A Cost-Benefit Analysis of US Motor Carrier Safety Programmes

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1. Introduction

This paper investigates the costs and benefits of two governmental safety compliance programmes aimed at the interstate trucking industry in the United States. The 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 minimum safety standards have been raised and more resources made available to ensure compliance.

The first programme involves "Safety Review" (SR) visits to the operating bases of firms. Managers are questioned about safety-related procedures and policies such as those governing maintenance, and driver hiring and training. The inspectors have a list of 75 questions, grouped under nine headings. A points system is used to determine whether the carrier is rated satisfactory, conditional or unsatisfactory (Moses and Savage, 1992). A second visit, termed a "Compliance Review" or CR, is made if the firm does not achieve a satisfactory rating. At a CR the firm is re-rated and, if necessary, evidence is collected to support legal action.

The SR/CR programme expanded considerably after October 1986. In 1991, 26,000 firms were audited, compared with approximately 10,000 per year prior to 1986. By early 1993, 40 per cent of firms had been audited. Because the programme initially focused on larger carriers, audited firms operate 78 per cent of industry mileage.

The second programme is a system of roadside inspections. The Motor Carrier Safety Assistance Programme (MCSAP), authorised under the 1982 Surface Transportation Assistance Act, provides federal funds to states to cover 80 per cent of the cost of these inspections. In 1991, 1.1 million interstate carriers were stopped for 30-minute inspections at weigh stations. Uniform inspection procedures apply throughout the United States

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and Canada. Inspectors conduct a comprehensive mechanical examination of vehicles, and check that drivers have correct licences, have adhered to hours-of-service rules, and are not under the influence of drugs or alcohol. Vehicles and/or drivers failing to comply are placed "out of service" on the spot until the problem is rectified.

The paper calculates the annual benefits and costs of the two programmes. All dollar figures are expressed in constant 1992 prices. Future benefits and costs have been discounted at a real rate of 7 per cent per year (Office of Management and Budgets, 1992). For the sake of space, most of the supporting calculations are not shown in their entirety. A working paper is available from the authors containing all the calculations and supporting appendices.

2. Programme Direct Benefits and Costs

2.1 Evidence of accident reduction from safety audits

The direct effects are on the 12 per cent of firms given an unsatisfactory rating in an SR audit. FHWA data indicate that these firms are about a quarter of the size, but have twice the accident rate, of firms with superior ratings.

We identified 6,000 firms which had been assigned an unsatisfactory rating in the initial SR audit and subsequently received a follow-up CR audit. Ninety-one per cent of these firms received an improved rating on the CR audit, and their average reportable accident rate fell by 43 per cent from 1.29 to 0.74 per million miles. "Reportable" accidents are the more serious accidents which at the time were defined as involving a fatality, a serious injury, or more than $4,400 in property damage.

The average improved firm operated about 250,000 fleet miles a year. Therefore such a firm could expect to have one reportable accident every three years prior to the SR. One might reasonably suggest that our finding of a reduction in the accident rate merely reflects 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 criterion for selection for an SR, but this is not always the case. In another study, we isolated 518 firms which in the 1991-93 period had both an unsatisfactory SR rating and poor roadside inspection performance. Of these 518 firms, 442 did not have a reportable accident in the year prior to their SR (Moses and Savage, 1996). In addition, the FHWA rating algorithm cannot assign an unsatisfactory rating to a small firm solely on the basis of a poor accident rate. The firm has to have poor safety management practices as well.

The accident improvement should also carry over to the far more numerous category of accidents which only involve relatively minor property damage. Based on information from the National Highway Traffic Safety Administration's (NHTSA, annual) *General Estimates System*, we estimate that total accidents are 4.94 times more numerous than reportable accidents. The seemingly large increase in the number of accidents when the definition is widened to total accidents is not crucial to the benefits of the safety programmes. The economic cost of the additional accidents is minimal compared with the cost of accidents in which a fatality or serious injury occurs.

