

THE ECONOMICS OF COMMERCIAL TRANSPORTATION SAFETY

by

IAN SAVAGE

Department of Economics and the Transportation Center
Northwestern University

Correspondence Address

Department of Economics
Northwestern University
2001 Sheridan Road
Evanston, IL 60208, USA
Phone: (847) 491-8241
Fax: (847) 491-7001
e-mail: ipsavage@northwestern.edu

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Crashes involving intercity commercial transportation carriers result in the deaths of 6,500 Americans each year, considerable destruction of equipment and merchandise, and occasional releases of hazardous materials into the atmosphere and the groundwater. Commercial transportation therefore poses the same risk to the public as the combined hazards of drownings and domestic fires. The risk is much less than that from automobiles, however; car crashes claimed approximately 37,000 lives in 1995.¹

As shown in table 1, trucking accounts for about three-quarters of total commercial carrier fatalities, followed by railroads, which account for about a fifth. Commercial maritime, commercial aviation, and pipelines each account for fewer than 200 deaths in a typical year. Surprisingly, a relatively small proportion of the people killed are directly involved in the production or consumption of transportation services. Only 15 percent of the fatalities are employees of carriers, and a scant 2 percent are passengers. The majority of the victims are other road users and pedestrians who are involved in collisions with trucks, and trespassers and grade-crossing users who collide with trains.

Table 1. *Average Annual Fatalities 1990-1995*

| | <i>Trucking</i> | <i>Railroads</i> | <i>Commercial maritime</i> | <i>Commercial aviation</i> | <i>Pipelines</i> |
|----------------------------|------------------|------------------|----------------------------|----------------------------|------------------|
| Employees | 645 ^a | 44 | ^b | 13 ^a | ^b |
| Passengers | n.a. | 13 | ^b | 93 | n.a. |
| Bystanders | 0 | 1 | n.a. | 6 | ^b |
| Trespassers or pedestrians | 442 | 546 | n.a. | n.a. | n.a. |
| Motor vehicle users | 3,824 | 615 | n.a. | n.a. | n.a. |
| Total | 4,911 | 1,219 | 188 | 112 | 16 |

Sources: Trucking: National Highway Traffic Safety Administration (various years). Railroads: Federal Railroad Administration (various years). Maritime and Pipelines: Bureau of Transportation Statistics (various years). Aviation: National Transportation Safety Board.

n.a. Not applicable.

^a Excludes non-crash occupational fatal injuries.

^b Specific breakdown by person type is not available, but almost all fatalities are employees.

Of course, unless one has knowledge of exposure, these absolute numbers give little indication of risk. Table 2 provides information on passenger fatalities per billion passenger miles for airlines, buses and railroads. Because major crashes resulting in substantial loss of life are rare, the reported fatality rates are for the ten year period from 1986 to 1995. Bus and commercial aviation have the best safety records at about one fatality for every five billion passenger miles. Riding a train is four times as risky. To put these numbers in context, driving

¹National Highway Traffic Safety Administration (1996); National Safety Council (1996). The 37,000 figure excludes auto drivers killed in collisions with trucks or trains. Note that safety professionals prefer the word “crashes” to “accidents” because the latter word suggests that occurrence is due to pure fate and cannot be influenced by human decisions.

in the mid-1990s was ten times more risky than taking a train and forty times more risky than riding a bus or flying.²

Table 2. *Passenger Fatalities per Billion Passenger Miles*

| | |
|-------------------------------|------|
| Automobiles (1990-95) | 8.29 |
| Railroad (1986-95) | 0.81 |
| Bus (1986-95) | 0.23 |
| Commercial Aviation (1986-95) | 0.21 |

Source: National Safety Council (1996).

Another indication of relative modal safety is fatality and injury rates for employees. Although this chapter does not focus on the labor market issues involved in risky occupations, employee fatality and injury rates do give some insight into relative modal safety. The maritime industry and the trucking and warehousing industries have the highest levels of employee risk.³ These risks are substantial: employees in these industries face more risk than if they were working in construction and about the same amount of risk as underground miners. In contrast, employees in the railroad and aviation industry face less risk, although the risks are still two or three times those in manufacturing.

Ships, planes and pipelines operate in places where their crashes rarely affect bystanders or other third parties, although there are exceptions, such as the crash of a freight aircraft into a parking lot at Miami in 1997, and the spill of oil from the tanker *Exxon Valdez* in Alaska in 1988. In contrast, trucks and trains frequently collide with pedestrians and other road users. For the average member of the public, the annual probability that they will be killed in a crash involving a truck is similar to the probability of dying in a fire, while the risk of dying from a collision with a train is the same as that of being killed by the accidental discharge of a firearm. Of course, not all of these victims are innocent bystanders. Many are careless, and may indeed be the “cause” of the collision.

Recent Trends in Trucking, Railroads, and Commercial Aviation

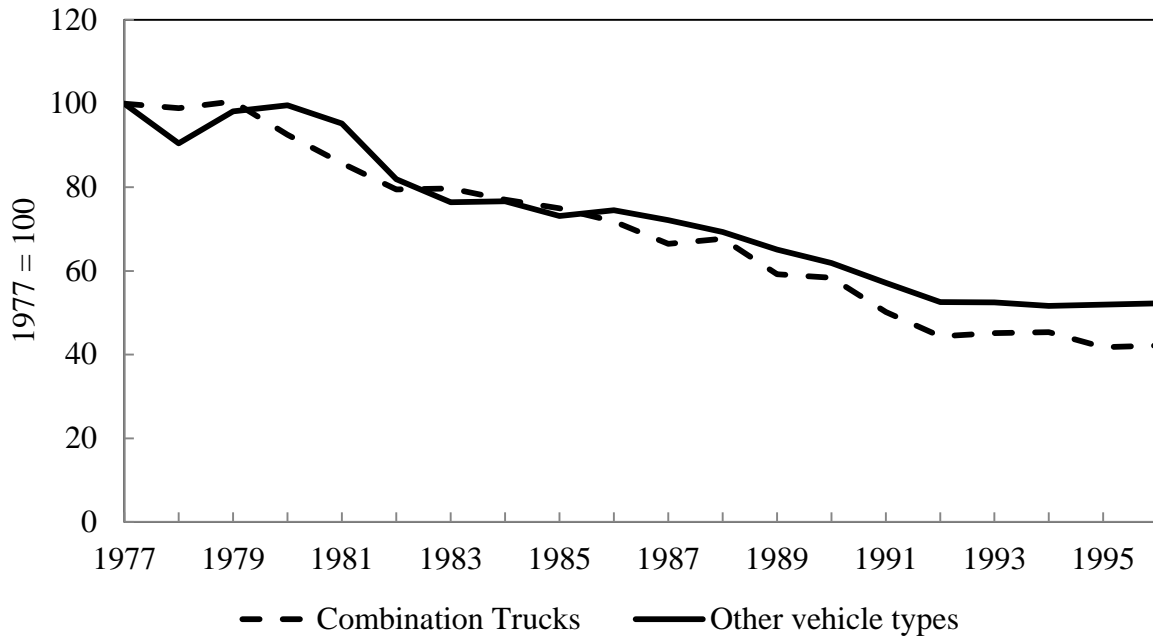
As shown in figure 1, fatal truck crashes per vehicle mile have declined by more than half in the past twenty years.⁴ The absolute number of fatal crashes has declined somewhat, while truck miles have doubled. Much of this improvement has occurred because roads in general are safer; a fact that is also reflected in declines in the fatal crash rates for other vehicle types. Improved automotive technology, better vehicle-occupant protection, and changing social attitudes toward the use of seat belts and drinking and driving have all contributed to safer highways. The fatal crash rate for trucks appears to have declined faster than that for other vehicle types since the mid-1980s.

