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A Comparative Analysis of Six Methods for Calculating Travel Fatality Risk

Kopl Halperin*

Introduction

There are various approaches to calculating transportation risk. It broadly includes property damage and financial loss; narrowly, fatalities and injuries; or still more narrowly, risk of death only. Here, discussion is limited to deaths from unintended transportation injuries and is thus standardized to the International Classification of Diseases ICD-9 cause of death codes.[1] This approach permits comparison of the risk of travel by various modes, e.g., walking, bicycle, auto, bus and airplane.

However, intermodal comparisons are difficult because of differing measures of travel risk. This paper begins by examining three common measures used in the U.S.: Mileage Death Rate (MDR), Registration Death Rate (RDR), and Population Death Rate (PDR).[2] Then it considers two more recently proposed measures: Trip Fatality Risk (TFR) and Aggregate Fatality Risk (AFR).[3] Finally, it incorporates a sixth measure discussed in a companion article, Route Fatality Risk (RFR).[4]

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1 PA DEP'T HEALTH, PA VITAL STATISTICS ANN. REP. 1989 (1991).

2 MDR is generally defined as fatalities per 100 million vehicle miles, reported annually, PDR is defined as annual fatalities per 100,000 people in the population, and RDR is defined as annual fatalities per 10,000 motor vehicles. *See* J.S. BAKER, W.R. STEBBINS, JR. & E.M. JOHNSON, DICTIONARY OF HIGHWAY TRAFFIC (1960).

3 Here, as explained below, TFR is defined as the risk of dying for a particular trip, made by a particular class of traveller, in a vehicle of a particular class, by a specific mode of travel. Also, as explained below, AFR is defined as the lifetime risk of dying from a particular cause.

Still other approaches to determining travel risk are possible,[5] but they do not lend themselves to a calculation of the risk to individuals, nor the risk inherent in constructing new facilities. One approach which could be useful in intermodal analysis would be temporal fatality risk, i.e., the risk for time spent engaged in an activity. Temporal risk has been discussed, but not, so far as is known, quantified for lack of accurate estimates of times.[6]

Here, it is shown that, by all methods of calculation, roadways-and-autos are the highest risk transportation mode, and surface mass transportation the lowest risk. The commonly reported death rates tend to minimize the relative risk of roadway/automotive travel, when compared to the other risks studied.

It is also shown that relative risk factors are quite different from one calculation method to the other. By the method of risk per mile travelled, for the average person auto travel fatalities are 70 (interurban) to 210 (intraurban) times more likely than are bus fatalities. By the AFR method, auto fatalities are 1,300 times more likely than are bus fatalities.

The Three Commonly Reported Death Rates

Professionals tend to report the death rate most relevant to their profession. The Motor Vehicle Manufacturers Association reports MDR and PDR.[7] The National Safety Council also reports both of these as well as RDR per class of vehicle: cars, trucks, farm tractors and so forth.[8] In Pennsylvania, the Department of Health reports PDR[9] and the Department of Transportation emphasizes MDR, but also reports

4 K. HALPERIN & J. REDMAN, *Route Fatality Risk as a Measure of Travel Death Risk*, 4 RISK 1 (1993).

5 *See, e.g.*, Silcock, Barrell & Ghee, *The Measurement of Changes in Road Safety*, 32 TRAFFIC ENG. + CONTROL 120 (1991) (reporting numbers of accidents per hectare for various regions of Scotland).

6 Wilde, *Beyond the Concept of Risk Homeostasis: Suggestions for Research and Application Towards the Prevention of Accidents and Lifestyle-Related Disease*, 18 ACCID. ANAL. & PREV. 377 (1986) (esp. at 385 ff).

7 MOTOR VEHICLE MANUFACTURERS ASSOCIATION, FACTS AND FIGURES '87 (1987).

8 NATIONAL SAFETY COUNCIL, ACCIDENT FACTS (1989, 1990).

9 *Supra* note 1.

PDR.[10] Wilde discusses the relative importance of the different measures to the different agencies involved.[11]

The National Safety Council states that all collisions are the result of a confluence of vehicle, passageway and operator.[12] The three commonly reported transportation risk measures are specific to vehicle (RDR and MDR) and operator (PDR) but not to passageway. For an individual traveler, operator-specific risk is the most important measure. For a society allocating resources to transportation, it is systemic risk which is paramount.[13] Passageway risk, if calculated, would give a measure useful in systemic risk analysis. Thus $100 million buys perhaps twenty miles of light rail or ten miles of highway in an urban district; the important risk calculation is that of comparing the twenty miles of light rail system to ten miles of highway.[14] Of course economic factors other than risk enter into transportation decisions, but safety considerations appear to dominate the economic outcome.[15]

The commonly reported MDR calculates deaths per mile of vehicle travel. Yet, as do Evans et al.,[16] this paper reports averaged annual fatalities per 100 million miles of passenger travel by dividing by average auto occupancy, i.e., 1.4. Thus, the 1978–87 average vehicle MDR, MDR(V), 2.94, becomes a population MDR of 2.10. To avoid confusion, this will be called MDR(P). MDR(P) is specific to the operator and thus more valuable for a risk discussion.

