

by the automobile manufacturing industry. So far only mediocre progress has been made in the reduction of automotive pollution through the attempt to impose fairly stringent standards on manufacturers, in terms of the performance of their vehicles as they leave the factory. The manufacturers have stalled, on the ground that the standards were impossible to meet, and the standards have been lowered. Manufacturers have elected to use the catalytic converter as the means to meet the standards, at least temporarily, which has resulted in automobile owners bypassing or discarding the converters or poisoning them with lead. Now a shortage of high-test unleaded gasoline is threatened. At best, manufacturers have been concerned with performance as measured at the factory gate, but what is important is the performance of automobiles on the road.

Ideally what might be called for is to periodically measure the pollution performance of each automobile on the road and levy a pollution tax, according to the results, on the owner. But such an approach would be inordinately costly to administer, especially in the light of the high proportion of total emissions accounted for by cold starts and the high cost in terms of inconvenience and otherwise of testing for this element. Moreover, important elements of the pollution control problem relate to design and quality control in a way that would be unlikely to affect manufacturers through the influence of taxes levied on owners or the demand for various models. Moreover, through the price or tax mechanism manufacturers could be made responsive to more than just the performance of the vehicle at the factory gate.

What suggests itself on this basis is as follows: As automobiles leave the factory they could be sampled, tested, and a pessimistic forecast made of the pollution likely to be emitted by automobiles over their lifetime. An appropriate tentative tax could be levied on the manufacturer, which, in principle, would represent the discounted present value of the marginal pollution damage attributable to this pessimistic forecast of pollution. Subsequently, at suitable intervals a random sample of these same automobiles could be selected in the field and tested for emission levels, and to the extent that the results are better than the pessimistic forecast, a rebate of the tax could be paid to the manufacturer. If the results should prove worse, a supplementary tax would be levied, though this might be difficult to collect if the manufacturer is no longer in business. Owners of vehicles selected for testing would be suitably compensated.

One might economize in the testing by testing at two levels: a smaller subsample to be tested fully, including cold-start tests, the full sample to be tested fully warmed up. The sample would have to be properly stratified by time of year, climate, altitude, and environmental density. It would be appropriate to weight more heavily the sampling in areas of highest pollution levels.

Such a pricing approach to pollution would have several advantages over mandatory standards. Setting of mandatory standards cannot deal with the problem of providing an incentive for action to improve emission performance after a lapse of time, as distinct from performance when new. Another advantage is that the incentive would be applied where it will do the most good. More care will be given to automobiles likely to be heavily used in polluted areas and less to automobiles likely to be used chiefly in areas where pollution is of little consequence. Instead of concentrating on devices that may abate pollution of new automobiles, attention will be paid to methods of pollution abatement that are less vulnerable to neglect or abuse by owners, such as stratified charge engines rather than catalytic converters. Manufacturers would be given an incentive to make appropriate maintenance, repair, and retrofitting kits available to their service stations and parts distributors. Perhaps most important, manufacturers would not simply balk at making the desired changes: Failure to respond adequately would merely result in the levying of a tax, and the manufacturer would not be able to threaten to suspend production or simply offer nonconforming vehicles and engage in a confrontation of technological experts over the issue.

Such a program would have a higher administrative cost than simply an attempt to impose standards. But it is hard to see what alternative could achieve better results.

The problem with all of this analysis is that, ever since Thomas Aquinas, the use of pricing mechanisms to achieve economic efficiency has had a bad press. But, if injustices are produced by efficient prices, they can often be remedied by appropriate transfer devices; if inefficiencies are produced by just prices, there will seldom be any way of making good this loss. If enough efficiency is lost by insisting on just prices, everyone may wind up the loser.

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## Issues in Measuring the Costs of Railroad Accidents

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The allocation of limited economic resources among competing investment proposals in the railroad industry, especially among projects and programs designed to reduce accident occurrence and severity, implies that a means exists for relating the costs of railroad accident-related deaths, injuries, and property damage. This paper addresses the principal associated issues and suggests courses of action to assist analysts and decision makers.

The principal focus of this paper is an assessment of the state of understanding and development of recommendations for an approach to the analysis of societal impacts of railroad accidents, including events involving fatalities, injuries, and property damage. Of particular interest is the investigation of alternative philosophies and methodologies for measuring societal impacts of death and injury in economic terms.

Each of nine separable but interrelated issues are dis-

cussed in this paper. For each, the relevant alternative positions are identified and discussed, and appropriate recommendations are provided.

#### SHALL THE COSTS OF MORTALITY, MORBIDITY, AND PROPERTY DAMAGE BE MEASURED IN ECONOMIC TERMS?

##### Arguments Against Measuring the Costs of Death and Injury in Economic Terms

Based on a review of the research activities in this area over the past 50 years, it is clear that there is no general consensus as to either monetary estimates of the costs of death and injury or an underlying philosophy and methodology. Estimates that are made are too uncertain to be relied on for decision making. Economic estimates, if used, can obscure other important issues, such as pain and suffering, that result from death and injury.