If 12 per cent of firms are assigned an unsatisfactory rating at SRs, and 91 per cent subsequently improve, we estimate that 1,966 firms improve each year. Based on the typical size of such firms, we estimate that they operated 507 million miles a year at the time of their SR audit. The improvement in accident rates requires expenditure by trucking firms. Later in this article we estimate that the effective price to customers rises by 5 per cent, and given a price elasticity of -1.3 (Oum *et al.*, 1992), the mileage 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 recognises that the improvement in accidents will only continue as long as the firm is in business. Since most of the firms which are rated unsatisfactory are small, an annual failure rate of 5 per cent is used, which is approximately three times higher than the failure rate for the entire industry.

The second consideration is that some firms do not maintain their improved accident rate. Management practices may backslide and the accident improvement might decay. Using a database of almost 100,000 firms which were initially assigned a satisfactory or conditional rating, we found that about 10 per cent had given the government cause to conduct a CR in the subsequent five years. The accident rate at the second audit was 24 per cent above that at the SR. If we take this latter group of firms as representing the proportion of firms which backslide, we can estimate that accident rates increase by 0.005 per cent for the population of "improving" firms. That is to say, the typical improving firm initially reduces its total accident rate by 43 per cent from 6.37 to 3.652 per million miles. After one year the accident rate creeps up to 3.671. The initial improvement in the number of accidents falls away by an average of 0.007 per annum.

Discounting future accidents at 7 per cent per year, the effect of the audit programme on accidents can therefore be calculated as:

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

It is therefore expected that 11,168 accidents are avoided because of safety audit activities in a given year.

2.2 Evidence on accident reduction from roadside inspections

The methodology for calculating accident reduction from roadside inspections involves a two-step process. The first stage of the calculation uses FHWA published data (1992a) and databases to estimate the number of vehicles and drivers placed out of service disaggregated by firm size and the type of violation found. Four categories of violations were used: vehicle brake problems, other vehicle-related problems, drivers found impaired through drugs or alcohol, and other driver problems. The third column of Table 1

Table 1
Summary of Calculations Used to Estimate Accident Reduction from Roadside Inspections

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

Sources: a Authors' calculations from FHWA data
b Hurst, Harte and Frith (1994)
c Gillespie and Kostyniuk (1991)
d Marsh (1990)

indicates that brake problems predominate among vehicle violations. Almost all the driver violations are for exceeding permitted hours of service.

Data were also disaggregated into seven firm size classes. These classes are used throughout this article. Firms vary significantly by size in their accident performance, roadside inspection frequency and performance, vehicle use, and cost. Some leading statistics on the various size classes are shown in Table 2. Note that the apparent diseconomies of scale shown in the final column are misleading, because the larger firms engage in types of operations that are inherently more costly.

The second stage of the calculation is to transform the data on violations into estimates of accidents avoided. Because of disagreements in the engineering literature, we have calculated upper bound and mid-range estimates of these effects. The figures we have used for both accident reduction and the duration of improvement are shown in the final two columns of Table 1. The following paragraphs elaborate on the literature from which this study has drawn.

The role of brake deficiencies in accidents is the subject of heated debate. The traditional literature, summarised by Gillespie and Kostyniuk (1991), suggests that brake failure is the cause of less than 5 per cent of accidents. At the opposite extreme, two NHTSA reports (Clarke *et al.*, 1987, 1991) calculate that braking deficiencies could be involved in up to 35 per cent of accidents. Included in this later figure are all accidents where a truck is driven into the back of another vehicle or has inadequate stopping distance. While sympathetic to the argument that the existing methods of investigating

Table 2
Characterstics of Firm size Categories

Firm Size Range (annual miles)	*Percentage of Total Firms*	*Average Annual Miles per Vehicle*	*Total Accidents per Million Miles*	*Cost Per Vehicle-mile*
< 40k	42%	9,000	7.49	$1.39
40k - 100k	28%	12,000	4.17	$1.39
100k - 210k	14%	14,000	3.81	$1.39
210k - 370k	8%	15,000	3.46	$1.39
370k - 850k	4%	18,000	3.17	$1.39
850k - 50m	5%	25,000	3.05	$2.65
> 50m	0.03%	23,000	3.19	$2.75
All firms	100%	19,700	3.37	$1.71