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10 PENNDOT, TRAFFIC ACCIDENT FACTS AND STATISTICS 1990 (1991). MDR is reported at 2, 7, 8 and 17; PDR at 17 only.

11 Wilde, *supra* note 5.

12 ACCIDENT FACTS, *supra* note 8.

13 *See* M. HORODNICEANU & E. J. CANTILLI, TRANSPORTATION SYSTEM SAFETY (1979) for a discussion of the need for systemic approaches to transportation safety.

14 S. PLOWDEN & M. HILLMAN, DANGER ON THE ROAD: THE NEEDLESS SCOURGE, A STUDY OF OBSTACLES TO PROGRESS IN ROAD SAFETY (1984) proposes intermodal solution to transportation risk problems.

15 Whitelegg, *Road Safety: Defeat, Complicity and the Complicity of Science*, 15 ACCID. ANAL. & PREV. 153(1983).

16 Evans, Frick & Schwing, *Is It Safer to Fly or Drive?*, 10 RISK ANAL. 239 (1990).

Registration Death Rate

RDR does not lend itself to ready comparison of various modes of travel. The National Safety Council reports RDR for bicycles as well as autos; the auto RDR is 36 times that of the bicycle RDR.[17] One could calculate fatalities per airplane or per bus, but not meaningfully. RDR does allow a comparison of fatality risk between cultures or governmental units,[18] but this risk comparison is per vehicle, a choice of denominator which is not obviously meaningful.

Mileage Death Rate

MDR suffers from the same limitations, when studied in the context of attempting to increase public safety, as does RDR. These limitations are best stated by Haight:[19]

> We do not measure the public health hazard by the fatality rate per distance traveled, a quantity much used in traffic engineering. This ratio is irrelevant to the public health question, just as it might be if we measured lung cancer per quantity of cigarettes consumed, or malaria per mosquito. The similarity is not that mobility and smoking are socially equivalent, but that the vehicle-mile fatality rate, like the per cigarette cancer rate, would confuse cause with effect.

Yet, MDR is the travel risk measure most widely used in the U.S. The figures for average MDR are well-known.[20] MDR is widely used in discussing the safety of various classes of roads and will be so used here. Evans et al. point out that the mean MDR for auto travel is not as relevant to an individual as would be the MDR for that individual as a member of a recognizable class.[21] The same would be true of pedestrian, bicycle and motorcycle travel. Mass transport MDR, including bus, train, ship and airplane is independent of the type of person travelling. Table 1 reports MDR for the various classes of traveller on various interurban modes of transport.

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[17] ACCIDENT FACTS, *supra* note 8.

[18] OECD, INTEGRATED ROAD SAFETY PROGRAMMES (1984). *See also,* Adams, *Smeed's Law: Some Further Thoughts,* 28 TRAFFIC ENG. + CONTROL 70 (1987).

[19] Haight, *Road Safety: A Perspective and a New Strategy,* 16 J. SAFETY RESH. 91 (1985).

[20] FACTS AND FIGURES, *supra* note 7.

[21] EVANS, *supra* note 16.

The mass transit figures are remarkably sensitive to single large crashes. This sensitivity produces a need to report ten-year averages. Pedestrian, bicycle and ship transport is a very small fraction of interurban passenger travel; data on these modes was unavailable.

Table 1

Interurban Mileage Death Rates and MDR(P) Relative Fatality Risks for Various Travel Modes[22]

Mode of Travel	*Deaths/ 100 million mi*	*Risk relative to safest mode*
18-year old males, no seat belts, intoxicated, driving light cars on rural interstates[a]	49.0	1,600
Aggregate Motorcycle (1989 only)[b]	29.0	970
Aggregate Roadway/Automotive[c]	2.1	70.0
Roadway/auto users, demographically similar to airline passengers, all types of roads[a]	0.95	32
Average drivers, only on rural interstates[a]	0.67	22
Forty year old females, wearing seat belts, sober, driving heavy cars on rural interstates[a]	0.080	2.7
Airline passengers, including sabotage risk[d]	0.061	2.0
Airline passengers, not including sabotage risk[b]	0.055	1.8
Amtrak passengers[d]	0.052	1.7
Bus passengers[b]	0.03	1.0