Rhoads and Singer argue (1), "It is demoralizing when society collectively and publicly places a value on life. It is especially so when a decision is made not to save an identifiable individual." To the lay public and their political representatives the attachment of monetary values to mortality and morbidity suggests a nonfeeling, noncaring indifference. There is an implied mechanical precision. Most public agencies avoid the issue operationally. For example, although the National Highway Traffic Safety Administration (NHTSA) has funded a substantial effort to identify the social costs of motor vehicle accidents, the resulting values are not currently being used by that agency.

##### Accident Cost Analysis

Accident costs can be defined in nonmonetary terms. In the evaluation of the relative efficacy of a proposed program or project having safety consequences, for example, the cost of the program or project could be stated in dollars and the effectiveness defined as reduction in risk, number of accidents, or number of casualties. However, no decision can be made as to the relative attractiveness of alternatives unless the decision maker knows something of the relation between the relative utility of the differences in effectiveness and the difference in costs. That is, the priority of alternatives cannot be determined unless effectiveness and cost can be expressed in a common dimension.

In the event that accident costs (i.e., deaths, injuries, and property damage) can be expressed in the same terms as the other consequences associated with a program or project, then a benefit/cost analysis can be performed to assist the decision maker in the allocation of limited capital resources.

Note that the actual implementation of benefit/cost analysis is not nearly as straightforward as outlined above. Complications arise, in large part, because of the stochastic character of principal estimates, chiefly the number of future occurrences of an event (e.g., fatality and injury) and the cost per occurrence. These are predictions of the future; they are not known with certainty.

##### Recommended Position

Inasmuch as accident costs must be described commensurately with other principal consequences in order to make informed decisions concerning capital allocation, and since the latter are normally described in monetary terms, accident costs, especially death and

injury, should also be stated in monetary terms. Jones-Lee makes the point effectively (2):

It is a fact of life that society confronts a problem of scarcity and must in consequence engage in continual allocative choices. Insofar as such choices occur in the public sector, it is desirable that those who make them should do so on the basis of more rather than less information concerning private preferences.

##### FROM WHOSE POINT OF VIEW SHALL IMPACTS BE ASSESSED?

Railroads generally assess costs from the point of view of the reporting railroad (e.g., loss or damage to freight, cost of clearing wrecks, and damage to railroad property). Railroad managements are concerned with effects that are directly reflected in their income statements. Federal agencies and the Association of American Railroads (AAR) have not required more extensive reporting, either because they see no particular reason to do so, the means are not at hand, or the costs would be prohibitive.

The bulk of public opinion on this matter concludes that, with respect to public decisions concerning the allocation of public funds, the appropriate perspective is that of the society at large. Jones-Lee summarizes this position (2):

The resemblance between cost-benefit analysis and "commercial" project appraisal is, however, more apparent than real. This is hardly surprising since the ultimate objectives of public-sector decision makers are unlikely to bear much resemblance to the objectives of decision makers in the private sector. The essential difference is that the managers of a firm will probably be largely concerned with their own and their shareholders' interests while the public sector decision maker normally will be concerned with a more nebulous index of the welfare of society "as a whole".

##### HOW SHALL ECONOMIC VALUE BE DETERMINED WITH RESPECT TO MORTALITY?

A variety of viewpoints concerning the value of life have been expressed in published literature. Generally, they can be summarized as follows:

1. Willingness to pay (WTP);
2. Discounted future earnings (DFE) (gross) and DFE (net);
3. Societal costs, including DFE; and
4. Miscellaneous other (e.g., insurance premiums and court awards).

There are virtually no advocates of reason 4, for reasons that are rather obvious. The other views, however, do have their partisans among thoughtful scholars and practitioners.

##### WTP

One body of thought argues that the value of human life is best determined by the individuals involved, who can express their willingness to pay for certain risk-reduction options, either explicitly or implicitly. There are variations in this viewpoint. Jones-Lee (2-4) determines the functional relation between an individual's future income stream and the amount he or she will pay to reduce the probability of death. Mishan (5) requires, for each affected individual, the maximum amount he or she will pay rather than forgo a project that results in certain probabilities of death.

Some results reported by investigators using this approach follow (all figures are for the year reported):

Table 1. Societal cost summary discounted at 10 percent, 1975.