Source: FHWA data, ATA (1990), authors' calculations.

truck accidents tend to understate the causal influence of mechanical problems, we cannot ascribe to braking difficulties those accidents caused by inappropriate speed and poor driver discipline. Recognising the contentious nature of the literature, our upper bound figure is based on the top end of the more traditional literature. Eleven per cent of accidents are ascribed to brake-related causes and 2 per cent to other vehicle defect problems. Our mid-range estimate is based on the median values of the existing literature with brake defects representing 6 per cent of accidents and other mechanical causes 2 per cent.

When an out-of-service fault is found and subsequently corrected, the "benefit" of the inspection may extend for some time because, even with no maintenance, it takes time for the vehicle fault to reappear and become "critical." Gillespie and Kostyniuk (1991) calculate that an out-of-service fault is certain to develop within six months from the point of last maintenance for a straight (that is, nonarticulated) truck, and in less than 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.

Each year, approximately 2,500 drivers are found impaired by drugs or alcohol during roadside inspections. There is an automatic one-year revocation of the Commercial Drivers' Licence for these offences. We assume that these drivers are replaced by unimpaired drivers. Hurst *et al.* (1994) calculate that impaired drivers have a 75 per cent higher probability of an accident than unimpaired drivers.

Most drivers are placed out of service for driving more than the permitted number of hours. While the enforced rest surely reduces the probability of fatigue-related accidents during the subsequent 24 hours, the longer term effects are more debatable. It is at the inspectors' discretion whether a traffic ticket is issued for an hours violation, and even if a ticket is issued and a conviction secured it does not automatically count towards revocation of the Commercial Drivers' Licence.

With a sophisticated system of control groups and a sample size of over 200,000 car drivers, state experts in California calculated that issuing a warning letter to drivers led to a 4.27 per cent reduction in accidents. The effect was estimated to last six months (Marsh, 1990). These figures are used as our upper bound. However, we feel that the true effect is much lower. For many truck drivers, the consequences of hours violations are not severe, and the probability of detection of recidivism is minimal. The mid-range assumption is a 3 per cent accident reduction with a three-month duration.

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 for different firm size classes are shown in Table 2. Two adjustment were made. The first was made because inspections largely take place on limited-access highway. The vehicles on such highways operate twice as many miles per year as a typical vehicle (Gillespie and Kostyniuk, 1991). The second was made because the vehicles and drivers found in violation of federal regulations should be much more accident prone than the industry average. Our analysis of FHWA data suggests that firms which perform poorly in roadside inspections have accident rates 31.6 per cent above average. The exception to this calculation is for impaired drivers where a much higher relative accident risk is assumed.

Calculation can then be made for the accidents avoided in each size class and type of violation. In total, the upper bound estimate is that 1,544 accidents are avoided each year. Using mid-range assumptions 967 accidents are avoided.

2.3 The cost of truck accidents

The social costs of a typical truck accident are estimated as $118,211. The breakdown of these costs is shown in Table 3. This value may appear low, but it should be noted that the definition of an accident is very wide, and includes many minor accidents. 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 shippers' cargo, and the need to provide a replacement vehicle to complete the delivery. These costs are discussed later in this section.

2.4 Governmental programme costs

Government expenditures were obtained from the federal budget (Office of Management and Budgets, annual). The audit programme costs the federal government $30 million a year. The roadside inspections are funded jointly by the federal and state governments. Approximately three-quarters of roadside inspections are conducted on interstate rather than intrastate carriers. Taking this into account, inspection of interstate carriers costs all levels of government $60 million a year.