Roadway/auto figures include all deaths due to roadways-and-autos involving physical accidents, in which the person died within the OECD reporting time.[23] It does not include lives shortened by eventual complications from crashes. Nor does it include deaths due to chemical exposure from the various modes.[24] These pollution deaths are not

22 1978–87 average unless noted. Notes in the table indicate that data was derived from: (a) EVANS, *supra* note 16, (b) ACCIDENT FACTS, *supra* note 8; (c) TRAFFIC ACCIDENT FACTS & STATISTICS, *supra* note 10; and (d) AMTRAK, AMTRAK ANNUAL REPORTS (1978–90); Personal communication from Scott Leonard, National Association of Railway Passengers (May 1991).

23 ECMT, STATISTICAL REPORT ON ROAD ACCIDENTS IN 1985 (1988).

24 Schwartz & Marcus, *Mortality and Air Pollution in London: A Time Series Analysis*, 131 AM. J. EPIDEM. 185 (1990). *See also*, Kinney & Ozkaynak, *Associations of Daily Mortality and Air Pollution in Los Angeles County*, 54 ENVT'L RESH. 99 (1991).

negligible. Aggregate roadway/automotive includes all deaths from the road/driver/self-driven motor vehicle system which meet these criteria.

The last column shows the risk of each mode divided by the risk of bus travel. Walking, bicycles, motorcycles and mopeds, domestic animals and water transport are omitted. The safety of walking and bicycles depends almost entirely on the other transportation with which they must mix.[25]

Table 2 shows the MDR for intraurban travel. Again, not insignificant pedestrian and bicycle travel are omitted for lack of data.[26]

Table 2[27]

Intraurban Mileage Death Rates and MDR Relative Fatality Risks for Various Travel Modes

Mode of Travel	*Deaths/ 100 million mi*	*Risk relative to safest mode*
18-year old males, no seat belts, intoxicated, driving light cars on average roads[a]	93.0	9,300.0
Aggregate Motorcycle (1989 only)[b]	29.0	2,900.0
Aggregate Roadway/Automotive[c]	2.1	210.0
Average drivers, on average roads[a]	1.3	130.0
Forty year old females, wearing seat belts, sober, driving heavy cars on average roads[a]	0.15	15.0
Railroad passengers (1988 only)[b]	0.02	2.0
Bus passengers (1988 only)[b]	0.01	1.0

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25 Petty, *Regulation vs. The Market: The Case of Bicycle Safety*, 2 RISK 77 and 2 RISK 93 (1991). *See also*, Janssen, *Road Safety in Urban Districts*, 32 TRAFFIC ENG. + CONTROL 292 (1991).

26 Janssen, *supra* note 24.

27 1978–87 average unless noted. Notes in the table indicate that data was derived from: (a) EVANS, *supra* note 16, (b) ACCIDENT FACTS, *supra* note 8; and (c) TRAFFIC ACCIDENT FACTS & STATISTICS, *supra* note 10.

Population Death Rate

PDR is a third widely reported value.[28] It reports the number of fatalities from a particular cause relative to the number of people then living. It is generally reported annually, for the population of a politically designated territory, or a subpopulation thereof. The units are in annual deaths per 100,000 population.

PDR is the one measure of risk which seems to be agreed upon by all observers. Its accuracy is limited to the accuracy of the census.[29] For purposes of intra- or inter-territorial comparisons over time, this accuracy limitation does not appear serious. The problem with PDR is that it does not appear to be easily communicable to the public. Specialists may be used to the numbers, but to the average person a risk of 25 per 100,000 may be incomprehensible.

More Recently Proposed Measures

Evans et al.[30] and Sivak et al.[31] calculate risk for travel for trips of particular lengths. Here their approach is generalized, and TFR is defined as the risk of dying for a particular trip, made by a particular class of traveller, in a vehicle of a particular class, by a specific mode of travel.

The lifetime risk of dying from a particular cause is here termed AFR; this measure is proposed as a quantification of what Wilde[32] calls aggregate mortality. AFR can be calculated by dividing the PDR from a specific cause by the total PDR,[33] but it is calculated here by

28 The major sources of data all report it. Then most review works pick up those widely reported values. *See, e.g.:* J.B. RAE, THE ROAD AND THE CAR IN AMERICAN LIFE (1971), J.B. RAE, THE AMERICAN AUTOMOBILE INDUSTRY (1984), H.J. ROBERTS, THE CAUSES, ECOLOGY AND PREVENTION OF TRAFFIC ACCIDENTS (1971). *See also*, L. EVANS, TRAFFIC SAFETY AND THE DRIVER (1991); G.C. BLOMQUIST, THE REGULATION OF MOTOR VEHICLE AND TRAFFIC SAFETY (1988).