²For this comparison, the driving risk is calculated for the period 1990 to 1995 because automobile safety has improved considerably since the mid-1980s.

³Bureau of Labor Statistics (1997a: table A-2; 1997b: table 1).

⁴National Highway Traffic Safety Administration (various years), Federal Highway Administration (various years).

Figure 1. *Fatal Crash per Vehicle Mile for Combination Trucks and Other Vehicles, 1977-96.*



Source: National Highway Traffic Safety Administration (various years)

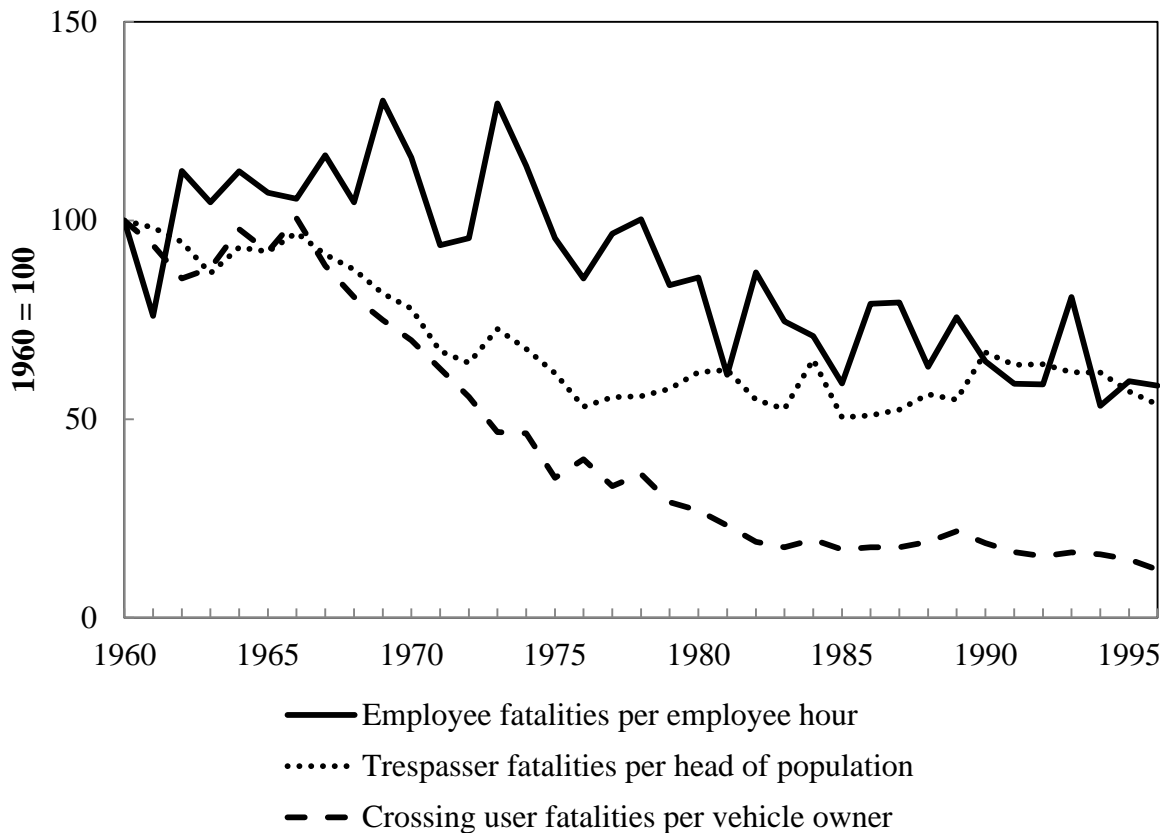
Trends in railroad fatality rates since 1960 are shown in figure 2 for the three major types of fatalities. Employee fatalities are expressed relative to employee hours, trespassers relative to the U.S. population, and crossing fatalities relative to the number of registered motor vehicles. The casualty rate for crossings has recorded the most impressive improvement, falling rapidly since 1967. The risk is now less than a fifth of what it was in 1960. The trespasser rates also stated to decline rapidly after 1967 but leveled out in 1975 at about 40 percent below the fatality rate in 1960. If anything, there may be a slight upward trend in recent years. Contrary to the popular view that trespasser victims are small children or people innocently taking a shortcut across the tracks, the reality is that most are single adult males who have consumed substantial amounts of alcohol and are using the right-of-way as a place to socialize or to sleep off the effects of the alcohol.⁵

The employee casualty rates show a different picture. After many decades of improvement, the rates started to increase in the 1960s and did not resume their downward trend until 1973. Figures on the rate of collisions and derailments are more difficult to analyze because the definition of property-damage-only crashes was not adjusted for inflation until 1975. Every indication, however, is that crashes involving property damage also increased significantly in the 1960s and early 1970s and started to decline only after 1978. Since the mid-1970s the improvement in safety has been dramatic. The fatality rate is now half of what it was in 1973, and the rate of collisions and derailments is a quarter of what it was in the peak year of 1978. In part, the improvement can be explained by a change in the way that railroads handle traffic. Starting in the late 1970s, traffic has been increasingly handled in unit trains (trains composed of permanently coupled sets of freight cars), a practice that necessitates much less switching of cars. The proportion of train miles that are represented by yard and switching miles has fallen by half,

⁵Pelletier (1997).

from 30 percent in the mid-1970s to close to 13 percent in 1995. Because 70 percent of collisions and 60 percent of derailments occur in yards and sidings, it is not surprising that the rate of collisions and derailments has fallen. Nonetheless, the reduction in the amount of switching does not explain all of the improvement in safety.

Figure 2. *Railroad Fatality Rates, 1960-96.*



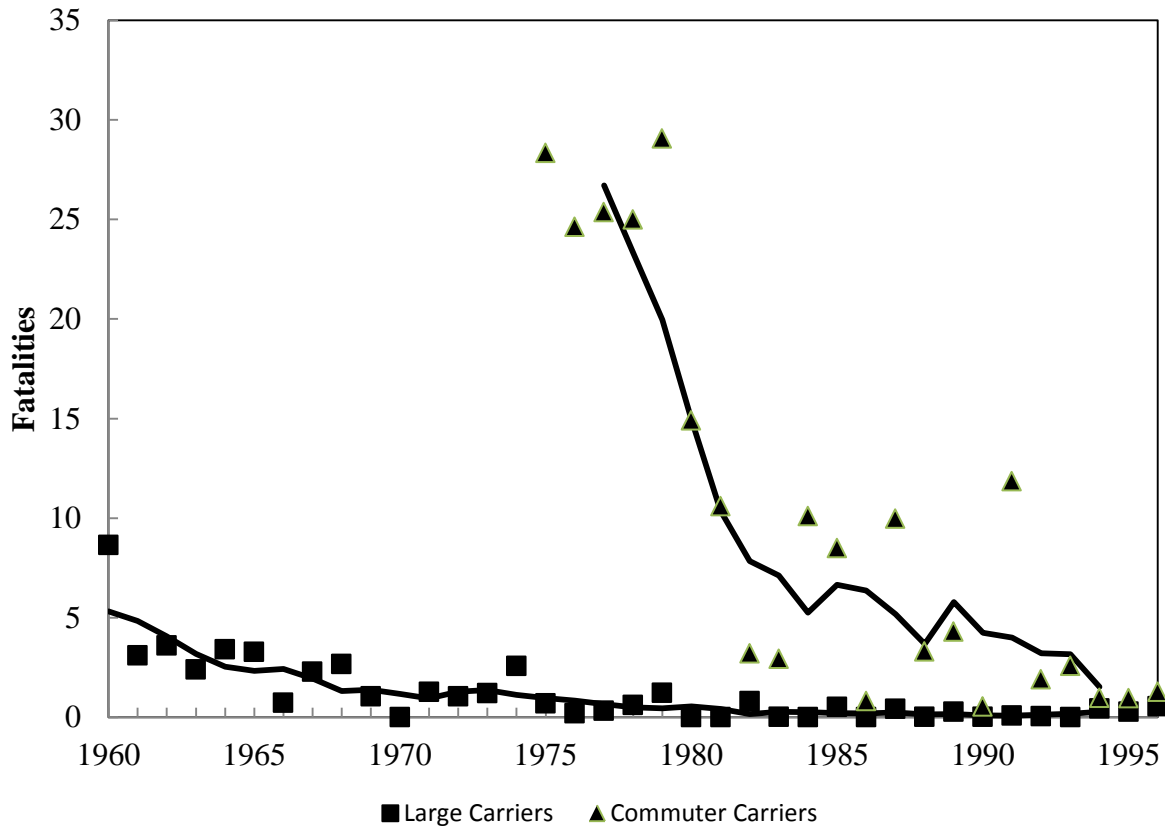
Source: Federal Railroad Administration (various years); Federal Highway Administration (various years); Bureau of the Census (various years).