Table 3
Social Costs of a Typical Truck Accident

Type of Cost	*Average Occurrence per Accident*[a]	*Unit Cost*[b] $	*Expected Cost* $
Fatality	0.013	2,835,693	35,823
Incapacitation injury	0.194	200,885	38,987
Non-incapacitating injury	0.402	39,378	15,820
Possible injury	0.635	20,181	12,808
Persons not injured	1.000	2,055	2,055
Property damage	-	11,960	11,960
Delays to other traffic	-	758	758
Total			118,211

Sources: [a] FHWA (1990), NHTSA *National Accident Sampling System* and *Fatal Accident Reporting System*
[b] Miller *et al.* (1991)

Most of the funds for the motor carrier safety programme are raised from federal motor fuel taxes. As usual in the cost-benefit analysis literature, a shadow value is calculated to represent the deadweight loss associated with raising tax revenues. Empirical studies suggest that sales taxes cause 21¢ deadweight loss for each dollar raised (Jørgensen and Yun, 1991).

2.5 Inspection costs to motor carriers

Senior management representatives of carriers have to be present during SR and CR audits to answer questions and show the inspector written records. A typical SR takes two to three hours to complete, and a CR 28 hours (Office of Technology Assessment, 1988). Assuming that these managers are diverted from other work, firms lose marginal productivity valued at the manager's wage rate including fringe benefits. Based on industry average managerial compensation including fringe benefits of $60,000 per year (ATA, 1990), the implied cost of an SR is $90 and $875 for a CR. The annual total cost to the motor carrier industry of the 18,000 SRs and 8,000 CRs conducted a year is $8.6 million.

The typical roadside inspection delays the vehicle by 31.5 minutes (FHWA, 1992b). Because the vehicle would have had to stop for weighing anyway, the considerable time costs of accessing the inspection area, and decelerating from and accelerating to mainline speeds need not be included. A dollar valuation can be made by: (a) assuming the inspection time is roughly equivalent to driving 20 miles; and (b) applying average cost-per-mile figures derived from ATA (1990) and shown in Table 2. Consequently, the time required for inspections is estimated to cost the industry $36.4 million a year.

Firms which have their vehicles or drivers placed out of service have to bear the cost of the delay until a trip can continue. No official data are kept on the length of time taken to eliminate problems. These were obtained by interviewing FHWA officials and managers of trucking companies. The average delays for different types of violations were:

Vehicle brake violations	1.25 hours
Vehicle lighting violations	1.50 hours
Other vehicle violations	3.00 hours
Impaired driver violations	4.00 hours
Driver hours-of-service violations	4.00 hours

The length of time for a vehicle violation to be corrected depends on whether the driver can make the repair or brake adjustment, or whether a mechanic has to be called. Drivers placed out of service for hours violations are forced to take an eight-hour rest before continuing their journey, except when a relief driver is called out. The extent of the network effect on the trucking firm depends on whether the driver's original schedule included rest during that period, which is why the industry suggests a four-hour delay. In the case of impairment, a relief driver has to be called.

Overall 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 from Table 2 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 labour and parts.

Assuming for the time being a long-run constant supply price industry, the costs of the safety programmes 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, inspections increase cost by 0.13¢ a mile, or 0.08 per cent, with an average industry cost per mile of \$1.71. Given an elasticity of demand of –1.3 (Oum *et al.*, 1992), this represents a deadweight loss of approximately \$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 is applied. This results in an upper-bound annual benefit of \$0.29 million, with a mid-range estimate of \$0.18 million.

2.6 Accident reductions resulting from inspection costs

The calculations in the preceding subsection suggest that if the costs of audits and inspections are passed on in price, industry output will fall. The audit costs reduce industry mileage by 6.5 million, while the cost of the thirty-minute roadside inspections reduces mileage by 28 million. Based on an estimated industry average accident rate of 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, and 93 because of the inspections.

Firms which have their drivers and/or vehicles placed out of service suffer a net time delay equivalent to $65 million a year after allowance is made for the delays that might have occurred as a result of an accident. Using the same methodology as that of the preceding paragraph, these costs should reduce industry mileage by 50 million. Given the assumption that firms placed out of service have an accident rate 31.6 per cent above the industry average of 3.37 per million miles, the mileage reduction causes 220 additional accidents to be avoided.