29 *See* Doll & Peto, *An Estimation of the Preventable Causes of Cancer*, 6(2) J. NAT'L CANCER INST. (1981) for a discussion of census accuracy.

30 *Supra* note 16.

31 Sivak, Weintraub & Flannagan, *Nonstop Flying is Safer than Driving*, 11 RISK ANAL. 145 (1991)].

32 Wilde, *supra* note 6, at 378.

dividing the number of deaths from that cause by the total number of deaths for a ten-year period.

Trip Fatality Risk

Evans et al.,[34] Barnett[35] and Sivak et al. [36] calculate TFR. Their motivation is the preponderance of airline crashes which occur on takeoff or landing. This preponderance makes airline travel risk almost independent of distance flown. This skews the airline safety data, reported as MDR, leading to the possibility that if trips were compared, one could find a distance tradeoff point, under which it would be safer to drive than to fly. For sober, seat-belted, 40-year old female drivers in cars 700 pounds heavier than the mean, driving on rural interstates, Evans et al. find the tradeoff to be 600 miles. Under 600 miles, it is safer to drive; above 600 miles, to fly. The other authors calculate a tradeoff of 300 miles for the same traveller.

It is impossible to imagine an auto trip which is entirely by rural interstate. All road/car trips begin and end on city or suburban streets or rural roads. The distances travelled on these streets and roads are assumed to be comparable to the distances traversed in getting to the airport, but airports can often be reached by public transportation, and interstates cannot.

The TFR for a hypothetical 600 mile trip, of which 580 miles are rural interstate, and twenty miles are average roads, for various classes of driver is thus recalculated. Table 3 presents the results of this calculation, together with a similar calculation for other modes of transport and assumes that the trip to the airport is twenty miles total.

The second column shows clearly that the TFR method does not add much to the overall discussion engendered by the MDR method. But it does at least provide individuals with a way to compare their risks for an individual trip.

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33 Fritzsche, *Severe Accidents: Can They Occur Only in the Nuclear Production of Electricity?* 12 RISK ANAL.. 327 (1992).

34 *Supra* note 16.

35 Barnett, *It's Safer to Fly*, 11 RISK ANAL., 13 (1991) (letter).

36 *Supra* note 31.

Table 3

Relative Trip Fatality Risks
For a 600 Mile Trip by Various Modes

Mode of Travel	*Fatalities expected per billion travelers*	*Risk relative to safest mode*
Roadway/Automobile,		
High-risk driver	290,000	1700
Average-risk driver	3,900	23
Low-risk driver	470	2.8
Airplane, drive to airport		
High-risk driver	19,000	110
Average-risk driver	560	3.3
Low-risk driver	330	1.9
Airplane, transit to airport	310	1.8
Amtrak, the full trip	290	1.7
Interurban bus the full trip	170	1.0

This trip is roughly comparable to one from El Paso to San Antonio. An individual contemplating such a trip could find out the actual MDRs for that trip, as well as the individual airline, bus and Amtrak records over that route, and do a more exact calculation. The individual would also know what sort of auto they had available, what time they were contemplating the trip, how tired they were, and so forth.

Trade-off Distance for Roadway/Automotive vs. Surface Mass-Transit Travel

Earlier papers[37] calculated a trade-off distance under which an individual contemplating a trip would be better off driving than flying. If the same is done for comparing auto travel to the safest alternatives, taking the bus or rail, the answer is trivial. For all classes of driver, all classes of auto, all classes of road, seat belt or not, sober or not, the distance it is safer to drive is zero miles. That is to say, the bus is always safer. The same is true for rail travel.

The implications of this for decision making are obvious. The individual interested in reducing travel risk will use surface mass transport. The society interested in reducing overall travel fatality risk,

[37] EVANS, *supra* note 16; Sivak, *supra* note 31; and Barnett, *supra* note 35.

will encourage the building and use of bus and rail facilities, and discourage the building of new roadways or the increased use of autos. It has been shown that road casualties are dependent on public transport fares; lower fares lead to increased transport use and decreased casualty rates.[38] Evans reviews the evidence from various jurisdictions and concludes that anti-drunk driving measures are more easily implemented in areas with greater access to public transportation.[39]

Particularly given the apparent space/time,[40] pollution[41] and economic development[42] advantages of rail on dedicated right of ways, more use of rail facilities is indicated. Flink postulates that Americans like technological solutions to problems;[43] indeed, there is a trend in North America towards giving automotive right-of-ways over to rail transport, evidenced by the Buffalo (1984) and Baltimore (1992) street rail lines. This trend needs analysis for its risk implications.