The fatality rate per billion passenger miles for commercial aviation since 1960 is shown in figure 3. The graph differentiates between large carriers, regulated under Part 121 of the federal regulations, and commuter airlines operating aircraft with thirty or fewer seats, regulated under Part 135.⁶ The risk of flying a large airline has declined by more than 90 percent in the past thirty-five years. In the earlier years of the period the increased safety resulted from improved technology. More recently it has resulted from increased average journey length. Under economic regulation airlines priced long-distance service high to cross-subsidize short-distance trips. Since deregulation the price of long-distance travel has fallen by a greater amount than that of short-distance travel, and the average journey length has increased by 20 percent, from 825 to 990 miles. As most of the risk in air travel is in the take-off and landing stages, increased average journey length decreases the risk per passenger mile.

⁶In March 1997 operators of aircraft with between ten and thirty seats were made subject to the stiffer Part 121 rather than to the Part 135 regulations.

Figure 3. *Aviation Fatalities per Billion Passenger Miles, 1960-96*

Source: National Transportation Safety Board. The symbols represent the annual rate, while the solid lines represent a five-year moving average.



Perhaps the most dramatic change has been the major improvement in commuter airline safety since 1975. In that year passengers on commuter airlines were six times more likely to be killed than passengers on large airlines, whereas now the difference is only in the range of 20 to 40 percent. Again technology has been a major contributor to this improvement. The commuter segment of the industry grew rapidly after deregulation as major airlines withdrew from secondary markets. The increased traffic required the deployment of larger, safer aircraft with turboprop rather than piston engines. In 1978, 70 percent of the commuter airline fleet was powered by piston engines, and 80 percent of the passenger miles flown were in aircraft with fewer than twenty seats. By 1996 the proportions were almost exactly reversed. Seventy percent of the fleet was turboprop-powered, and 80 percent of passenger miles were on commuter aircraft with greater than twenty seats.

The “Transportation Safety Problem”

The risk of crashes has declined by at least half in all modes of commercial transportation in the past twenty years. Yet the still substantial number of annual fatalities, and the spectacular nature of many crashes keep the issue of transportation safety in the public mind. Psychologists

have documented that the public is especially fearful of causes of death that claim multiple victims at a time, and the press devotes considerable coverage to these events.⁷ The suggestion is that the public demands even more improvements in safety.

Safety improvements are not costless, however, although the costs incurred by carriers to prevent crashes are difficult to determine. The only relevant piece of work that I am aware of calculated that high-quality trucking firms, measured on the basis of shipper perceptions of quality measures other than safety, had costs about 6 to 7 percent higher than firms perceived to offer lower quality.⁸

The implication is that transportation safety is valued by customers but costly to provide. Economists have skills that can contribute to the consequent debate about how much safety should be provided. The interest of economists in these matters is heightened by the general feeling that optimal determination of safety cannot be left to a free-market interaction between carriers and their passengers and shippers. The most obvious manifestation of this is the long history of government regulation of safety.

The main purpose of this chapter is to review the knowledge that economists can bring to bear on the various facets of the transportation safety problem: How much safety should be provided? To what extent can the free market ensure safety? What are the major market failures? How well has existing government intervention responded to these failures? Should there be any changes in public policy?

How Much Safety?

Given the marked improvements in safety, one might well ask how much more can be provided. One of the simplest economic models, that of the social-welfare maximizing monopolist, gives the powerful result that the optimal level of safety is determined when customers' willingness to pay for a marginal increase in safety is equal to the marginal cost of supplying this safety.⁹ In general, the optimal number of crashes will probably exceed the minimum technically feasible. When this occurs "society" has optimally chosen not to avert some crashes. This result is comparable to the economists' models showing that the optimal levels of congestion and pollution are also not zero.

In principle, economists can calculate this optimal level of safety from information on the value that customers place on safety, the marginal cost of preventing crashes, and the relationship between expenditures on prevention and the number of crashes. Evans and Morrison make such a calculation for a railway in Britain.¹⁰

⁷Lichtenstein and others (1978); Combs and Slovic (1979). Barnett (1990) calculated the ratio of front-page stories in the *New York Times* to the risk for six common causes of mortality and found that reports on aviation safety appeared fifty times more frequently than any other risk.

⁸Allen and Liu (1995).

⁹Spence (1975).

¹⁰Evans and Morrison (1997).

Unfortunately, few transportation markets can be characterized as monopolies. Most markets have inter- or intramodal competition. Equilibrium in these models becomes less well defined, especially if customers have different tastes for safety. Presumably nobody wants to die, but some members of society demonstrate that they are willing to bear more risk than others. For example, some people go rock climbing, ride bicycles without helmets, or engage in other pursuits that others would avoid as too risky or dangerous. On the freight side it is reasonable to suppose that shippers of expensive, delicate equipment will be more prepared to pay a premium for safer transportation than would shippers of gravel or coal.

The consequence of this variation in tastes is that a vertically differentiated market will emerge, making it optimal for several different safety levels to prevail in the market.¹¹ Less-safe carriers who charge a lower price may optimally coexist with safer carriers who charge a premium price. Customers will decide which carrier to patronize, and whether to consume at all, based on their tastes for safety and sensitivity to the differences in prices charged. Markets of this type clearly exist in both the maritime and trucking industry. Shippers can obtain service at almost any level of safety they want. The differentiated market also exists in aviation, where charter carriers who cater to budget-conscious travelers have poorer safety records than scheduled airlines catering to well-heeled businesspeople.

That some carriers are found to be less safe than others is considered by many lay people to be a market failure. This is not the case. In a well-functioning market, some customers decide of their own free will to patronize a less-safe carrier in preference to safer alternatives. They do so because the service is offered at a discounted price, and compared with other customers, they are less sensitive to the lower safety. This important insight is perhaps one of the most useful contributions that economists can bring to the safety debate. Society may be better served if carriers are allowed to offer a range of safety alternatives rather than being required to provide a uniform high level of safety.