2.7 The cost of improved operating quality

The 1,966 firms a year which improve their accident performance as a result of the audit programme face increased costs. There are increased expenditures on training and maintenance which are only partially offset by reduced insurance premiums and accident costs. The best approximation to the magnitudes of the cost increases comes from a study by 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 between 6 and 7 per cent.

Since the firms assigned an unsatisfactory rating are primarily small, we assume that their costs rise from $1.31 per mile to the $1.39 per mile which is the average cost for smaller firms (ATA, 1990). We assume that the trucking industry is a series of vertically differentiated, perfectly competitive markets. At each quality level there are enough firms for price to be driven to costs. Therefore, the cost increase of 8¢ per mile as a result of safety improvements gives an 8¢ increase in price.

The above description is of a move along a demand curve. However, the demand curve also shifts upwards as shippers are now consuming a higher quality product. We estimate the value that shippers might place on the higher quality is equivalent to the reduction in damage to their goods. Given that a typical truck accident causes $5,000 of damage to the cargo, the safety improvement of 2.72 accidents per million miles results in shippers gaining 1.4¢ per mile in reduced cargo damage.

At the time of the SR inspection the unsatisfactory firms operated a total of 507 million miles. If the net cost to the shipper increases by 6.4¢, or 5 per cent, and there is a price elasticity of -1.3 (Oum *et al.*, 1992), output of these carriers falls 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 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 cent per year, and adjustment is made for the probability of firm failure and the decay in accident improvement.

The calculation is predicated on the assumption that shippers have to accept the higher price or exit the market. In the short run this might not be true if there exist unaudited low-quality firms available to fill the void. Our analysis is based on a view that ultimately low-quality service will become scarce and then disappear. To take a contrary view logically undermines the economic case for safety programmes. If new low-quality firms continually emerge to replace those firms which are forced to improve their safety performance, average industry accident rates will not decline. Furthermore, those trucking firms which do improve will be competing with existing firms which offer higher quality for a fixed pool of shippers, and firms will have to exit the market.

3. Estimate of Direct Benefits and Costs

Table 4 contains estimates of the direct benefits and costs of the audit and inspection programmes. The audit programme has a $1 billion net benefit. The benefits exceed the costs by 4:1. A sensitivity analysis was conducted by varying the level of cost increase needed to bring about the safety improvements. In Table 4, it was assumed to be 6 per cent. The benefit-cost ratio rises to 5.5:1 if the cost increase is only 4 per cent, and falls to 3.4:1 if the cost increase is 8 per cent.

Under the most favourable assumptions, the benefits of the inspection programme only exceed the costs by 26 per cent. The effect of any more moderate assumption implies that the inspection programme 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 behaviour.

4. Estimation of a Deterrence Effect

It is quite possible that the benefits of the two safety programmes extend far beyond those firms which are given an unsatisfactory SR rating or have many of their vehicles or drivers placed out of service in roadside inspections. Other firms may observe these programmes and decide voluntarily to improve and reduce the chance of detection and level of penalties.

The deterrence effect is investigated by time-series analysis of fatal combination-truck accident rates. The data for 1977 to 1992 are shown in Table 5. While the data include both intrastate and interstate trucking, the former is inspected at the roadside and is increasingly subject to state audits.

It is clear from the fourth column of Table 5 that combination-truck accident rates declined continually even after economic deregulation, and before both the safety programmes 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 fitted a linear time trend to the logarithm of truck accidents for the years prior to increased enforcement (1977 to 1985). The calculated figure was then used

Table 4
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".

to construct a detrended series of truck accident rates for the entire period 1977 to 1992. The logarithm of the detrended truck-accident rates was then regressed against a measure of the increased enforcement from 1985 onwards. The enforcement variable was the expenditure, in 1992 dollars, by federal and state governments on truck safety enforcement activities, minus the expenditures in 1984 which we regard as the base year prior to the current programmes. A statistically significant negative relationship was found with a t-statistic of 2.73, and 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 penultimate column of Table 5 under the heading "Method I." Using this methodology, it is estimated that in 1992 the effect of the enforcement programmes was to reduce the accident rate by 8.2 per cent.

