TRANSPORT SAFETY

by

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1. Introduction

Transport has always been associated with the risk of death, injury and the destruction of property. From the earliest days people have been thrown from horses and fallen out of canoes. The advent of mass transport simply turned private, localized, grief into public spectacles in the form of shipwrecks, train crashes, and aviation disasters. While it is tempting to think that the risks are much higher in our technological world where we speed across the ground at 100 mph or more, or defy gravity in an aluminum tube some five miles above the surface, you would be wrong. Travel on the rudimentary roads of two hundred years ago was very hazardous, as was venturing out on the ocean without proper navigational aids, or traveling on river steamboats that routinely exploded and sank.

The improvements continue. The risks in all modes of transport have fallen by at least half since the 1950s. Yet the absolute level of harm is still very high. Even in a technologically advanced economy such as the United States, one in 6,000 of the population dies each year due to transport crashes (note that safety professionals prefer the word Acrash" to "accident" because the latter suggests that occurrence is due to pure fate and cannot be influenced by human decisions). The annual death toll of about 44,000 represents half of all accidental fatal injuries when one includes workplace injuries but excludes homicides and suicides.

2. Measures of Safety

Enumerating the harm caused by crashes is difficult. While one can be fairly certain about the number of fatalities, there is under reporting of non-fatal injuries and damage to property. In addition, while research has allowed reasonably accurate enumeration of the monetary costs of lost productivity and out-of-pocket expenses, the valuation of the associated pain and suffering is controversial. After correcting for undercounting, Miller et al. (1991) estimate that the direct costs associated with highway crashes in the United States were equivalent to 2.6% of Gross National Product. If a value is attached to pain and suffering and lowered quality of life for those injured, the total costs are much higher and equivalent to a staggering 6.6% of GNP.

Reasonably reliable cross-modal comparisons can only be made on the basis of fatalities. Table 1 shows typical annual modal fatalities in the 1990s for the United States, a country of about 260 million people. The averaging gives a better representation for modes where there are infrequent high-fatality events such as major train wrecks and aircraft crashes. Analytically it is useful to divide the fatalities into three groups. The first we will term "private user" modes such as walking, cycling, driving, general aviation and recreational boating where the user is often the operator of the vehicle or is a friend or relative of the operator. The second is "commercial transport" where passengers and freight shippers contract with corporations. The third are those situations where private modes and commercial operators collide with each other, such as when trucks collide with cars, or trains collide with cars at grade crossings.

Table 1
Average Annual Fatalities in the United States 1990-98

	Crashes solely involving Private Users	Collisions with Commercial Carriers	Commercial Transport Passengers	Commercial Transport Employees	Bystanders to Commercial Crashes
Cars/ Motorcycle	29,650	4,500	-	-	-
Pedestrians	6,100	1,120	-	-	-
Trucks	-	-	-	650	
Aviation	720	-	80	15	4
Railroads	-	-	10	45	1
Bus/Subway	-	-	20	10	0
Maritime	820	-	0	170	0
Pipeline	-	-	-	15	5
	37,290	5,620	110	905	10

Only 15% of the fatalities involving commercial carriers. The remainder occur when private pilots, mariners and highway users are involved in single vessel/aircraft/vehicle crashes or collide with other private users. Furthermore, most of the risk in commercial transport does not fall on those directly involved in production and consumption of these services. The majority of the victims are road users and pedestrians involved in collisions with trucks, and trespassers and grade crossing users who suffer collisions with trains. In the global scheme of things, the number of commercial passenger fatalities is quite small. The number of true bystanders who get killed each year is also relatively small. However, one should not underestimate the public outrage associated with crashes that lead to the release of explosive or toxic substances, or oil spills that defile places of natural beauty.

Of course, Table 1 says nothing about risk as exposure to crashes varies widely across modes. Table 2 shows driving and commercial passenger fatalities relative to passenger miles, and employee fatalities relative to total employees. Bus and commercial aviation have the best passenger safety records, at about one fatality for every five billion passenger miles. Riding the train is four times as risk, and driving is twelve times more risky than taking the train. However, this comparison is somewhat misleading. While passengers in commercial transport are victimized in a somewhat random fashion, driving risks are heavily dependent on the characteristics of the driver. A disproportionate number of auto crashes involve young male drivers and people who have been drinking. The fatality risk for sober middle-aged drivers is about 75% of the average driving risk.