Cost Component	Injury Severity												Property Damage Only	
	6 (Fatality)		5		4		3		2		1			
	Cost (\$)	Percent	Cost (\$)	Percent	Cost (\$)	Percent	Cost (\$)	Percent	Cost (\$)	Percent	Cost (\$)	Percent	Cost (\$)	Percent
Production-consumption market	145 670	72.35	82 250	61.14	36 075	58.53	1645	20.35	865	19.86	66	3.01		
Home, family, and community	43 700	21.71	24 675	18.34	10 820	17.55	425	5.26	310	7.13	20	0.91		
Medical														
Hospital	275	0.14	5 750	4.27	2 250	3.65	1095	13.54	450	10.34	45	2.05		
Physician and others	160	0.08	5 520	4.10	2 160	3.50	525	6.49	165	3.80	55	2.51		
Coroner-medical examiner	130	0.06												
Rehabilitation			6 075		3 040									
Funeral	1 080	0.54												
Legal and court	2 190	1.08	1 645	1.22	1 090	1.77	770	9.52	150	3.45	140	6.39	7	1.35
Insurance administration	295	0.15	295	0.22	285	0.46	240	2.97	220	5.06	52	2.37	30	5.77
Accident investigation	80	0.04	80	0.06	70	0.11	45	0.56	35	0.81	28	1.28	6	1.15
Losses to others	3 685	1.83	4 180	3.11	1 830	2.97	260	3.21	130	2.98	32	1.46		
Vehicle damage	3 990	1.98	3 990	2.97	3 960	6.42	2920	36.12	1865	42.87	1595	72.83	315	60.58
Traffic delay	80	0.04	60	0.04	60	0.09	160	1.98	160	3.68	160	7.31	160	30.77
Total	201 335		134 520		61 640		8085		4350		2190		520	

Table 2. Costs of death, injury, and property damage per occurrence.

Source	Fatal (\$)*	Injury (\$)*	Property Damage Only (\$)*	Ratio of Cost of Fatality to Nonfatal Injury
Fromm (7), 1975*	287 175	3185	520	90
NSC (19), 1973	90 000	3700	570	24
NHTSA (20), 1971	43 000	2200	-	20
White House (15), 1972	140 000	2750	-	51
Helms (21), 1971*	83 200	1300	-	64
Niklas (22), 1970*	32 400	362	-	90
Reynolds (12), 1956 <sup>d</sup>	5 580	1450 serious 112 slight	-	4 50

\*Values are expressed in dollars for the year of the study, not in constant dollars.

<sup>a</sup> Assuming a 7 percent discount rate.

<sup>c</sup> In 1971, \$1.00 = DM 3.70.

<sup>d</sup> In 1956, \$1.00 = £0.36.

(a) Carlson (6), \$200 000-\$1 000 000 (1963); (b) Fromm (7), \$210 000 (1965); (c) Thaler and Rosen (8) \$200 000 (1975); (d) Ghosh, Lees, and Seal (9), \$260 000 (1975); and (e) Blomquist (10), \$257 000 (1977).

## DFE

Advocates of the DFE viewpoint argue that the value of an individual's life is measured by the wages that society is willing to pay for his or her future services. These are then discounted (by the social rate of discount). Most investigators take the view that the most appropriate measure is the net loss of output [i.e., future production less future consumption (11,12)]. Others argue that the gross loss of output should be measured (13):

The accidents that need to be costed are those that do not occur but which, without the introduction of some safety measure, would have occurred. The fact that on this basis the individual concerned is, indeed, still alive means that the individual consumption should not be deducted when assessing the benefits of preventing accidents, as he is alive and able to enjoy that consumption.

Some quantitative results are summarized as follows (all figures are for the year reported):

1. Gross—Dublin and Lotka (11), \$27 209 (1930); Bolla and Associates (14), \$250 000 (1963); White House (15), \$140 000 (1972); Usher (16), \$150 000 (1973); and Faigin (17), \$184 110 (at 7 percent discount) (1975).
2. Net—Dublin and Lotka (11), \$9802 (1930).

## Societal Costs

Perhaps the most widely held view of the value of life

is one that aggregates a number of societal cost components, including the forgone production of the individual, relevant medical costs, legal and court costs, and accident investigation costs (7,12,17,18). In some variations the component that represents value of life to the individual is measured by WTP (2).

The most detailed and current effort based on this view is that of NHTSA during the early 1970s (17). The results for the principal cost elements are given in Table 1. [Results are given for five levels of severity of nonfatal accidents from critical (5) to minor (1)]. It is particularly interesting to note that, using a 10 percent discount rate, the production-consumption component (\$145 670) represents more than 72 percent of the total cost of a fatality (\$201 335). This element is determined by discounting forgone compensation, which is a proxy measure of societal valuation of production. The second largest component, home, family, and community services production losses, represents about 22 percent of the total. Thus, these two cost elements alone represent 95 percent of the total, a result that should influence the allocation of additional research resources.

## A Sample of Results

Costs of fatalities, as well as injuries and property-damage-only accidents, are summarized in Table 2 for a number of sources. The data used by the National Safety Council (NSC) are shown for 1973; these most probably have been updated since 1973, but current values are not generally available. The principal reason for the substantial differences between NHTSA and NSC values for fatalities is that NHTSA discounts gross future earnings whereas the NSC discounts net future earnings.

## HOW SHALL ECONOMIC VALUE BE DEFINED WITH RESPECT TO MORBIDITY? WHAT ARE THE COSTS OF INJURIES?

There are two fundamental questions closely related to this issue.

1. Shall a single cost per occurrence be established, irrespective of the severity of the injury, or shall separate costs be estimated with respect to separate levels, or classes, of injury severity?
2. Shall the cost of pain and suffering be included as a relevant component?

