165	294	2,055

Table B2 summarizes the values reported by Miller et al. updated from 1988 to 1992 prices. One will note that even uninjured persons incur some costs in making statements to police officers, filing insurance claims, or taking their vehicles to be repaired.

B.3 <u>Delay to Other Traffic and Property Damage</u>

Miller et al. made a special study of truck-involved accidents. They estimate that a typical truck accident incurs $758 in delays to traffic at the scene of the accident and $11,960 in property damage. This is considerably in excess of that estimated for accidents involving other classes of vehicles which were estimated to be $306 in delays and $4,104 in property damage. The above figures include damage to a truck company's property in an accident, but do not include the costs associated with disruption to the truck company's business. These costs will take the form of delays to shipper's cargo and the need to provide a replacement vehicle to complete the delivery. These costs are discussed in sections 3.5 and 3.7 of the main text.

B.4 <u>Average Social Cost per Truck Accident</u>

The various calculations described above allow estimation of the social cost of a typical truck accident. Note that the calculations indicate that 1.25 persons are either killed or injured in each truck accident. While there are some rollover and "run-off-the-road" accidents in which the truck is the only vehicle involved, most truck accidents involve another vehicle or road user. A working assumption will be made that there is, on average, one other person involved in each accident who is uninjured. The breakdown of the total societal cost of $118,211 is shown in table B3.

TABLE B3: SOCIETAL COSTS OF A TYPICAL TRUCK ACCIDENT

Type of Cost	Average Occurrence per Accident	Unit Cost $	Expected Cost $
Fatality	0.013	2,835,693	35,823
Incapacitation Injury	0.194	200,885	38,987
Nonincapacitating Injury	0.402	39,378	15,820
Possible Injury	0.635	20,181	12,808
Uninjured Persons	1.000	2,055	2,055
Property Damage	-	11,960	11,960
Delays to other Traffic	-	758	758
TOTAL			118,211

APPENDIX C: INDUSTRY OPERATING COSTS

ATA (1990) reports financial and operating data on larger for-hire trucking companies. Table C1 breaks down data on costs per mile, adjusted to 1992 dollars, into three categories of firm size, and three types of operations. The size categories are: "large" firms with more than $25 million in annual revenue, "medium" size firms, and "small" firms with less than $5 million annual revenue. The three types of operations are truckload (TL) general freight, less-than-truckload (LTL) general freight, and specialized carriers. TL firms are those where the shipper hires the truck outright for the trip while LTL firms operate on a hub-and-spoke system to consolidate small shipments for line haul.

TABLE C1: COSTS PER MILE IN DOLLARS BY FIRM SIZE

	Large	Medium	Small
General Freight: Truckload	1.28	1.51	1.89
General Freight: Less-than-Truckload	4.07	3.07	2.81
Specialized Carriers	4.59	1.67	1.02

Two problems are faced in generalizing the data in table C1 to the whole industry. The first is that the data reported by the ATA are for firms that are large by industry standards. For this analysis, "large" firms in table C1 are equated with size band 7 described in appendix A, "medium" with size band 6, and "small" with size bands 1-5. The second difficulty is that these data only apply to for-hire carriers. The data on which the estimates of industry size are made in appendix A used three different categories of firms: private carriers, general-freight for-hire carriers, and specialized for-hire carriers. In associating the costs in table C1 with these categories the following principles were used: (1) general freight for-hire is the weighted average of TL general freight and LTL general freight; (2) specialized for-hire is the equivalent of the specialized category; and (3) private firms are equivalent to the weighted average of the TL general freight and the specialized carriers. The latter case of private firms a value of $1.90 per mile is used for the large firms. This adjustment was used because we felt that the figure reported in the ATA book of $4.59 for large specialized for-hire carriers included high cost operations such as household goods carriers which do not have equivalents in the private carrier sector. This produces the estimated costs per mile and annual mileages shown in table C2. Therefore an industry average cost of $1.71 a mile is estimated.

TABLE C2: ESTIMATED INDUSTRY COSTS PER MILE BY TYPE OF FIRM AND SIZE AND ESTIMATED SIZE OF INDUSTRY SEGMENT

	$/Mile			Estimated Miles (m)		
	Large	Medium	Small	Large	Medium	Small
Private	1.90	1.59	1.33	1,452	12,495	14,443
General Freight	2.50	1.68	1.99	8,388	13,388	2,477
Specialized	4.59	1.67	1.02	1,774	15,927	7,314
Average Cost	2.75	2.65	1.39			

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