The empirical literature has not attempted to characterize the equilibrium in this latter model. The reasons are threefold. First, knowledge about the distribution of customers' tastes for safety is limited. Second, the relationship between expenditures on prevention and the number of crashes is poorly understood which means that a "marginal cost of safety" function is difficult to estimate. Third, the equilibrium conditions in the vertically differentiated model are difficult to model, especially when one moves away from the social-welfare maximizing model toward the more realistic cases where a limited number of profit-maximizing carriers compete with each other.¹²

Therefore, although economists know which theoretical models should be used, they cannot make any definitive statement as to whether the observed levels of safety differ from those that would be optimally chosen by a social planner. It is embarrassing to admit that economists cannot even say whether there is currently "too much" or "too little" safety, let alone

¹¹Shaked and Sutton (1982). Entry occurs in this model until prices are driven down to marginal cost. The nature of the marginal cost functions, the number of consumers, and the distribution of their tastes determines the socially beneficial equilibrium number of carriers and hence levels of safety in the market.

¹²See Dixit (1979) for oligopoly; Spence (1976), Dixit and Stiglitz (1977), and Koenker and Perry (1981) for monopolistic competition.

comment on the magnitudes of any deviation. All is not lost, however. Perhaps a more useful goal for the safety analyst is not predicting what the optimal levels should be, but trying to understand why a free-market does not lead to an optimal determination, and what can be done about it.

Market Forces and Market Failures

It would be wrong to think that a market does not operate in some fashion in the provision of safety. The mere existence of vertically-differentiated service in most modes provides adequate evidence that some carriers seek to obtain a market advantage by providing a high-quality and high-safety service to customers who have a high willingness to pay for safety. Presumably, these customers must be able to recognize which carriers are providing high-safety service, and the carriers can financially justify the extra expenditures they make to prevent crashes. In general, one would imagine that since the demise of economic regulation, safety should improve in some segments of the market as some carriers elect to offer high-quality service to escape from the intense price competition at the lower end of the market.

There has been a traditional reluctance to leave the determination of safety entirely to the free market, however. This is unlike other quality attributes such as reliability, courtesy of staff, accuracy of invoicing, and cleanliness which are generally left to be determined by the interactions between carriers and customers. Theoretical economists advance several reasons as candidates for explaining market failure in transportation safety:

- A belief that many customers cannot observe the efforts to prevent crashes by individual carriers;
- The possibility that carriers may be myopic, because the costs of preventing crashes occur in the present, whereas the consequences of crashes occur in the future;
- The possibility that even fully informed customers may make poor choices on safety because of the unpleasant consequences of a crash;
- The negative effects that crashes have on innocent bystanders; and
- Confusion as to which party should make the most effort to prevent crashes when other road users and trucks collide, or when trains collide with trespassers and grade-crossing users.

In the past twenty to thirty years, economic models have been developed to provide insights into the nature of market failures that may result, and the ways that public policy can contribute to their amelioration. The extent that each market failure arises for the various modes is, of course, an open question, but the theoretical and empirical evidence for each market failure is reviewed below.

Imperfect Information

Clearly, individual customers can only exercise their tastes for safety if they can accurately assess the safety level offered by a mode and by rival carriers within that mode. The problem of imperfect information is likely to be more prevalent in passenger rather than freight transportation. Some freight shippers are so large that they have intimate contractual

relationships with a small number of carriers, permitting them to make a knowledgeable appraisal of safety. Even relatively small shippers make consignments on a daily basis. The continual settling of claims for minor loss and damage provides plenty of information on safety.

In contrast the typical passenger consumes rather infrequently and does not have the necessary specialist knowledge. Consequently, passengers must form perceptions of the risks involved in traveling. Psychologists have found two systematic biases in the ways that people perceive risk.¹³ The first, termed primary bias, is the tendency to overestimate infrequent causes of death, such as commercial transportation accidents, and to underestimate more frequent causes. This upward bias is compounded by a secondary bias. Hazards with an upward secondary bias are generally dramatic and sensational, whereas hazards with downward secondary bias tend to be unspectacular events, which claim one victim at a time.

The consequences of this general tendency to believe that transportation crashes happen more frequently than they actually do can be examined in a simple model of monopoly. The general result is that the upward misperception will lead carriers to provide *less* than the optimal level of safety. This somewhat counterintuitive result emerges because customers do not fully incorporate into their demand functions the “benefits” of the preventive actions taken by the carriers.¹⁴

The situation becomes more complicated in competitive markets where passengers not only have to have some idea of the general safety level of the mode, but also have to be able to distinguish between the safety records of individual carriers. Theoretical models show that in the extreme, if customers were unable to distinguish on the basis of safety between carriers, then no carrier would choose to supply a high-safety service because customers would not recognize the service and would be unwilling to pay a higher price to obtain it.¹⁵ This extreme situation does not apply in practice, however. Passengers can probably identify notoriously poor carriers through press reports, but they are probably less sure about the safety rankings of more mainstream carriers. This is primarily because crashes occur rarely for individual carriers, and those crashes that do occur often are caused by a bizarre set of circumstances that makes it unclear whether passengers should infer that the carrier was at fault or instead blame the weather, an “act of God,” or pure bad luck.

The situation is made worse because it is regarded as somewhat unseemly for carriers to advertise that their crash rate is better than that of their competitors. It may also be counterproductive in that highlighting an essentially negative aspect of transportation may reduce the demand for all carriers. At best carriers have to use codewords to communicate to potential customers that they are supplying a premium service. Examples are highlighting the experience of their mechanics, or indicating that they offer high quality in other attributes of service and hoping that this reputation will also be inferred concerning their safety performance. The problems in effectively communicating information to passengers probably helps explain why most mainstream passenger carriers offer similar safety to their peers within their modes.

¹³Lichtenstein and others (1978).

¹⁴Spence (1977).

¹⁵Akerlof (1970).

For example, most of the major American airlines have statistically indistinguishable safety records.

Carrier Myopia

The most prevalent and feared market failure goes hand-in-hand with imperfect information. Some carriers that take little effort to prevent crashes can take advantage of imperfectly-informed customers by masquerading as a high-safety carrier, and charging a premium price. The incentives to engage in this kind of behavior are strong, because the costs of prevention are borne in the present, whereas the effects of crashes occur at randomly defined points in the future. Even a carrier that becomes very careless may not suffer a visibly increased crash rate for several years. In the interim the carrier can earn excess profits, which will cease only when it incurs the costs of crashes or when its customers find out and either shun the carrier or demand a lower price.

Two types of carriers are particularly susceptible to such behavior. The first are new entrants. These carriers may take too little prevention in the present and regret it when crashes and adverse customer reaction occur in the years ahead. While the motivation for some of this behavior might be avaricious, it is more likely to be attributed to inexperience. This is a very real concern, given the considerable new entry to the trucking, airline and railroad industries that has occurred since economic deregulation. There is evidence that new entrant trucking firms have a worst crash record than existing carriers.¹⁶ Investigations show that the new jet airline entrants of the early 1980s were not noticeably worse than established carriers, but that was not true of the cohort of entrants in the early 1990s.¹⁷

The second candidate for myopia is a more established carrier that decides to cheat. Expenditures on preventing crashes are reduced, yet prices are maintained, and the carrier hopes that its customers do not notice. This type of behavior has been studied in both the theoretical and empirical literature.¹⁸ The usual explanation is that the carrier is close to bankruptcy, and reasons that it can save on prevention costs now and declare bankruptcy to protect itself against the cost of crashes later on. A less callous explanation may be that a financially distressed carrier hopes that cost economies can prolong its life until better times come along.