Table 2
Modal Passenger and Employee Risk

	Passenger Fatalities per Billion Passenger Miles 1990-98	Annual Employee Fatalities per 1,000 Employees 1998
Motor Vehicle Driving	9.58	--
Maritime	-	0.28
Trucking	-	0.21 (includes Warehousing)
Railroads	0.79	0.07
Aviation	0.18 (commercial)	0.06
Bus	0.15	0.18 (transit & taxi)

Employment in transport is relatively risky as it entails working outdoors with heavy, moving equipment, often in hostile weather conditions and far from immediate medical attention. The maritime and trucking and warehousing industries have the highest levels of employee risk. These risks are substantial with employees facing more risk than they would if they were working in construction (0.14 per 1,000 employees) and comparable to the same amount of risk as miners (0.23 per 1,000). The rate shown for buses is defined in government publications as workers in "local transport," and is unusually high due to the elevated risk of homicide of taxi drivers. In contrast, employees in the railroad and aviation industries face less risk, although the risks are still twice those in manufacturing (0.03 per 1,000). It is not surprising that much of the public concern for safety has originated from organized labor.

3. The Transport Safety "Problem"

While the level of harm is substantial, one cannot tell from risk data whether transport safety is "a problem." Ever since the dawn of civilization, humans have valued the ability to travel and to ship their goods, and have been prepared to endure the inherent risks. To the economist, if a person knows of, and can evaluate, both the benefits and the risks, and still decides to travel then there is no inherent problem. Even in the labor market, risks are not unreasonable if workers are aware of the risks of different jobs, and decide of their own free will to work in relatively risky occupations because of their own tastes and because riskier occupations pay premium wages.

Risk preferences can change over time. Innovative technology such as navigation systems and new materials have allowed firms to provide more safety at a lower, or comparable cost, than was possible a generation ago. The same is true for highway and automotive design. In addition, as a country becomes more wealthy, its citizens demand that all types of risks - transport, medical, food quality - are mitigated to ensure longer life expectancy. Consequently, risks that were acceptable at mid century would be regarded as unacceptable today. Transport crash risks are much higher in developing countries because society has different priorities for the use of its scarce resources, such as providing for basic education and health care. Consequently increasing wealth and product innovation mean that one should expect that there will always be pressure to reduce transport risks.

To summarize the discussion, if users of the transport system are fully aware of the risks, irrespective of their magnitude, and voluntarily accept them then there is not a "transport safety problem." Consequently society only minimally intervenes in the decisions made by private aviators and recreational boaters. It is assumed that these individuals are aware of the risks, and that in most cases they themselves are the only victims. There is only public concern when private planes crash on the houses of innocent third parties or when large amounts of public money are used to conduct search and rescue operations at sea. Likewise, society is less motivated to intervene in risks incurred during employment. Workers are generally assumed to have the expertise to appraise the risks they face. This is especially true in industries such as transport where the threats are primarily due to observable mechanical rather than unobservable toxic and health related sources, and where unions are highly motivated to investigate and report on job risks to their membership.

Society will be motivated to intervene when the market breaks down. Over the past forty years academics in economics, law and psychology have developed models to formalize the various possible market failures and examine their consequences and how they can be mitigated (see Savage, 1999, for a full set of basic references). There are six possible causes of market failure. The first occurs when people are not knowledgeable about the risks that they face. This is more likely in commercial transport where passengers consume relatively rarely and do not have the technical expertise to understand the mechanics of the risks or have the knowledge and access to understand crash data. Shippers of freight, while removed from the actual operations, are more knowledgeable because they are typically repeat purchasers who deal with carriers on a daily basis to settle claims for minor loss and damage to their products. Because the losses are material rather than human, shippers can afford to take a rather analytical approach to assessing risks. Private users are generally better informed. It is immediately clear to the driver that they are driving while drunk or tired, or driving at higher speeds than the conditions might suggest are prudent. Most private drivers, pilots and mariners are also aware of the dangers of various weather conditions, and the prudent action they should take. Albeit that private users do have to choose between purchasing various types and brands of vehicles, whose safety properties may not be apparent.