Of course, a social decision to promote the use of one mode or another is not based solely on risk. Among other factors, speed is often cited as most important.[44] This paper does not consider other variables in depth, but reasonable evidence suggests that for speed there is some sort of homeostatic mechanism at work. Thus society builds around the transportation infrastructure so that the travel time tends to remain constant. In a culture where various surface transportation modes are equally available, Johnson found overall trip times to be invariant across them.[45]

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38 Allsop & Turner, *Road Casualties and Public Transport Fares in London*, 18 ACCID. ANAL. & PREV. at 14 (1986).

39 EVANS, *supra* note 28.

40 Harris, *Some Results of Mode Choice in an Urban Corridor*, 28 TRAFFIC ENG. + CONTROL 298 (1987). *See also*, Mogridge & Holden, *A Panacea for Road Congestion? — A Riposte*, 28 TRAFFIC ENG. + CONTROL 13 (1987) and previous papers by and about that group's work, cited therein.

41 Prindle, *Health Concerns and Urban Transport*, 3 HIGH SPEED GROUND TRANS. J. 73 (1969).

42 P. HALL & C. HASS-KLAU, CAN RAIL SAVE THE CITY?: THE IMPACTS OF RAIL RAPID TRANSIT AND PEDESTRIANISATION ON BRITISH AND GERMAN CITIES (1985).

43 J.J. FLINK, THE CAR CULTURE (1975).

44 G. HAIKALIS, ECONOMIC ANALYSIS OF ROADWAY IMPROVEMENTS (1962).

Aggregate Fatality Risk

Dividing the PDR due to a particular cause by the PDR for the population as a whole, gives the percentage of people dying of a particular cause, for the given year and jurisdiction. For example, Fritzsche[46] gives an overall PDR of 845 per 100,000 population for the U.S. for 1979, a PDR due to what is termed accidents (roughly half being auto crashes) of 51 per 100,000, and thus a ratio of 6%. It is clear that the population appears twice, in the denominator of the overall death rate and in the denominator of the cause-specific death rate; it can thus be eliminated. That is, dividing the number of cause-specific deaths by the total number of deaths gives the same result. The number is presumably more accurate than are PDRs, as deaths are more carefully tallied than are census totals.[47]

For mass-transport modes, because of their low risks, single year data are subject to wild fluctuations; Evans et al. suggest the use of ten-year (decade) data.[48] AFR is here suggested for the decade risk of dying from a particular cause. It is calculated by dividing the number of deaths from that cause by the total number of deaths, for a given territory and decade. AFR is an approximation of the lifetime risk of dying from that cause. For the U.S. for auto deaths, the PDR has not changed much since the auto reached what historians call "maturity" in 1925.[49] The approximation is thus a good one.

The AFR figures are shown in Table 4. Also shown is the AFR relative risk of each method to that of bus travel fatalities. Bus travel is compared to make the comparison to the MDR relative fatality risks in Table 1 obvious. The mass transit total includes bus, train and airplane. For the period, one in 40 Americans dies in a auto crash, and one in 11,000 dies due to any other mode of travel.

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[45] Johnson, *The Mechanisms of Speed Similarity in Urban Areas 2; The Similarity of Observed "Door-to-Door" Speeds*, 29 TRAFFIC ENG. + CONTROL 6 (1988).

[46] Fritzsche, *supra* note 33.

[47] Doll and Peto, *supra* note 29.

[48] *Supra* note 16.

[49] FLINK, *supra* note 43.

Table 4[50]

Total Deaths in U.S. and Transportation Deaths, 1978-87

Mode of death	*Number of deaths*	*Deaths per 100,000 deaths*	*Aggregate Fatality Risk*	*Risk Relative to bus*
Roadway/auto[a]	490,000	2,400	0.024	1,300
Scheduled airline[b]	1,332	6.6	0.000066	3.5
Buses[b]	374	1.9	0.000019	1.0
Railroad passenger train[b]	75	0.37	0.0000037	0.19
Bus and train total	449	2.3	0.000023	1.2
Mass transit total	1,781	8.8	0.000088	4.6
Total	20,200,000	100,000	1.0	

Aggregate Fatality Risk Compared to Population Death Rate and Mileage Death Rate

PDR is one of the more widely-reported values.[51] It reports the number of fatalities from a particular cause relative to the number of people then living. PDR tends to downplay the seriousness of a problem, particularly for attempting to communicate risk to non-specialists. That one in every 40 Americans dies from a particular cause (AFR) is noteworthy.[52] That one in every 2,500 people alive at the start of a year has died from that cause (PDR) is less noticeable, and PDR does not lend itself to direct comparison to MDR.