Table 3. Casualties of employees on duty on class 1 and 2 railroads, 1976.

Injury or Illness	Injuries	Workdays Lost	Average Days Lost per Injury
<b>Nonfatal injuries</b>			
Bruise—contusion	12 309	75 111	6.10
Sprain—strain	18 549	166 951	9.00
Cut or laceration—abrasion	10 018	33 701	3.36
Electrical burn or shock	261	1 546	5.92
Other burns	1 559	6 460	4.14
Dislocation	315	6 007	19.06
Fracture			
Arm or hand	722	18 840	26.09
Fingers	1 616	12 693	7.85
Leg or foot	1 011	40 062	39.62
Toes	667	6 806	10.20
Head or face	230	4 010	17.43
Torso	476	15 688	32.95
Other	165	2 326	14.09
Amputation			
Arm or hand	16	3 391	211.93
Fingers	151	4 040	26.75
Leg or foot	39	8 387	215.05
Toes	16	989	61.81
Other	1	365	365.00
Cinder or other foreign particle in eye	6 124	8 515	1.39
Hernia	377	12 655	33.56
Concussion	139	2 523	18.15
Nervous shock	35	337	9.62
Internal injuries	83	2 685	32.34
Loss of eye	7	632	90.28
Other	1 428	7 994	5.59
<b>Total</b>	<b>56 314</b>	<b>442 714</b>	<b>7.86</b>
<b>Nonfatal occupational illnesses</b>			
Occupational skin diseases or disorders	868	1 494	1.72
Dust diseases of the lungs	4	37	9.25
Respiratory conditions due to toxic agents	262	1 131	4.31
Poisoning	82	414	5.04
Disorders due to physical agents	144	308	2.13
Disorders due to repeated trauma	23	212	9.21
Other	192	719	3.74
<b>Total</b>	<b>1 575</b>	<b>4 315</b>	<b>2.73</b>
<b>Fatalities</b>	<b>100</b>	<b>3 911</b>	<b>39.11</b>
<b>Total</b>	<b>57 989</b>	<b>450 940</b>	<b>7.77</b>

### The Cost of Pain and Suffering

With respect to the latter question, we note that nowhere in the literature is an attempt made to include pain and suffering as a cost component of morbidity. In part, this may be explained by the fact that the WTP approach has been associated historically only with the cost of fatalities, not injuries. And it is the WTP concept that provides a theoretical basis for estimating that amount that individuals would be willing to pay to avoid pain and suffering. An injury, moreover, is not the finite event that death is perceived to be. Pain and suffering are even less definable. Thus, even in using the WTP approach, it is probably infeasible to attempt to include pain and suffering as a societal cost element measured in monetary terms.

### Injury Severity

As illustrated in Table 3 (23), injuries are currently described by reporting railroads in terms of the type (e.g., bruise or strain) rather than the severity. The existing classification scheme does not readily lend itself to costing. A contusion, for example, may result in very substantial costs or may require little or no medical aid or lost time. Moreover, as will be shown below, societal cost data developed by other investigators are related to injury classes other than that currently used by railroads.

The Abbreviated Injury Scale (AIS), published by the American Medical Association, Society of Automotive Engineers (SAE), and American Association for Automotive Medicine (AAAM) in 1971 and revised in 1976, is gaining increasing acceptance throughout the United States and abroad and is used almost exclusively in the classification of injuries from traffic accidents. The AIS is used in coding specific individual injuries. The codes are

- 0—no injury,
- 1—minor,
- 2—moderate,
- 3—severe (not life threatening),
- 4—serious (life threatening),
- 5—critical (survival uncertain), and
- 6—maximum (currently untreatable).

The overall AIS(OAIS) is used for coding multiple injuries (24): "Basically, the coder equates what in his judgment is the total effect of multiple injuries on a victim's body and systems with the effects on the body and systems of a single injury with a known AIS."

The advantages of using the AIS (or OAIS) for classifying injuries include (25) the following:

1. Single, comprehensive system for rating tissue damage,
2. Acceptable to both physicians and engineers,
3. Severity of injury can be rated in the AIS without regard to whether or not the victim dies,
4. Adopted by the multidisciplinary accident investigation (MDAI) teams established by the U.S. Department of Transportation (DOT) and by crash investigators worldwide, and
5. Good interrater reliability has been demonstrated.

### Cost Estimates by Injury Severity

In Table 1 cost estimates were presented for various injury classes as reported by NHTSA (17). These values are given as point estimates. However, recent studies at the University of Michigan indicate that the variance of the cost distribution is quite large. Ranges of costs as actually experienced by a fairly small sample are reported as follows (18, 26):



OASIS Code	Costs (\$)		NHTSA (1975 dollars)
	Range	Mean	
1	0- 4 327	983	2 190
2	1775- 3 382	2 497	4 350
3	2569- 16 313	7 568	8 085
4	4457-217 979	46 924	61 640
5	4730-364 493	68 134	134 520

For comparison, costs derived by NHTSA (17) are shown in the last column of the above table. The reference year for both sets of data is 1975. Clearly the NHTSA-derived values are substantially higher than the means of costs actually experienced in the University of Michigan studies. Not too much should be made of this, however, inasmuch as the University of Michigan data are from a small regional sample.