A classic example of this behavior was the railroad industry in the 1960s. Poor management and constraints caused by regulation led many railroads in the East and Midwest to the verge of bankruptcy. Some of these railroads responded by allowing their infrastructure to deteriorate. This is a very insidious form of cheating because some time must pass before shippers can recognize the effects of the deterioration. Ultimately, the cheating led to the reversal of the previous longstanding improvements in the rates of collisions, derailments and employee casualties. The rates started to improve again only after deregulation was implemented and the overall financial health of the industry began to improve.

¹⁶Corsi and Fanara (1989).

¹⁷Savage (1999).

¹⁸For the theoretical treatments, see Bulow and Shoven (1978), Golbe (1981), Klein and Leffler (1981), and Shapiro (1982).

In the airline and trucking industry, deregulation is said to have had the reverse effect. The emergence of competition led to financial difficulties for some long-established but poorly managed carriers. Some of these carriers ultimately exited the industry. Empirical evidence shows that financial distress leads to poorer safety performance in the trucking industry and among small- to medium-sized airlines.¹⁹

Impending bankruptcy is not the only cause for cheating. Carriers may cheat simply because they feel that they need a short-term financial boost to improve their stock price or to make them more attractive to a potential purchaser. An example is the Union Pacific Railroad, which in the summer of 1997 wished to demonstrate to its stockholders that it had made cost economies as a result of acquiring the Southern Pacific Railroad. Unfortunately, these economies led to a decline in service quality and an increase in crashes. Fortunately, this action was soon discovered both by shippers and the press, and the railroad had to improve its quality in the face of adverse customer and government reaction.

Needless to say, most carriers don't behave in this fashion. Some refrain from cheating for moral reasons, others because of market constraints. There is some literature, most of it dealing with the airline industry, on whether crashes lead to a decline in demand for individual carriers or a decline in stock prices.²⁰ In general, the evidence of long-lasting effects on either demand or stock value is limited. Of course, casual empiricism could point to specific examples of carriers with notoriously poor records having been forced to contract or exit the market. Most of the high-profile examples have been in aviation. Nevertheless, market failure caused by myopia is not only theoretically very plausible, but, according to ample empirical evidence, it occurs in all modes of transportation.

Customer Rationality

It is reasonable to suppose that shipping managers rationally compare the prices quoted by the various carriers and different modes, assess the probability that their goods will be lost or damaged in transit, and make an informed and calculated choice. Transportation passengers may not make similar rational choices, however. The unpleasant consequences of a crash may cause even fully informed passengers to downplay the probability of a crash. This cognitive dissonance was evident in 1996, for example, when many passengers continued to patronize a low-fare airline with a known poor safety record because they believed that "it will not happen to me." Calabresi explains this behavior as the "Faust" attitude whereby people are myopic when making a choice between a lower price now and increased probability of death or injury later.²¹

Whether this type of behavior would be described as a "market failure" is a matter of semantics, given that the failure is in the minds of the customers rather than in the trade between customers and carriers. Intervention in the market may therefore be justified to protect customers from themselves rather than to protect them from the carriers!

¹⁹Chow (1989); Rose (1990).

²⁰For a summary, see Rose (1992).

²¹Calabresi (1970). Oi (1973) explains the phenomenon as consumers with a very high time preference who in retrospect regret their choices because their retrospective time preference is different.

There is a related issue: in a vertically-differentiated safety market, high-safety choices will be available at premium prices, whereas low-safety choices will be available at discounted prices. Less well-off members of society may be able to afford to patronize only carriers with very poor safety records. Even though these people may make that choice in a fully informed way, society may paternalistically decide that it would prefer that these people did not travel rather than face inordinate risks.

Externalities

A well-known result in economics is that markets fail if there is no mechanism for carriers to internalize harms caused to third parties. If carriers do not pass on the costs of externality harms to customers, the prices charged will be too low, and too much transportation will be produced. The carrier will also select a lower-than-optimal level of preventive effort because it is no longer motivated to increase preventive efforts to reduce the negative externalities caused to third parties.²²

Bilateral Crashes

Not all third parties to transportation crashes are innocent bystanders. Table 1 shows that more than eighty percent of all fatalities occur in collisions at rail-highway grade crossings, between trucks and automobiles, between trucks and pedestrians, and between trains and trespassers. In the law and economics literature, these types of crashes are called bilateral crashes because the probability of a crash depends on the level of effort (or “care,” as it is known in legal parlance) taken by both the carrier and the other party to prevent the crash.

The socially optimal level of care that each party should take is determined by the relative costs each party incurs in taking care and the extent to which they can influence the probability of a crash. Absent legal liability, a market failure will occur in this determination when the consequences of not taking care by one party significantly increase the harm that the other party can expect to suffer from crashes.²³

Legal Institutions that Ameliorate Market Failures

Many of these market failures have been recognized for more than a century. Consequently, longstanding legal arrangements have developed to respond to three of them: imperfect information, externalities and bilateral crashes.

The 1906 Carmack Amendment to the Interstate Commerce Act of 1887 made common carriers strictly liable to shippers; that is, carriers must pay shippers for the “full actual loss and injury” caused by reasons of loss, damage, or delay. The situation for passenger travel is a bit different in theory, but perhaps not in practice. Injured passengers have to show that the carrier acted negligently and that the passenger’s negligence did not make the situation worse. For most crashes, however, the standard of proof to show negligence is quite low, and carriers will nearly

²²Shavell (1987).

²³Shavell (1987) provides a comprehensive analysis.

always have to compensate innocent passengers.²⁴ (Awards may not reflect actual losses, however. For example, the Warsaw Convention limits the size of awards to international airline passengers.) Consequently, the carrier bears the cost of both preventing of crashes and compensating for the harm caused when crashes occur. In theory, therefore, the carrier should be able to make an informed decision on the correct level of safety to supply, irrespective of the knowledge of customers.

In practice, however, there are limitations to this legal solution. Injured customers can rightly complain that legal judgments are inherently market corrections after the fact. Even so, carriers still have strong incentives to engage in myopic behavior. The theoretical economics literature also points to some less obvious limitations. Liability totally ameliorates the market failure caused by imperfect information only when customers are risk neutral, have homogeneous tastes, and are fully compensated for both pecuniary and nonpecuniary harms.²⁵ In practice it is unlikely that all three conditions will be met. Although freight shippers may plausibly be risk neutral, some costs, such as delays in production schedules or the costs of claim administration, cannot be legally recovered. Passengers are unlikely to be risk neutral and, in fact, are probably risk averse. Passengers or their relatives are unlikely to feel that they can be adequately compensated for their loss by legal settlements or insurance payments. Passengers therefore attach a higher disutility to the risk of crashes than would be covered by an actuarial determined amount of harm they can expect to suffer in a crash.

These observations should not be taken as a condemnation of the usefulness of liability to customers. Liability undoubtedly restrains some carriers from engaging in myopic behavior, although it obviously does not totally eliminate it. In contrast, liability does play a large role in amelioration market failure caused by externalities. Injured bystanders have had longstanding rights to bring a claim against a carrier. The bystander must show that the carrier was negligent in causing the harm. Evidence that a plane crashed on your house or that a railroad spilled hazardous chemicals on your field would be taken as *prima facie* evidence of negligence, however. Compensation can be obtained for loss of property or increased out-of-pocket expenses, but certain types of losses such as loss of profits are not recoverable under law. Therefore, carriers will internalize most of the externalities caused. Of course, this does not totally mitigate the concern because psychologists have shown that bystanders who are involuntary exposed to a hazard are far less tolerant of the risk than customers or employees who are voluntarily involved.²⁶ The intolerance may far exceed the monetary harms that bystanders incur. For example, there was considerable public outrage over the spill from the tanker *Exxon Valdez* despite unprecedented expenditures by Exxon to clear up the spill and settle lawsuits.