The MDR gives, of course, a per distance travelled approach to risk.[53] The AFR is an alternative to the approach of risk per distance travelled. Each postulates a different approach to travel. A true comparison of the risks of travel, for an entire society, would include both calculations. The main use of the two approaches is by an individual attempting to minimize the risk associated with travel.

50 Notes in the table indicate that data was derived from: (a) U.S. BUREAU OF THE CENSUS, STATISTICAL ABSTRACT OF THE UNITED STATES 1990 (110th ed. 1990), and (b) ACCIDENT FACTS, *supra* note 8.

51 *See supra* note 28.

52 R.S. KUHLMAN, KILLER ROADS: FROM CRASH TO VERDICT *xliv* (1986).

53 BAKER, *supra* note 2.

The distance travelled (MDR) approach implies the desire to travel is equivalent regardless of the technology available. Thus two people both need to go twenty miles: one decides to travel by auto, the other by bus. The one using roadway/auto travel has a 70 times greater chance of dying on the trip than the one using the bus. As Evans et al. point out, there are different risk categories of auto travel, depending on type of road, age of driver, and so forth.[54] Bus travel does not vary in safety over as wide a range — from unmeasurable, for individual operating systems such as the Erie Metropolitan Transit Authority,[55] to 0.03 fatalities per 100 million miles.[56] Rail travel follows a similar pattern. It was shown above that the risks to different auto travellers range from 2.7 to 9,300 times that of a national average bus passenger, by the MDR method.

AFR postulates that people with access to different technologies will pattern their behavior around the available technology. Thus a person with access to an auto will travel differently than a person without such access. One can imagine a person who only uses bus and a second person who only uses the auto system. The second person, the road-user/automobilist, will probably travel more than the bus passenger and will have a travel AFR over a ten-year period that is 1,300 times greater than that of the dedicated bus passenger. This is taking a road-user/automobilist of average risk, and can be compared with the factor of 70 found by the per mile travelled approach.

The lowest AFR of the set (bus, train, plane, auto) is due to train travel, and may be relevant for those in major metropolitan areas. If a person could be found who travels exclusively by rail, an average automobilist has a lifetime risk an astounding 6,800 times greater. Also, for completeness it should be noted that certain populations, e.g., Old

54 EVANS, *supra* note 16

55 Personal communication from P. Zielewski, Erie Metropolitan Transit Authority (1991). The EMTA did not have a single fatality of a bus driver or passenger, in the period 1981–90, in over 300 million passenger miles. Examination of the Erie County Coroner's reports for 1961–1980 shows that the same to be true for that time period. Hence the EMTA, and its private predecessors, have had no driver nor passenger fatalities in over one billion passenger miles.

56 U.S. BUREAU OF THE CENSUS, *supra* note 50.

Order Amish, the transportation AFR is due only to pedestrian and domestic-animal powered transport and may be lower yet. Analysis based on bus and auto use are chosen because they are widely available to North Americans, if not equally to everyone.

Of the methods for comparing fatality risks between different modes of transportation, the AFR method most effectively highlights the high fatality risk factor of roadway/automotive transport compared to surface mass transportation. Let us postulate that all the travel done by auto would still be travelled under an all mass transit transportation system. That is to say, it is possible to project the risk per mile onto an AFR that assumes the present total of miles travelled.

It is a simple matter to combine Tables 1, 2 and 4, and calculate how many people would die if all travel in the U.S. were by transit. The results are shown in Table 5.

Table 5

Projected deaths due to travel, with present road/car data

Mode	*Deaths per 100,000 total deaths*	*Deaths per year*
Roadway/Automotive	2,400	49,000
All mass transit, if all miles were travelled on transit, and none by auto	40	810
Surface mass transportation, if all miles were by bus and rail	32	650
Buses only, if all miles were by bus	23	460

The second entry in the first column in Table 5 was derived by multiplying the 2,400 per 100,000 figure of death by auto by the factor 0.035/2.1, which is the ratio of fatalities per 100 million miles travelled by mass transit to fatalities per 100 million miles travelled by road/car, assuming an average of intraurban bus, intraurban rail, and interurban rail, plane and bus fatalities. The figure for buses is 0.02/2.1, again using a simple average for intraurban and interurban bus travel. And the figure for mass transit averages the bus and rail figures; it is 0.028/2.1. The last column uses the same multiplicative factors with the total annual auto death figure, 49,000.