#### AS CURRENTLY REPORTED BY RAILROADS, ARE INJURY DATA ADEQUATE FOR ASSESSING COSTS OF MORTALITY AND MORBIDITY?

##### Reportable Accidents and Incidents

Railroads are required to file monthly accident and incident reports with the Office of Safety, Federal Railroad Administration (FRA). These include

1. A monthly report of railroad accidents,
2. A rail equipment accident and incident report,
3. A rail-highway grade crossing accident and incident report, and
4. A railroad injury and illness summary.

Reportable accidents and incidents are defined as any impact between railroad on-track equipment and automobile, bus, truck, motorcycle, bicycle, farm vehicle, or pedestrian at a highway grade crossing; any collision, derailment, fire, explosion, or other event involving railroad on-track equipment that results in more than \$2900 in damages to railroad on-track equipment, signals, track, track structures, and load bed; and any event arising from operation of the railroad that results in the death of one or more persons, injury to persons other than railroad employees requiring medical treatment, injury to employees (limited), and occupational illness of employee.

Major revisions in reporting requirements, effective January 1, 1975, are summarized in Table 4. Because of these changes, comparisons of the data from 1975

and later with data from previous years are virtually impossible.

##### Major Problems

The accident and incident data reporting system currently used by railroads is inadequate for an assessment of the qualitative and quantitative effects of safety impacts. Among the principal problems are the following:

1. Reporting is incomplete; minor injuries are unreported unless medical treatment beyond first aid is necessary.
2. The description of injury severity is imprecise and does not facilitate comparison with OASIS data developed in other contexts.
3. There appears to be little quality control; no mechanism exists for monitoring or ensuring that reporting procedures are uniform among the various railroads.
4. Objectivity of reporting is questionable; it is possible, indeed probable, that biases arise as the result of the reporting railroad's desire to avoid the appearance of negligence and inefficiency.
5. Currently, time lost due to injury is truncated at 365 days; if, for example, an injured person is expected to be incapacitated for 18 months, the cost of that lost time between 12 and 18 months is ignored. This is a systematic bias and tends to understate the true cost of time lost due to injuries.

#### ARE CURRENT PROCEDURES ADEQUATE FOR ASSESSING PROPERTY DAMAGE DUE TO RAILROAD ACCIDENTS?

A variety of data sources are used to identify property damage due to railroad accidents. The major sources are the Interstate Commerce Commission (ICC) (uniform system of accounts) and the FRA (yearly financial reports). Supplemental sources include the AAR and the internal accounting systems of the various railroads.

Damage to railroad property is reported to the FRA when the damage estimate exceeds \$2900. All railroads are required to report damage to livestock on the right-of-way to the ICC in their annual reports. Costs include direct expenses and related employee salaries, expenses, office rent, and probable liability (i.e., the railroad's liability). Freight loss and damage is also reported annually to the ICC. The costs of clearing wrecks are not included in the damage costs reported to the FRA in the accident reports. Omitted are the costs of emergency services, which are borne

Table 4. Some changes made in reporting requirements.

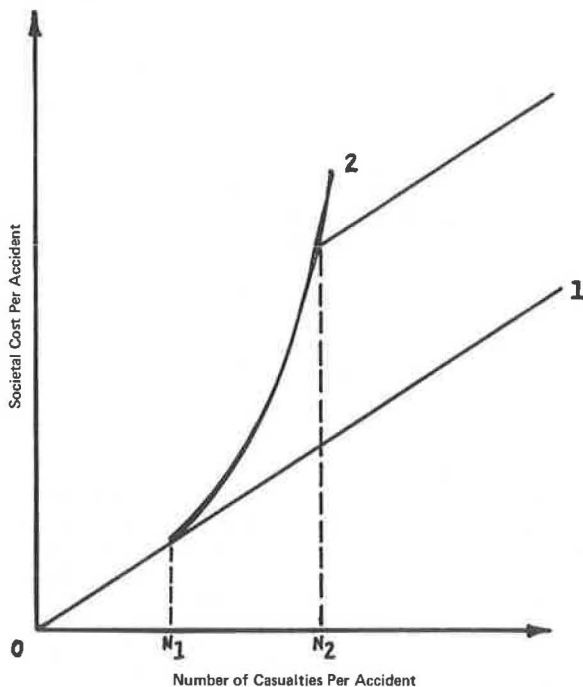
Reporting Requirement	Through 1974	1975 and Later
Damage threshold for reporting train accidents	\$750	\$1750 as of 1/1/75 \$2300 as of 1/1/77 \$2900 as of 1/1/79
Requirements for reporting rail crossing accidents and incidents	Only if reportable casualty or minimum of \$750 damage to railroad equipment, track, or roadbed	Any
Reporting of fatalities	Death occurring more than 24 h after occurrence of injury reported as injury	Reported as fatality
Reporting of employee injuries	Only those injuries causing at least 2 days of lost or restricted time. Case remains active for 10 days	Those injuries that result in one or more lost or restricted workdays, medical treatment beyond first aid, transfer to another job, termination of employment, or lost consciousness. Case remains active for 365 days
Reporting of nonemployee injuries	Prevented from following vocation for more than 24 h during following day	Requires medical treatment beyond first aid

Table 5. Freight loss and damage costs reported to the AAR.