Legal processes regarding liability in bilateral crashes also provide incentives to take appropriate care.²⁷ In most jurisdictions in the United States, the legal rule is that of comparative negligence. Courts determine the care that each party should have taken, known as “due care” in legal parlance, compare this with the actual conduct of the parties, and award damages based on the relative deviations from due care. The main complaint about this system centers primarily on

²⁴Kenworthy (1989).

²⁵Spence (1977).

²⁶Starr (1969).

²⁷Shavell (1987) provides a comprehensive analysis.

the ability of the courts to determine the level of due care expected of each party. The law does provide some guidance, but it is up to the court to decide how this translates into the specific conduct expected. Carriers frequently argue that “anti-corporate” sentiment biases juries to give the non-carrier party the benefit of the doubt. The main example is collisions at rail-highway grade-crossings. It is frequently argued that juries take a permissive view of the behavior of highway drivers, while finding railroads negligent for not installing flashing lights or gates, even at crossings where a cost-benefit analysis would indicate that such warning devices are not justified. This problem is caused in part by a legal failure in that railroad companies are legally responsible for safety at highway grade crossings even though decisions on the provision of gates and flashing lights are made by the highway authority.

Legal judgments may not be a sufficient deterrent to all of the people involved in bilateral crashes. Many automobile drivers who are involved in collisions with trucks and trains do not exercise the proper amount of skill or attention; frequently they are driving under the influence of alcohol or drugs. Many poorly educated single males still trespass on the railroad right of way to drink and socialize even though the law firmly places the burden of taking care on the trespasser.

Public Policy Responses to Market Failure

While legal arrangements undoubtedly reduce the magnitude of many of the market failures, they do not totally eliminate them. Consequently, a sizeable theoretical literature has developed which explains why government intervention should be deployed as a complement to existing legal processes.²⁸ The government has several options available to it; it may require insurance, provide information to customers, and directly regulating carriers. Each of these deals with a subset of the market failures. Table 3 presents a matrix showing which policy option may be applicable to each market failure.²⁹ An important conclusion of the literature is that these policy responses should be seen as complements to each other and not as direct substitutes.

Insurance Requirements

A common concern with a purely legal response is that myopic carriers can declare bankruptcy to avoid paying large legal judgments. Therefore, in most modes of transportation the government requires that carriers hold insurance to cover tort liability settlements. The primary benefit is that insurance companies pool risks across carriers, thus ensuring that crash victims will obtain some compensation. A secondary benefit is that insurance can reduce the incidence of myopia, especially among new entrants. By charging premiums to cover future losses, insurance companies make inexperienced new carriers very aware of future crash costs.

²⁸See Kolstad, Ulen, and Johnson (1990); Shavell (1984a, b).

²⁹There is an additional market failure that has not been discussed. Many transportation markets are characterized by competition among relatively few carriers due to economies of density at the route level. Therefore relatively few safety choices will be offered to the customer, which could lead to reduced social welfare. Of course, market power will have far more dramatic effects in raising prices and restricting output, and this will probably be the motivation for an antitrust response by government.

Carriers can then decide on appropriate levels of safety by trading off between the size of insurance premiums and levels of preventive effort.

Table 3. *Matrix of Market Failures and Legal and Policy Responses*

| <i>Market failure</i> | <i>Liability</i> | <i>Insurance requirement</i> | <i>Information provision on safety</i> | | <i>Safety regulation</i> |
|-----------------------|------------------|------------------------------|--|---------------|--------------------------|
| | | | <i>Outputs</i> | <i>Inputs</i> | |
| Imperfect information | X | ... | X | X | X |
| Myopia | ... | X | ... | X | X |
| Customer Rationality | ... | ... | ... | ... | X |
| Bystanders | X | ... | ... | ... | X |
| Bilateral crashes | X | ... | ... | ... | X |

Source: Author's calculations.

Of course, myopic behavior is still possible if, as is generally likely, insurance companies have imperfect knowledge of carriers' crash probabilities. An unscrupulous carrier can take actions, such as reducing maintenance expenditures, that adversely affect crash risk yet are hidden to the insurer.³⁰ Such behavior is equivalent to the cheating described earlier. The only difference is that the insurance company is the ultimate victim, because injured parties receive at least some compensation from the insurance company.

Making Customers Better Informed

An obvious response to a market failure caused by imperfect information is for the government to provide appropriate data to customers. Carriers in all modes have a legal obligation to report all serious crashes to the federal government. These data are tabulated but are typically disseminated in obscure documents. There seems to be a certain squeamishness in making the information more widely available. Change is in the air, however, spurred by the development of the Internet. Since March 1997 the Federal Aviation Administration has provided safety information on airlines to the public on its World Wide Web site.

Direct Safety Regulation

Government has been involved in the direct regulation of safety for more than a century. Safety regulations for railroads were introduced in 1893, for the maritime industry in 1914 (by international convention following the sinking of the *Titanic* two years earlier), for trucking in 1940, and for commercial aviation in 1958. Safety regulations continue to be revised and tightened. There was considerable rulemaking concerning the railroads in the early 1970s, commercial aviation in the mid-1970s, and trucking in the early 1980s.

³⁰Shavell (1979).

In general the approach taken has been to set minimum training qualifications and maximum hours of work for staff, and engineering rules on the design and maintenance of plant and equipment. To monitor and enforce these standards, government inspectors conduct semi-random inspections of equipment and staff records and issue citations for violations found. The government retains the power to close down very dangerous carriers.

The underlying theory is that a perfectly informed government should be able to calculate the levels of safety that will maximize social welfare. The lowest common denominator would then be used to define the minimum standard. The government then translates the minimum desired safety output into minimum specification or design standards for safety inputs. Carriers who wish to provide a higher level of safety are free to deviate upward from this minimum. The advantage of expressing safety objectives in these terms is to detect carriers with poor equipment and staff before crashes occur.

The primary thrust of these regulations is directed at the problem of myopia. Regulations act to inform new entrant carriers of appropriate minimum standards. In some modes such as aviation, new carriers must demonstrate that they meet certain requirements before they can begin operations. Safety inspectors then serve as a deterrent to prevent established carriers from acting myopically and to detect and punish those carriers who cheat.

The Effectiveness of Public Policy in Recent Safety Performance

With the foregoing as background, let us revisit figures 1, 2 and 3 to determine the role of public policy relative to other factors in explaining the improvements in crash rates witnessed in all modes in recent times.

The Trucking Industry

As reported earlier, the trucking industry's crash rate has declined faster than might be explained by factors that have improved safety on the roads in general. The good record of the trucking industry might come as somewhat of a surprise given the predictions that economic deregulation of the industry in 1980 would lead to declining safety. Before deregulation much of the safety regulation was embodied in the economic controls that limited entry into the industry. Consequently some observers expressed concern new entrants might act in a myopic, fly-by-night fashion and cater to the taste of those shippers who prefer discounted prices over additional safety.

The government responded by substituting explicit safety regulation and enforcement activities for the implicit safety regulations inherent in the old system. Legislation in the early 1980s tightened vehicle standards, introduced new rules for transporting hazardous materials, and implemented a coordinated national "commercial drivers' license." The new license requirements impose uniform testing across states and prevent drivers from holding multiple licenses as a way to avoid the consequences of revocation in one jurisdiction. Many states had to raise driver-testing standards considerably. In addition, federal funding allowed increased enforcement through safety audits of carriers and semi-random inspections at the roadside.