Of course, let us reiterate that if all transportation were bus, train and plane, the total distance travelled would probably be less. The true annual death rate due to an all-mass transit system would lie somewhere between the present annual death rate from mass-transit, shown in Table 4, which is 180 deaths per year, and the projected figure of Table 5, 810 annual fatalities. For an all bus-and-rail system, the brackets would be 45 and 650. This presumes present safety levels for these carriers. A bus-and-rail system is more likely to develop than an all bus system, because of the speed advantages of rail.

Thus, in a U.S. transportation system entirely without autos the number of people dying annually would be at most 650 to 810, at present total mileages — compared to 49,000 currently. Calculations for other OECD countries would show similar savings of lives.[57] This does not account for people who die from air pollution, industrial accidents or exposure to toxic materials involved in making transit products; for those who may die because of lifestyle changes brought on by various transportation methods; or for those who die eventually from transportation failures — after the short-term reporting period.

Finally, a demographic breakdown by age of transportation-related deaths might be useful. Table 6 shows this breakdown for auto-related fatalities. The risk to the young from mass transit is equal to the risk to the old, since they are not driving. Thus, we can easily see that minimizing transportation risks would especially benefit the young. In an analysis based on statistical deaths, i.e., years of life lost, road-and-car would fare even worse.

Blomquist[58] calculated very similar figures for 1984. The above data are for the U.S. as a whole. Smaller geographic units follow suit; Pennsylvania Vital Statistics for 1989 shows roadway/auto deaths to be 34.6% of all deaths in the age group 5 to 24 — the leading cause of death for that age cohort.[59]

[57] One could begin with the data in ECMT, STATISTICAL REPORT ON ROAD ACCIDENTS IN 1985 (1988), or ECMT, COSTS AND BENEFITS OF ROAD SAFETY MEASURES (1984).

[58] *Supra* note 28.

[59] *Supra* note 1.

Table 6[60]

Roadway/Automobile related deaths, by age group in the U.S., 1988

Age group	*Deaths from roads/cars*	*Total deaths at age*	*Cars as percent of total*
0-1	240[61]	38,400	0.62%
1-4	960	7,390[62]	13%
5-14	2,500	9,220	27%
15-24	14,600	39,600	37%
25-44	16,400	135,600	12%
≥45	14,300	1,940,000	0.74%
Total	49,000	2,170,000	2.3%

The AFR method could be applied to other social risks. This might enable policy-makers to concentrate scarce resources on the solution of the most severe problems. If, for example, the survival of children were to become an important cultural value in the U.S., resources could be concentrated on the present premier ranking of transportation among childhood killers.

Conclusions

The various means of calculating travel risks are of different uses to society. Now, only two such analyses find widespread use; it would probably benefit society if the other measures were more widely used.

Vital statisticians tend to use PDR.[63] This is adequate for workers in the field. It is known with reasonable accuracy, and adequately conveys the generally flat trend in auto fatality risk in the U.S. — particularly when compared to other OECD states. As Baker et al. have

60 U.S. BUREAU OF THE CENSUS, *supra* note 50. *See also,* ACCIDENT FACTS, *supra* note 8.

61 ACCIDENT FACTS, *supra* note 8, reports 1,250 automobile fatalities for age 0–4 in 1988. We have assumed that each year accounts for one fifth of the total.

62 The deaths in each age group were calculated by multiplying the death rate per 100,000 population, by age and sex (Table 108, STATISTICAL ABSTRACT OF THE UNITED STATES 1990, *supra* note 50) by the total population by age and sex (Table 12). The data in Table 108 is preliminary for 1988.

63 1990 PA VITAL STATISTICS, *supra* note 1.

shown, it is quite useful in risk comparisons between governmental districts.[64]