Cause	Total Freight Loss and Damage (%) <sup>a</sup>
Shortage, packed equipment	1.78
Shortage, bulk shipment	4.07
Defective or unfit equipment	3.40
Temperature failures	5.06
Delay	2.54
Robbery, theft, pilferage	5.26
Concealed damage	0.69
Error of employees	0.94
Vandalism	0.64
Fire, marine, and catastrophes	1.78
Train accident (loading only)	20.69
Miscellaneous	53.24

<sup>a</sup>1976 data.

Figure 1. Cost to society per accident as a function of the number of casualties per accident.



by local governments, and the costs of damage to structures owned by others.

The costs of freight loss and damage are especially interesting. As noted in Table 5 (27), more than one-half of the costs are attributable to miscellaneous causes. This categorization hinders the ability to relate damage to specific causal actions and also calls into question the reliability of the source data. Of the remaining cause categories, note that train accident is paramount.

**GIVEN THAT COSTS OF MORTALITY, MORBIDITY, AND PROPERTY DAMAGE CAN BE EXPRESSED IN ECONOMIC TERMS, ARE THESE COSTS STRICTLY ADDITIVE?**

This question can be rephrased: Does the whole equal the sum of the parts? or, Is the total cost of a specific accident equal to the sum of the costs of property damage, injuries, and fatalities associated with that accident? Current practice is to view a single accident that results in 100 deaths, for example, as just as costly as 100 separate accidents, each of which results in one death (everything else being equal).

Experience suggests that there may be an additional

severity cost that is a function of the magnitude or gravity of the accident. Journalists seem to recognize this fact: Multiple-fatality accidents are much more likely to rate press coverage than single-fatality accidents, in part because their relative rarity makes them more newsworthy. The attention of legislators is also more likely to be drawn to perceived disasters and catastrophes even though aggregate losses may be no greater than that arising from a large number of relatively minor events.

This position is shown in somewhat simplified form in Figure 1. The line 0-1 represents the classical position: Total cost is the number of casualties (e.g., deaths and injuries) multiplied by the cost per casualty. The line 0-2 reflects the additional severity cost. A threshold ( $N_1$ ) is indicated below which the severity cost is perceived to be negligible. Similarly, beyond  $N_2$  the incremental severity cost is also perceived as negligible.

**GIVEN THAT A SOCIETAL COSTS APPROACH TO THE VALUE OF LIFE IS INAPPROPRIATE, WHAT ARE THE RELEVANT COST ELEMENTS?**

#### NHTSA Study

The cost elements included in the NHTSA 1975 societal cost study (18) are

1. Production losses—market, home, family, and community;
2. Medical—hospital, physician and other, coroner-medical examiner (fatalities), and rehabilitation;
3. Funeral;
4. Legal and court—tort action and accident citation;
5. Insurance administration;
6. Accident investigation;
7. Losses to others—employer and home care;
8. Vehicle damage; and
9. Traffic delay.

#### Jones-Lee Study

Jones-Lee, although much less specific, identifies these cost elements as follows (2):

1. Reduction in the individual's share of real resource costs occasioned by the death of others,
2. Reduction in the individual's share of the loss of net output due to the death of others, and
3. Reduction in the risk of his or her own death or that of anyone he or she cares about.

#### NSC Study

The position of the NSC is of special interest because of the relative influence of NSC figures among transportation planners. The NSC position was described in a recent paper (28):

We have tried to measure the real dollars lost as the result of motor vehicle accidents. This includes: dollars that had to be spent as the result of the accident and dollar income that would not be received. This latter is seen as a reduction in contribution to the wealth of the nation using wages as a measure of the loss of productivity.

Specifically, the NSC cost elements are (a) net discounted value of future earnings and (b) medical costs (assuming 50 percent of fatalities are dead on arrival), including hospital charges, doctor's costs, insurance (premiums less claims paid), and property damage (assumes one vehicle destroyed for every fatality).

### The Conservation of Resources Approach

Winfrey proffered his own list of relevant cost elements (9):

1. Normal automobile use not incurred,
2. Costs and benefits of autopsies,
3. Costs and benefits of accident investigation,
4. Nonlegal expenses to fix accident responsibility,
5. Legal and court expense to fix accident responsibility,
6. Funeral costs (discounted),
7. Estate settlement,
8. Administration cost (overhead) of motor vehicle insurance in addition to cost of accident,
9. Work time lost and wages not continued,
10. Estimated future gross wage or salary income (discounted),
11. Future costs to maintain a worker in working status (discounted) (this is a reduction to cost),
12. Benefits of not working (union dues), and
13. Training of replacement employees (discounted).