The Railroad Industry

In response to a worsening safety record, brought about by financial problems that led some segments of the railroad industry to myopically reduce maintenance expenditures, Congress passed the Federal Railroad Safety Act of 1970. This act was the first substantial change in railroad safety regulation in sixty years; until its passage, the railroads had very little formal regulation. The 1970 regulations introduced design standards for track for the very first time and codified existing industry standards on the design and maintenance of freight cars. The government also appointed an inspectorate force to ensure compliance with the laws.

What happened next is the subject of considerable controversy.³¹ Everyone agrees that collision and derailment rates and employee injury rates have improved since the mid- and late 1970s; the disagreement is over the source of the improvement. The Federal Railroad Administration says it is a direct result of safety regulatory efforts. The industry points to the deregulation of the industry in 1980, which allowed railroads to spin off unprofitable branch lines and negotiate price with shippers. As a result, the financial health of the industry improved, and there is clear evidence that maintenance expenditures increased dramatically.³² Unfortunately for the analyst, the increase in deregulation-induced expenditures parallels increases in the number of federal safety inspections and decreases in the amount of risky switching. It is probably impossible to separate these effects econometrically. Meanwhile the federal government and the railroads are at an impasse as to whether federal safety regulations have helped or hindered the industry.

One area where government intervention has clearly had a measurable effect has been grade-crossing collisions. Figure 2 shows an impressive decline in risk since the mid-1960s. A federal government program, enacted in 1973, to equip crossings with active warning devices such as flashing lights and gates, is in part responsible for the decline. The justification for the government funding is that some auto drivers cannot be trusted to act appropriately at crossings with only a “crossbucks” warning sign, despite a railroad-funded campaign *Operation Lifesaver* to educate the public on appropriate behavior.

Commercial Aviation

Most of the improvement in aviation safety can be attributed to new technology. The government has played a considerable role, however. A government-funded air traffic control system was developed in the late 1950s and early 1960s to respond to the increased probability of collisions as the skies became more crowded. Regulations also contributed to the dramatic improvement in commuter airline safety in the 1975-85 period. The safety regulations for the commuter industry were changed substantially in 1978 with stricter pilot qualification and training requirements, new maintenance requirements, and an upgraded list of required safety equipment.

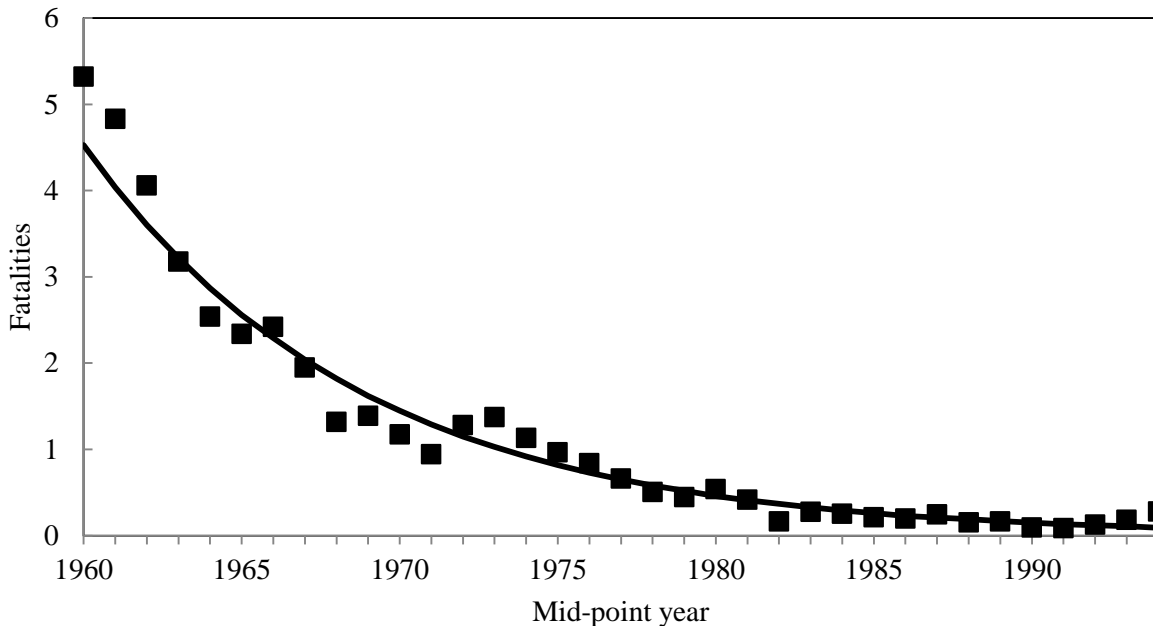
³¹Savage (1998).

³²Association of American Railroads (various years).

The government has also had a role in restraining some of the myopic behavior that occurred after economic deregulation. The evidence of entry of inexperienced new jet airlines with a lower level of safety than incumbent carriers has already been discussed, as has the financial distress among some incumbent carriers that led to myopic reductions in maintenance and training. The success of some of the regulatory activities can be determined by investigating whether deregulation slowed any of the longstanding improvements in safety for large airlines.

Figure 4 shows five-year moving average fatality rates for midpoint years 1960 through 1994 for large air carriers. Five-year averages have been used to smooth out year-to-year variations. A logarithmic time trend is fitted to the pre-deregulation data for 1960 through 1978 and then extrapolated forward. This is shown as the smooth curve. As one can see, the actual post-deregulation fatality rates, indicated by the squares, continued to follow the decline from the previous decades, at least until an unusual rash of high-fatality crashes in 1994, 1995 and 1996, which were not repeated in 1997 or the first half of 1998.

Figure 4. *1960-78 Time Trend Fitted to Five-Year Moving Average of Fatality Risk per Billion Passenger Miles for Large Airline Carriers, 1960-94*



Source: Author's calculations based on National Transportation Safety Board data.

Policy Recommendations

Analysts cannot definitively say whether current levels of safety are too high or too low. What is known is that safety has been improving dramatically in all modes of transportation in recent decades. Yet, there is still pressure for more and even tougher safety regulations. Underlying these possibly contradictory pieces of evidence is the well-documented fact that as a nation grows richer, its citizens demand lower mortality risks from all forms of hazards. Crash

rates that were deemed acceptable in the 1950s and 1960s are quite likely to be considered unacceptable today.

How these future improvements will be achieved, and whether these improvements are justified, is somewhat speculative. Undoubtedly technological advances will continue to be very important, especially in aviation. Improved scientific understanding of how human beings function will help government and carriers take actions to combat fatigue and inattention. Changes in the nature of demand will also improve safety by allowing deployment of even larger “regional jet” aircraft in secondary markets and further reducing the need for switching of railcars. Because profit-maximizing firms are taking the lead in all of these areas, it is safe to assume that all of these safety improvements would pass a cost-benefit test.

There are also possible changes in public policy that may bring about improved safety at reduced cost to taxpayers and carriers. These include the provision of more information, greater involvement by the insurance industry, and innovative strategies in safety regulation.

A More Informed Public

In recent years the development of personal computers and the Internet has made it possible to provide up-to-date safety information directly to passengers and shippers. The longstanding requirement for carriers in all modes to report crashes puts the federal government in the ideal position to make this information available. In theory such information could attack the root cause of a major safety market failure.