Table 5
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%

Sources: Accidents: NHTSA *Fatal Accident Reporting System*
Exposure: FHWA *Highway Statistics*
Enforcement: OMB *Budget of the United States Government*

A second method used 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 5. Accident rates declined by almost 50 per cent for all vehicle classes in the past 15 years. However, there appears to be evidence that truck accidents have 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 related negatively and significantly 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 5 under the heading "Method II." In 1992 the enforcement programmes are estimated to have caused a 12.2 per cent decline in accidents, a figure that is approximately 50 per cent larger than that estimated using Method I.

All the data in the deterrence analysis relate to fatal accidents. Even if fatal accidents fell by 8 to 12 per cent 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. Evaluation of the Magnitude of a Deterrence Effect

The regression analysis indicates that by 1992, the seventh year of the safety programmes, truck accidents declined by 8 to 12 per cent more than would be expected given long-standing time trends. The direct accident effects calculated earlier in the paper account for a 3.9 per cent reduction in accident rates. Is the difference between these two figures a credible estimate of the deterrence effect?

A simple calculation can put the magnitude of the deterrence effect in context. Assume that the firms which voluntarily improve have characteristics similar to those which are given an unsatisfactory rating in an SR audit, and their accident performance improves by an amount that is similar to the reduction for these firms. In Table 6, the number of firms which would have to improve voluntarily for different magnitudes of the deterrence effect is shown. These numbers are also shown as a percentage of the firms which have not yet received an SR audit. A deterrence effect, similar in size to the direct effect, or twice the direct effect, is not credible. Over the history of the SR programme only 6 per cent of firms have been rated unsatisfactory, and even the most recent audits, which have concentrated on smaller firms, find 12 per cent to be unsatisfactory.

A small deterrence effect can also be justified by calculations of the economic choices open to a trucking firm with poor safety performance. If it decides to improve voluntarily, it needs to have the capital to invest in improved training, equipment and maintenance. In a hedonically perfectly competitive market, the profits of firms do not change as quality-induced cost increases are passed on in prices. However, let us assume that a firm incurs sub-normal profits for one year until its improved reputation permits an increase of 8¢ per mile in price. Annual average mileage per truck is approximately 15,000, so the firm incurs sub-normal profits of \$1,200T where T is the number of trucks owned.

If the firm decides not to improve, it may be subject to audits and inspections in both the coming year and in future years. Our calculations are based on a nine-year time horizon, by the end of which time the firm is certain to have been audited. An unsatisfactory SR audit and a subsequent CR audit costs the firm \$965 in management time, and then the firm incurs profit penalties similar to those stated immediately above. Discounting future costs at an annual rate of 7 per cent and making allowance for a 5 per cent annual probability that the firm ceases operating, the discounted present cost of the audits is \$(650 + 810T).

FHWA data indicate that on average a truck receives a roadside inspection once every five years. The firm therefore has $0.2T$ inspections per year. Based on our earlier methodology, an out-of-service action results in a delay to the firm of 4.5 hours; 30 minutes for the inspection and four hours while the fault is corrected. The expected annual

Table 6
Firms Required to Improve for Different Magnitudes of the Deterrence Effect

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

cost to the firm from failed inspections is 47*T*. 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 the same way as for the audits produces a discounted present inspection cost of \$174*T*.

Therefore, over a nine-year horizon, a firm will incur a loss of \$1,200*T* if it voluntarily improves now, and a discounted present value loss of \$(650 + 984*T*) if it waits until it is audited before improving. It is irrational for firms with four or more trucks to improve voluntarily. While only 30 per cent of firms have more than four trucks, these firms operate 90 per cent of industry mileage. The choice in favour of waiting would be decisive for small, poorly capitalised firms which do not have the financial means or borrowing capacity to send drivers to training courses, enter into leases for new equipment, or upgrade workshop facilities.