The second possible failure is that even fully informed people may make poor choices due to cognitive processes. People have a tendency to overestimate the possibility of low probability events and events that kill multiple people at any one time (Lichtenstein et al., 1978). They are also particularly fearful of life-threatening events where they have no control over the outcome. Therefore aviation risks cause a disproportionate amount of fear compared with auto driving where many drivers feel that they have the skill to mitigate or avoid hazardous situations. Working in the opposite direction is the possibility that some people underestimate risk partly because the consequences are too horrendous to contemplate, and partly because of a feeling of invincibility that bad outcomes "will not happen to me." This is particularly the case for young male drivers, where there is the additional factor that risky behavior, such as driving fast powerful cars, may actually be a positive attribute of transport. Even for more mainstream drivers, there is evidence that risks are underappreciated. There is considerable evidence that most drivers believe that they are more skillful and safer than the average driver! Because most auto trips are completed without a crash (the

U.S. average is one crash per ten years) there is daily reinforcement of drivers' beliefs. It is not an understatement to suggest that much of society's intervention in the safety market is to protect people from themselves rather than from avaricious carriers and third parties.

For commercial carriers the likelihood that most, or all, of your customers will be imperfectly informed allows the possibility of a third market failure. Safety has the characteristic that the costs of preventing crashes are incurred "up front," in the form of investment in equipment and staff training, whereas the "benefits" of a reduced number of crashes occur at unpredictable points in the future. Carriers who are very myopic in their preferences for short-term profits can reduce expenditures on crash prevention yet continue to masquerade as having high safety and charge a premium price. As crashes occur rarely, even for careless carriers, it may take some time before consumers become aware and either shun the carrier or demand a lower price. The victims of this "cheating" can be either the carrier's customers and/or society if the consequences of a crash affect bystanders. Inexperienced new entrants may also be myopic if they are well aware of the costs of crash prevention but unaware of the likelihood of crashes and how their decisions affected this probability. It is not surprising that public policy has focused on ensuring that new entrants are well qualified, and policing existing carriers to detect slipping safety.

The fourth possible failure occurs when crashes impose costs on innocent bystanders ("externalities"). Examples include oil spills, the release of explosive or toxic materials, planes crashing on peoples' houses, and innocent pedestrians hit by vehicles mounting the curb. Work by psychologists suggests that nonparticipants value the risks that they face much more highly that those who benefit from the risk either as users or employees. Therefore, although the law has long recognized the right for these victims to claim compensation, the public outcry tends to be much in excess of the harm caused. One only needs to look at the consequences of the wrecks of the oil tankers *Exxon Valdez* and the *Torrey Canyon* or the railcar explosion at Mississauga, Canada to appreciate this point. Indeed it is possible to argue that most of the safety concern about freight transport is solely due to the fear of externalities. While it is a legitimate issue between the carrier and its employees and the affected shippers when ships sink on the open sea and freight trains wreck on the private right of way, the public only becomes concerned when bystanders are affected.

The fifth possible failure is associated with collisions between private users, and when private users have crashes with commercial carriers. These collisions, which represent more than 60% of annual fatalities are called "bilateral crashes" because the actions of both parties influence the probability of occurrence. There is a complicated literature in law and economics that discusses the socially-optimal actions of both parties, and the role of legal mechanisms to compensate victims, penalize perpetrators and generally give both parties the correct incentives to take appropriate "care" (see Shavell, 1987, for an excellent summary). It is not an exaggeration to say that much of the development of accident law and insurance has occurred because the automobile allowed individuals unprecedented opportunities to interact with each other in a potentially harmful way.

The sixth and final possible failure is concerned with the amount of competition. As will be discussed later, individual drivers, passengers and shippers may have varying tastes for the amount of safety that they desire. Individuals will prefer to purchase a transport service with safety characteristics close to their own tastes. In some markets, such as trucking, there are thousands of carriers of all ilks and shippers can find a service which matches their taste. However, in some other markets there is less competition and such a matching of tastes is less likely. The problem is compounded where a common safety-critical infrastructure, such as air traffic control services or airport runways, is used by all carriers or where a common highway infrastructure is used by all drivers. In these situations a common level of safety may be provided which may not be to the taste of those desiring very high or very low levels of safety.