IN WHAT WAYS, IF ANY, ARE THE COSTS OF RAILROAD ACCIDENTS DIFFERENT FROM THOSE EXPERIENCED ELSEWHERE, ESPECIALLY HIGHWAYS?

### Employees Affected

Can the results of other investigators, working in other contexts, be applied directly to railroad accidents? The costs of fatalities and injuries described in other (non-railroad) contexts universally assume that the individual affected is drawn from the general population. However, railroad employees represent about 6-8 percent of the total mortality and morbidity in railroad accidents and incidents (23). This proportion is not insignificant. The foregone earnings of railroad employees will influence the value of life, especially with

respect to the DFE approach to valuation, because their earning patterns differ somewhat from those of the general population. Differences should also be noticeable with respect to injury valuation (e.g., medical costs and workdays lost).

### Injury Severity

As illustrated in Table 6 (17), estimates of average cost per injury are dependent on the proportions of the total injured population that fall within each severity class. In the absence of comparable data for railroad injuries (i.e., the proportions of railroad injuries that fall within each severity class), it is questionable whether the same estimates are transferable to the railroad context. Railroad accidents, for example, may involve a larger (or smaller) proportion of less severe injuries than that experienced in the highway context.

### Age Distribution

The DFE approach to the valuation of life depends on the age of the individual at the time of death. The distribution for motor vehicle and railroad casualties in 1976 is shown in Table 7 (30). The percentage distribution by age group is summarized in Table 8 along with comparable data from the 1975 NHTSA study.

Railroad employees killed and injured in rail accidents are clearly older than casualties in motor vehicle accidents. The total number involved in railroad accidents, employees as well as nonemployees, are also somewhat older than those involved in typical motor vehicle accidents. [Note the surprisingly high percentage (20.9 percent) of nonrail employees in the 0-4 age group who are in motor vehicles at the time of the railroad accident or incident. Only 3.9 percent of the other motor vehicle accidents are in the same age group. The difference may be explained, in part, by the large proportion of railroad accidents that occur at grade crossings in which very young children are passengers in the involved motor vehicles.]

### Probability of Catastrophic Events

As discussed, there is an accident cost that is a function of the perceived overall gravity of the event. (Certainly this is evident with respect to commercial aviation accidents.) Catastrophic events are more likely to occur in rail accidents than in motor vehicle accidents. In terms of Figure 1, the critical threshold ( $N_1$ ) is more likely to be surpassed in rail accidents. Thus the additional cost of severity becomes of interest.

Table 6. Frequency and cost of highway fatalities and injuries.

Injury Severity (AIS)	Number of Occurrences	Relative Frequency	Cost per Occurrence* (\$)	Total Cost (\$'000 000 000s)
1	3 400 000	0.841	2 190	7.45
2	492 000	0.122	4 350	2.14
3	80 000	0.020	8 085	0.65
4	20 000	0.005	86 955	1.74
5	4 000	0.001	192 240	0.77
6 (fatality)	46 800	0.012	287 175	13.44
Total	4 042 800			26.19

\*1975 dollars, 7 percent discount rate.

Table 7. Age distribution of highway and railroad casualties, 1976.

Age Group	Motor Vehicle Casualties*						Railroad Casualties							
	Deaths		Injuries		Total		Rail Employees		Nonrail Employees				Total	
									In Motor Vehicle		Other			
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0-44	1 600	3.4	70 000	3.9	71 600	3.9	0	0.0	1179	20.9	1027	14.8	2 206	2.9
5-14	3 100	6.6	160 000	8.9	163 000	8.8	0	0.0	338	6.0	337	4.8	675	0.9
15-24	16 500	35.3	690 000	38.3	706 500	38.3	14 418	23.0	1632	28.9	1259	18.1	17 309	23.0
25-44	12 100	25.9	530 000	29.4	542 100	29.4	31 825	50.7	1392	24.7	1838	26.4	35 055	46.5
45-64	7 600	16.3	260 000	14.4	267 600	14.5	16 292	25.9	774	13.7	1712	24.6	18 778	24.9
65-74	3 100	6.6	60 000	3.3	63 100	3.4	90	0.1	209	3.7	493	7.1	792	1.1
75	2 700	5.3	30 000	1.7	32 700	1.8	27	0.0	114	2.0	287	4.1	428	0.6
Unknown	-	-	-	-	-	-	143	0.2	-	-	-	-	143	0.2
Total	46 700		1 800 000		1 846 700		62 795		5638		6953		75 386	

\*Includes pedestrian and pedalcycle casualties.

Table 8. Percentage distribution for motor vehicle and railroad casualties by age group.