Transportation analysts tend to use MDR, particularly MDR(V). Unfortunately this MDR is based on a calculated value, the number of miles driven, and is thus a measure of limited accuracy. The use of MDR, even if valid, has the even more unfortunate consequence of obscuring the fundamental trend in roadway/automotive fatality risk. This obfuscation causes great difficulties and tends to work against solving the transportation problem. Thus, Waller is able to state,[65] "Canada experiences one of the lowest traffic fatality rates per mile driven of any country in the world. Clearly, the measures that are in place are effective." This belief is misguided. Canada's PDR has remained effectively constant since the 1920's. Also, Canada is one of the few countries to lose an equal percentage of its people to transportation death that the U.S. does.[66] Like Waller, most workers in transportation risk encounter MRD first and begin thinking in those terms. This eventually leads to what Veblen called "trained incapacity."[67] Gusfield elaborates by stating that "our training leads us to ignore alternative conceptions of reality and thus to resist innovation."[68] Consequently, when Wilde, a psychologist, analyzes 70 years of flat PDR figures and proposes a theory to account for them,[69] others attack his theory on the basis of MDR.[70]

Reliance on MDR spans the spectrum from fervent proponents of increased automobility to those who believe that autos are a dying technology. Evans, a transportation analyst for General Motors, relies

64 Baker, Waller & Langlois, *Motor Vehicle Deaths in Children: Geographic Variations*, 23 ACCID. ANAL. & PREV. 19 (1991).

65 P. Waller, *Preface*, in J. P. ROTHE, CHALLENGING THE OLD ORDER: TOWARDS NEW DIRECTIONS IN TRAFFIC SAFETY THEORY xii (1990).

66 EVANS, *supra* note 28.

67 T. Veblen, cited by J.R. Gusfield, *Concept, Context and Community: Sociological Perspectives on Traffic Safety*, in ROTHE, *supra* note 65, at 6.

68 Gusfield, *id.*

69 Wilde, *The Theory of Risk Homeostasis: Implications for Safety and Health*, 2 RISK ANAL. 209 (1982); *see also* Wilde, *supra* note 6.

70 *See, e.g.*, EVANS, *supra* note 28; he cites other opponents at 299.

almost entirely on MDR, to the extent that he states that[71] "the total number of fatalities is the product of the distance of travel and fatality rate (fatalities per unit distance of travel)." However, the PDR shows clearly that the number of deaths is *not* a function of mileage. At the other end of the spectrum, Ward, a town planner and non-driver with an anarchist perspective, compares MDR in Britain with MDR in the U.S. to find that, because the latter is so much lower, British drivers must be inferior.[72] Yet, the British PDR is less than half of that in the U.S. Between Evans and Ward is Blomquist, an economics professor. Blomquist analyzes the U.S. auto safety regulations of the late 1960's and early 70's on MDR but admits to confusion about the apparent lack of relationship between MDR and PDR.[73]

Perhaps neither Waller, Evans, Ward, nor Blomquist have considered Haight's observation quoted earlier.[74] Transportation fatality rate is first a health problem, then a transportation problem. The health profession uses PDR, and those in the transportation field would do well to gradually abandon MDR.

In the short run, since it is well-known, the MDR remains useful in intermodal risk analysis. Transportation planners contemplating a decision between investments in surface mass-transport and investments in further roadway construction can easily use the analysis shown here to calculate the savings in life and property, and subsequent lowered legal liability to themselves, inherent in mass transport investment. Such an analysis includes MDR, as well as other measures.

RDR appears to be of limited use. The surprising result that bicycles are lower risk than autos, per registration, might lead to further analysis.

Of the less established methods, TFR appears to offer little ground for further work. It is unfortunately based on MDR, limiting its accuracy. A possibility for intermodal comparison of automotive travel to airplane travel has been explored and shown to add little to the discussion if rail and bus travel are included.

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71 *Id.*, at 337.

72 C. WARD, FREEDOM TO GO: AFTER THE MOTOR AGE 33 (1991)

73 BLOMQUIST, *supra* note 28, at 75, n. 5.

74 *Supra* note 19.

AFR also offers little ground for further analysis specific to transportation. Yet, AFR analysis could be applied fruitfully to a comparison of other human endeavors. And vital statisticians interested in communicating their results to the public would do well to explore AFR for that purpose. Those without scientific training may find it more meaningful to hear that transportation causes the death of one in every forty persons in the U.S. than to hear that transportation causes the death of one in every 2,500 citizens who were alive at the start of a particular year. Thus, AFR is useful for risk communication and hence risk amelioration — particularly when used to calculate the risk of residing in a particular location; this use requires further study.

Finally, as discussed in a companion article,[75] RFR holds great promise, especially in local transportation planning. It can be used to identify routes that most need re-designing. It appears to lend itself for use in predicting the number of lives that can be saved by either roadway re-design for speed limit enforcement or conversion of road to rail right-of-ways.

Not enough attention has been paid in North American culture to the use of risk in intermodal analysis. By a judicious use of all available measures, risk should be more successfully ameliorated.

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75 HALPERIN & REDMAN, *supra* note 4.