Table 3
The Magnitude of the Six Market Failures by Mode

	Imperfect Information	Cognitive Failure	Carrier Myopia	Extern-alities	Bilateral Crashes	Imperfect Competitio n
Private Driving	*	***	n/a	*	***	*
Private Aviation and Boating	Few failures					
Commercial Passenger	***	***	***	*	**	**
Road Freight	*	none	***	***	***	*
Maritime Freight	*	none	***	**	*	none
Rail Freight	*	none	**	**	***	***
Pipelines	*	none	**	***	none	***

Notes: * = limited failures, ** = some failures, ***= substantial failures

The applicability and magnitude of the six market failures vary significantly by mode. I have attempted to provide a summary in Table 3 using a star rating. It is only by recognizing where the market failures occur that there can be intelligent public policy prescription. Policy responses need to be tailored to the root causes of the problem in each mode. The remainder of the paper is devoted to a description and evaluation of a century or more of public intervention in the transport safety market. Because the root causes of the safety problem are so different, we divide our discussion into two parts: private automobile driving, and commercial transport.

4. Public Policy Regarding Private Automobile Driving

Traditionally public policy has been directed at the minority of drivers who do not appreciate the risks of driving and do not conduct themselves in a prudent manner (see Evans, 1991, for a comprehensive discussion of driver behavior). These drivers can be divided into four categories. The first are young drivers, especially males. Their crash rates are much higher than would be explained purely by inexperience behind the wheel. Of course, this age group also exhibits risky behavior in other ways such as their disproportionate involvement in criminal activity. There is a large literature discussing the effectiveness of new driver education and testing and possible options of restricting the types of vehicles and the times of day at which young people can drive (the journal *Accident Analysis and Prevention* is a good source for this and all other aspects of highway safety)

The second group is older drivers. There is evidence that driver performance starts to deteriorate at the age of 50 and gets markedly worse after 65. However, societal risks are moderated as older people drive less and elect to drive at times of day and in places which are generally safer. Nevertheless this is a growing area of concern as the "baby boomers" move into retirement and medical advances prolong life expectancy. Therefore, we can expect to see calls for additional research regarding the appropriate response by licensing authorities.

The third group comprises people who drive while under the influence of alcohol. Some proportion of these people have a chemical dependency. However, the majority are more social drinkers who are heavily influenced by societal attitudes that condone and even encourage drinking as a desirable leisure pursuit. Because alcohol plays a large part in the social activities of young people, it worsens their already poor driver behavior. Since the 1960s most countries have attacked the problem by establishing laws that specify the maximum permissible blood-alcohol content In some countries it is legal to randomly test motorists while in others police officers can only do so with cause (see Zaal, 1994, for a review of the law enforcement literature). While these programs have been very successful, Evans (1991) comments that a significant effect has been the ongoing change in social attitudes that now eschew excessive public drunkenness. If in the next thirty years attitudes toward alcohol change in a similar way to the change in attitudes toward tobacco in the past thirty years, then much of the traffic safety problem would go away.

The final group consists of drivers who fit into none of the above categories yet seem to be more accident prone (or exhibit "differential crash involvement") than other drivers. This is a very controversial subject, especially when elevated driving risk is linked to other risky or deviant social behavior. Nevertheless a considerable amount of police time is spent in identifying these drivers by means of enforcing speed limits or catching drivers who do not obey signals at intersections (Zaal, 1994). Presumably the fines and possible loss of diving privileges act as a deterrent to some drivers, as does the insurance industry which devotes considerable energies to assessing premiums that reward responsible drivers and penalize poor ones (Dionne, 1992).