Age Group	Faigin Study (NHTSA) (%)	Motor Vehicle Casualties (%)	Railroad Casualties	
			Employees Only (%)	Total (%)
0-14	19.5	12.7	0.0	3.8
15-24	21.0	38.3	23.0	23.0
25-44	41.3	29.4	50.7	46.5
45-64	18.6	14.5	25.9	24.9
≥65	0	5.2	0.3	1.9

## SUMMARY

The costs of mortality, morbidity, and property damage should be measured in economic terms. The appropriate point of view is that of the general society with respect to those decisions requiring expenditure of public funds. However, it will be both useful and appropriate to identify also those costs to be incurred by the railroads and their employees.

Among the contending approaches to the valuation of human life, the societal costs approach appears most promising. Both the WTP and DFE perspectives should be explored over the near term to evaluate the most important cost component. Morbidity costs should be related to relative injury severity; the OAIS, as revised, shows greatest promise.

The quality of existing data bases is poor with respect to mortality and morbidity. Substantial improvements must be made before these data can be used with a reasonable degree of confidence. Current procedures for estimating the cost of property damage are poor. From a societal point of view the costs are understated.

The total cost of an accident is not equal simply to the sum of individual cost elements (i.e., mortality, morbidity, and property damage). An additional severity cost is a function (not necessarily linear) of the perceived magnitude of the accident. It is neither feasible nor desirable at this time to provide an exhaustive listing of societal cost elements. Nevertheless, as discussed in this report, an initial set of relevant components is available. It would appear that either WTP or DFE makes up the greatest part of the total.

There are some important differences between costs of railroad and other accidents. Thus standard costs developed in other contexts should be used only with considerable care. Indeed, it would appear that railroad-specific standard costs should be developed.

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# Economics of a Unified Transportation Trust Fund

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The paper describes the pricing and investment rules that might be appropriate to a unified transportation trust fund and suggests that they could be based on the same criteria of profitability that are used in the private sector. The consequences of applying such rules to the U.S. transport sector are explored, and it is concluded that rail passenger transport and some waterway transport could be lost, but bus transport and rail freight services could benefit. The effect on air transport would be to divert traffic from the more congested airports to less congested ones. The effect on road transport could be a substantial rise in fuel taxes, especially on diesel fuel, and in the annual registration fees payable by vehicles that impose heavy axle loads on the road system. It is concluded that, if suitable pricing and investment criteria are introduced, a unified transportation trust fund would be unnecessary; if they are not, a unified transportation trust fund could be wasteful.

The Highway Trust Fund is due to expire in 1979, and a number of proposals have been made for alternative financing mechanisms for highways and other transport modes. One such proposal is for the establishment of a unified transportation trust fund (UTTF) that would be used to finance all transport modes (1). The main purpose of this paper is to discuss the economics of a UTTF, particularly the rules that it might follow for pricing and investment.

## CRITERIA FOR PRICING AND INVESTMENT RULES

A principal advantage of the UTTF, according to the Congressional Budget Office, is that it would "consolidate fiscal decisions for transportation as a whole and would permit better congressional coordination of modal financing" (1). It would also enable the U.S. Department of Transportation (DOT) "to better carry out the original purpose of integrating transportation programs" (2). Such integration implies that the same pricing and investment rules would apply to all modes supported by federal funds, so that the most economic solution can be developed for every need, irrespective of mode. Thus, a basic requirement of UTTF decision rules is that they can apply to all modes. A further requirement is that the rules should be applicable to transport activities in the private and public sectors. This is necessary to ensure that activities that can be carried out more eco-

nomically in the public sector are not carried out by the private sector and vice versa.

## PROFIT- AND BENEFIT-MAXIMIZING RULES

One of the main difficulties in the formulation of pricing and investment rules that would apply to all projects is that some modes, such as railroads, buses, and air carriers, provide services that are paid for by users, and investments in these modes can, in theory, be justified by the profits that they generate to the producers, without regard to the benefits enjoyed by the consumers. In a market economy, investments are typically justified in this way. On the other hand, facilities such as roads and waterways are generally regarded as free, and no charges are levied for use. Road and waterway projects are therefore generally assessed not by their profitability to their suppliers, but on the basis of cost/benefit analysis (CBA), which attempts to rank alternative schemes by comparing the benefits to society from each scheme with its costs to society. The private sector cannot function without profits and can only invest in projects that produce revenue in excess of expenditure. In contrast, the public sector can finance projects out of tax revenues and is not confined to revenue-raising projects. However, it should not be assumed that the benefits from revenue-producing projects go only to the suppliers: Laker's transatlantic air services produce substantial benefits to the consumer as well as profits to the airline.

Much of the effort that has gone into multimodal transportation planning has been directed at developing CBA to enable it to deal with revenue-producing, private sector projects, such as railroads, within the framework developed for the assessment of non-revenue-producing projects, such as roads. The method requires that total benefits to consumers, producers, and the general public be worked out for each project component and compared with the appropriate costs. The difficulty and ambiguity of such calculations enable poor projects to be justified on the basis of alleged social benefits. For example, according to Senator Domenici, the inability to measure the social demand for navigation projects leads to a