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 non-compliance 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 per cent of the direct effects then by 1992 truck accidents should have been reduced by 5 per cent as a result of the safety programmes: 4 per cent from the direct effects; and 1 per cent from the deterrence effect. Accident rates are estimated to have fallen by 8 to 12 per cent depending on the methodology used to correct for long-standing time trends. Our position is that the residual 3 to 7 per cent accident reduction is explained by other unidentified or unmeasured effects on truck safety which took place in the 1987 to 1992 period and are collinear with the increased enforcement programmes. Since the mid 1980s many legislative Acts concerned with truck safety have been passed. These Acts have changed vehicle standards, introduced new rules for the carriage of hazardous materials, and implemented the national Commercial Drivers' Licence. The licence was phased in over the period 1987 to 1992. It imposed uniform testing standards across states and prevented drivers from having multiple licences as a way of avoiding the consequences of revocation in one jurisdiction. Many states had to raise driver testing standards considerably.

Table 7
Costs and Benefits of Safety Programmes for Different Magnitudes of the Deterrence Effect

Deterrence Effect as a Percentage of Direct Effect	*Upper Bound Accident Reduction from Audits and Inspections*		*Mid-Range Accident Reduction from Audits and Inspections*	
	Audits	*Inspections*	*Audits*	*Inspections*
0	4.14	1.26	4.14	0.87
25%	4.24	1.63	4.24	1.27
50%	4.32	1.94	4.31	1.60

6. Estimates of Costs and Benefits for Both Direct and Deterrence Effects

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 which 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.

In the preceding section, it was estimated that the expected annual costs of the audit programme and the inspection programme were $\$(111 + 138T)$ and $\$47T$ respectively, where T is the number of trucks a firm owns. The expected consequences of the audit programme are approximately three times those of the inspection programme. It would therefore be reasonable to assign 75 per cent of the estimated deterrence effect to the audit programme, and 25 per cent to the roadside inspection programme.

Table 7 shows the benefit-cost ratios of the two programmes under a variety of assumptions concerning the size of the direct effect of the roadside inspection programme, and different magnitudes of the deterrence effect. The audit programme shows a consistent benefit-cost ratio of approximately 4:1. This programme has low governmental costs, so even if additional firms improve as a result of a deterrence effect there is not much to be gained from spreading the costs of the audits. The roadside inspection programme is reasonably expensive to the government and to motor carriers. Therefore, if firms improve voluntarily without the costs of inspection, the benefit-cost ratio of the programme increases significantly.

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

7. Policy Implications

The most immediate conclusion is that something needs to be done about the roadside inspection programme. Its main weakness is the delays it imposes on motor carriers. There are field trials of new technologies which may shorten inspections. Roller dynamometers can reduce brake inspection times, and infrared scanning of brakes while the vehicle is at mainline speeds is in the research phase. Tests 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 tests 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 ratings, and refrain from inspecting them unless a problem is evident.

It is tempting to recommend that the FHWA should expand its "level III" roadside inspection where only driver compliance is investigated. However, we would only recommend this if the penalties for failure to comply with permitted driving hours were made more severe. It should become normal to issue a traffic ticket for hours offences, subject to inspector discretion in exceptional cases, and that these tickets carry demerit points on the Commercial Drivers' Licence.

Net benefits would be larger if a reallocation of resources from roadside inspections to SR/CR audits took place. With 150,000 trucking firms still unaudited, there is little immediate prospect of diminishing returns from expanding the audit programme. With additional resources the programme could overcome the criticism made by the Congressional Research Service (US Senate, 1989) that the lack of federal inspectors means that most trucking firms can reasonably expect that they will not be audited or re-audited in the next five years.

In a previous paper, we were critical of the audit programme (Moses and Savage, 1992). That 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.

Nevertheless, the SR/CR audit programme appears to be very worthwhile. It is a relatively small programme. Its main virtue is that the government is seen as taking an interest in the performance of a small number of individual firms. Using the threat that a CR audit can be used to support legal action and, in the extreme, the withdrawal of operating authority, the programme threatens and cajoles the worst firms to improve.

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