Influencing driver behavior is just one part of the issue. Haddon (1972) introduced the useful concept that traffic safety can be characterized by a 3x3 matrix. The categories on one axis are the driver, the vehicle, and the highway. The other axis is composed of actions before a crash ("crash avoidance"), the crash phase, and the post-crash phase. All of the discussion so far has concentrated on the top left-hand cell of this matrix. Starting in the 1960s there was a conscious move to attack traffic safety via other cells in this matrix. For example, a significant reduction in fatality risk has come from improved medical response in the post-crash phase. Highway design is clearly important in both promoting crash avoidance and in mitigating the harm when a crash occurs (Lamm et al., 1999). A controversial aspect of highway design has been the assignment of speed limits which in the United States were reduced during the energy crisis of the 1970s and only liberalized in the past decade. The subsequent discussion of the relationship between risk and speed has led to a quite acrimonious debate between some economists and highway and automotive engineers.

Academic interest has been generated by regulations that imposed automotive solutions that promote crash avoidance and increased survivability in the event of a crash. An example of the first is center-mounted rear brake lights at eye level. These are designed to mitigate the risks of driving too close to the vehicle in front by providing for a quicker response if the vehicle in front brakes. Examples of the second are requirements for collapsible fenders, strengthened passenger cabins, seatbelts and air bags. All of this equipment adds to the cost of new vehicles. Seat belts also require the driver to devote time to fasten them, and police resources must be deployed to enforce seatbelt laws. Consequently, this presented the opportunity for economists to enter the debate to discuss whether the benefits were worth the costs (Loeb et al., 1994, chapters 2 and 3; Crandall et al., 1986; Blomquist, 1988). Not all changes have promoted safety. Requirements that automakers increase fuel efficiency have lead to reductions in automotive size and weight which have increased the risk to occupants. Even the market-driven reversion to heavier sports utility vehicles is not without safety consequences, as these vehicles have higher centers of gravity and are more susceptible to roll-over crashes.

Economic evaluation is complicated and controversial because it involves assigning monetary values to the number of lives saved and injuries avoided, the extra time involved in buckling seatbelts, and in the case of changes in speed limits, longer or shorter journey times. In addition, it is very difficult to discern the effect of one particular policy measure as other contributory factors are usually changing at the same time. One particular problem is known as "risk compensation" by economists and as "human behavior feedback" by automotive engineers and human factors analysts. For example, it is well known that in the event of a crash a seatbelt will reduce fatality risks by at least 40%, primarily because of reduced risk from being ejected from the vehicle. However, the national fatality risk reduction, even assuming everyone wore their belts, may be much less because drivers may partially compensate for the increased safety by, for example, driving faster or talking on a mobile phone. The magnitude of this effect provokes heated debate between automotive engineers and economists (see Evans, 1991).

5. Public Policy Regarding Commercial Transport

Before one can analyze public policy for commercial transport, it is important to gain an understanding of the marketplace for safety. Customers make consumption decisions regarding mode and carrier to patronize based on a whole array of considerations including price, speed, frequency, comfort, and safety. Safety is valued by consumers yet costly to provide. It is likely therefore that consumers will choose a lesser amount of safety than is technically possible because it saves them time and/or money, and be quite happy with this choice. If this was not the case, one would assume that consumers would demand five pilots in every cockpit and that trains operate at a maximum speed of forty miles per hour.

Not all customers value safety equally. In freight transport, it is reasonable to suppose that shippers of expensive delicate goods will be more prepared to pay a premium to obtain high quality transport than would, say, shippers of inexpensive bulk materials. While it is more controversial, it is quite reasonable to assume that passengers have a variety of safety tastes. Albeit, those demanding high safety may be wealthier individuals who can afford a premium price. A basic result in economics is that a “vertically differentiated” market will emerge with some carriers offering high quality at a premium price, and others offering lesser quality at lower prices (Shaked and Sutton, 1982). If consumers are knowledgeable about the array of services on offer and freely choose among them, an optimal situation occurs. Such a situation occurs in trucking and bulk maritime. To many lay observers the fact that some carriers can be shown to have worse safety records than their peers is typically taken as evidence of a market failure. On the contrary, when customers are fully informed, this should be taken as a sign that the market works.