Whether wide dissemination of this information will help customers make better choices and dissuade carriers from indulging in myopic behavior is an open question, however. The traditional concern is that the public is unable to draw proper inferences from data on events that occur with a low probability. This concern would seem to be a trifle patronizing. A more serious concern is that providing historical crash data does nothing to ameliorate the problem of current myopic carriers. Unscrupulous carriers who wish to cheat will, by definition, deviate from their past performance. Consequently, it is often argued that the public should be provided with information on carriers’ safety inputs such as the average experience of staff and the age and condition of equipment. In this way customers can make predictions of future safety performance. This information is currently not widely available or disseminated. Some also argue that this data may be misleading because even safety professionals cannot definitively relate input measures to the expected effect on safety. Nevertheless, the information age provides the opportunity for disseminating safety information directly to the public. Future research will show whether the experiment is successful and whether a more-informed public obviates the need for some safety regulations.

A Greater Role for Insurance Companies

Currently insurance companies play a somewhat subsidiary role in correcting market failures in commercial transportation. In other markets, such as consumer-product safety and automobiles, insurance companies are in the forefront of encouraging safe practices and punishing errant parties. This difference in roles may result from extensive government

regulation of carriers. Insurance companies can avoid the expense of conducting their own investigations of the safety practices of potential policyholders by relying on government agencies to specify which carriers are safe and which are not.

Insurance companies could play a large role in providing the economic incentives for small and newly formed carriers not to engage in myopic behavior. Yet premium schedules are currently of a coarse nature and, in the extreme, set on the basis of the overall risk displayed by the industry or some broad subset of it. Thus carriers do not necessarily face a premium closely related to the level of prevention they undertake. This is particularly the case in the trucking industry, where most small firms are placed into a “pool” which is then divided among the various insurance companies.

In other words, extensive direct regulation has allowed insurance companies to free-ride on the backs of the regulators. Consequently they have not been heavily involved in providing economic incentives for safe operation. It would be interesting to see what would happen if a greater responsibility for monitoring the activities of the industry were placed on insurance companies.

A New Era for Safety Regulation?

The safety regulators who appear to have had some success in reducing crash rates in most modes in recent decades are not without their critics. In general, these critics do not question the need for safety regulation. Rather, they question whether there are better and cheaper ways of regulating safety. The critics point to two major failings. The first is the mechanism by which standards are set. The second is the strategy by which federal agencies monitor and enforce these standards.

Regulators face an unenviable task in setting minimum safety regulations. Not only must they form a view on the elusive question of “how safe is safe enough?” but they must also translate this into minimum standards on the quality and quantity of staff and equipment. Because the exact specification of the production function for safety is generally unknown, even the most well-intentioned rule maker is unlikely to get it just right.

This uncertainty about the production function for safety opens the door for parties such as labor unions, trade associations, and manufacturers of safety equipment to argue for legislation for self-interested purposes by claiming that the legislation is justified on the basis of safety. Classic examples are the activities of railroad unions to attempt to use legislation to retain the services of firemen on diesel locomotives, or to write brake inspection laws that provide work for a specific type of employee. The larger trucking firms have pushed for increased safety standards as a barrier to entry against new carriers. Such lobbying can succeed because there is always that element of doubt about whether even the most blatantly avaricious proposals might have beneficial safety effects.

A legislature may also respond to perceived safety problems in a knee-jerk fashion, implementing regulations that make the legislator look good in the eyes of constituents but that may have questionable safety effects. An excellent example is the Oil Pollution Act of 1990,

which requires the use of double-hulled oil tankers. Congress was reacting very quickly to the public outrage concerning the grounding of the oil tanker *Exxon Valdez*. My research found that even under the most wildly favorable assumptions, the benefits are fifty cents for every dollar of costs, while under more reasonable assumptions the benefits are only twenty cents.³³

In fairness it should be said that the Department of Transportation has a very good record in evaluating proposed regulations, particularly when a comparison is made with other government agencies such as the Environmental Protection Agency and the Occupational Safety and Health Administration.³⁴ There is a long history of the use of cost-benefit analysis to assess the desirability of various regulations in transportation, and transportation has been at the forefront of estimating the social cost of crashes and the valuation of lives saved.

Design of a strategy for monitoring and enforcing standards to prevent myopic behavior is a nontrivial economic problem.³⁵ Because monitoring is costly, both to the government and carriers, the government bears a heavy burden to design an effective and efficient system. My observation is that the traditional methods of conducting semi-random inspections are becoming discredited, partly because of the costs of inspection and partly because randomly written citations do not seem to modify the behavior of carriers. My own work has found substantiating evidence in the inspection of trucks at the roadside and the inspection of railroad track and cars.³⁶ Some government agencies have responded by using their inspectorate force more effectively. Under a very successful program in the trucking industry, inspectors audit the safety management practices of carriers, assign safety ratings and concentrate enforcement efforts on the worst carriers.

Problems with traditional methods of regulation have given rise to a new regulatory strategy commonly referred to as performance standards. Under this strategy the desired minimum safety level is expressed in terms of the output of safety. An example might be the setting of a particular crash rate as the minimum. The government agency would then act as a risk analyst by observing crash rates and taking action against carriers who fail to meet the standard.

This strategy has three big advantages. First, the regulator does not have to infer the relationship between specifying standards for safety inputs and the consequent effect on crashes. Second, carriers are no longer constrained in their decisions on how to combine inputs to achieve the desired safety standard at minimum cost. Third, performance standards are less susceptible to politicking.

Performance standards are not a panacea in all situations. They are of limited use when crashes occur very infrequently or when the amount of exposure to crashes is small. In these situations, it would be difficult to determine whether the performance of an individual carrier is changing from year to year given the inherent variation that one would expect when observing low probability events. For performance standards to be meaningful, one has to select a measure

³³Brown and Savage (1996).

³⁴Viscusi (1996).

³⁵Becker (1968).

³⁶Moses and Savage (1997); Savage (1998).

of crashes that occur relatively frequently and confine the analysis to carriers with large exposure to crashes. It is likely that small carriers in all modes would have to continue to be regulated by traditional means.

The common argument against performance standards is that they are essentially an ex post form of regulation in that deficient carriers are only identified after their crash rate has increased. The solution to this problem is to use measures of less serious crashes than occur relatively frequently to indicate the presence of conditions that might lead to a major catastrophe. There are opportunities for statistically minded researchers to help in developing measures of safety performance. Another disadvantage is that performance standards may “encourage” some carriers to try to avoid enforcement by not recording and reporting crashes. Such behavior may have a negative effect on the safety consciousness of employees who could take the failure to report a crash as an indication that a carrier’s management does not place a very high priority on safety.

Trials of performance standards are now underway. The Occupational Safety and Health Administration pioneered such an approach, called the Cooperative Compliance Program, in a trial in Maine in 1993 and is extending the strategy nationwide. Under this program, larger firms undertake to achieve a certain level of safety performance through self-evaluation and development, if necessary, of a remediation plan. If they meet these criteria, they are exempted from random inspections and maybe even be allowed to operate under liberalized specification regulation. If they do not meet their targets, however, the traditional methods of monitoring and enforcement kick in with a vengeance. The Federal Highway Administration has a similar program for trucking firms that achieve crash rates that would put them in the top quarter of the industry for three consecutive years. It remains to be seen whether the Federal Aviation Administration or the Federal Railroad Administration will move in the same direction. Ultimately, there will be research opportunities to investigate empirically whether this new strategy is superior to traditional methods.

In conclusion the risk of transportation crashes has declined considerably in recent decades. Nonetheless, opportunities for further reductions are apparent. Some will come from market-driven changes in technology, human factors, and the nature of demand. Others will come from a review of the most cost-effective methods by which public policy deals with the pervasive market failures.

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