The situation in passenger markets is a little different. Passengers are typically not as well informed and dispassionate about their choices as professional shipping managers. If they cannot recognize which carriers are offering premium quality, there is little incentive for carriers to differentiate their product. It is not surprising that most mainstream airlines, for example, offer roughly identical safety. However, even in these markets there exist low price and low quality choices, such as charter carriers, that some consumers decide to patronize. Of course this may, in itself, cause a problem in that some impecunious passengers would voluntarily select carriers that the more mainstream society would regard as posing unreasonable risk. Society may, and does, act to ban such carriers and consequently restricts the mobility of some people.

So how much safety should a carrier provide? For a monopolist or an infrastructure supplier, the answer is quite clear. The marginal revenue from providing a higher quality service should be equated with the marginal cost of doing so (see the excellent empirical paper by Evans and Morrison, 1997). In a vertically-differentiated market, the answer is less clear in that a carrier has to decide how to position itself in the market vis-a-vis other carriers. This is an area that has not been well researched. The somewhat controversial suggestion that carriers make conscious choices on the inherent safety of their production processes and the layers of “defenses” that they build into their systems to protect against errors has gained prominence in the past decade. The work of James Reason and others has popularized the concept of “organizational accidents,” which is totally in keeping with economists’ thinking. Reason’s coauthored book on aviation safety (Maurino et al., 1995) is required reading for those interested in safety of all modes.

As described earlier, when some or all customers are imperfectly informed, there is the opportunity for some carriers to act in a myopic fashion. Some established firms can “cheat,” and inappropriate decisions can be made by inexperienced new carriers. The net result is that some passengers end up consuming a service of a lower quality than they expect, and pay with their lives, and third parties and bystanders suffer from crashes involving myopic freight carriers. There is plenty of anecdotal evidence of this behavior in all modes. A number of academic studies have been conducted which primarily focus on whether new entrants or firms close to bankruptcy have elevated crash rates. It is reasonable to suggest that the fear of myopic behavior is behind most of the public policy action on safety, and specific instances of myopic behavior are usually the catalysts for tightened regulations and/or tougher enforcement action.

Of course not all carriers will act in this way. Some will be constrained by morality, others will take a long term perspective and not wish to lose future custom if their reputation is sullied. In addition society has instituted a number of institutional processes which act as behavioral modifiers.

Injured parties can bring legal suits, and insurance companies who write policies to protect against legal settlements have some incentive to monitor and constrain the behavior of their policyholders (Shavell, 1987). However, these processes are not panaceas. In most markets there is a need for additional intervention. One option is to attack the root cause of the problem by providing information to make consumers better informed. This logical policy tool has traditionally been underutilized. But this may change. The revolution in information technology has decreased the cost of providing timely information on the safety performance of carriers directly to consumers. Of course, there are many unresolved questions such as which data are the most informative, how to interpret data on rare events, and the thorny issue that for cheaters, data on past performance is not an accurate predictor of the future.

A more common policy is to directly regulate the conduct of carriers. Safety regulation is both highly visible and controversial. High profile disasters frequently lead to calls that "something should be done." Consequently there is a plethora of regulations in every mode that define acceptable safety standards, and provide for inspections to certify the competence of new entrants, and check for continued compliance. Traditionally the designated standards have been expressed in terms the quality and quantity of staff and equipment, which are easily to inspect and confirm compliance. An alternative approach is "performance standards" which designate minimum acceptable crash rates. These have several advantages. First, carriers are allowed to use entrepreneurial skill to produce the desired level of safety at minimum cost. Second, new technology can be introduced quite quickly, unhindered by the need to change the regulations. Third there is less susceptibility to politicking by avaricious parties who wish to use regulation of safety inputs to preserve old working practices, exclude new entrants, or promote the use of their own specific safety-related product. There are moves toward performance standards and this will provide a fruitful area of research for the coming years (see Savage, 1998, for a discussion with regard to the freight railroad industry). A further issue is that economic theory suggests that in effective law enforcement there is a tradeoff between the frequency and nature of inspections and the scale of penalties assessed (Polinsky and Shavell, 2000). There are research opportunities to discover whether regulatory agencies currently have the balance correct. Because there are many unanswered questions, safety policy analysis and prescription remain an exciting multi-disciplinary field of research.

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