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Kopl Halperin

Jim Redman

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Introduction

At least since the 1930's, some roadways have been known to pose higher user risks than others. Essentially, the straighter, wider and faster roadways are, the greater the number of fatalities.[1] Yet, very little research seems to have been done on the relative risks of different roadway types and the amelioration thereof. This lack of attention is perhaps an outgrowth of the three common methods of calculating transportation risk that emphasize vehicle miles, number of vehicles and population and deemphasize length and type of roadway.[2]

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* Professor Halperin teaches Mechanical Engineering at Penn State Erie — The Behrend College. He received his B.A. (Political Science) from Duke University, M.Sc. (Mechanical Engineering) and M.S (Solid State Science & Engineering) from Columbia University, and Ph.D. (Materials Science & Engineering) from Northwestern University.

Mr. Redman is President of North American Woonerf, in Los Alamos, NM. He received his B.Sc. from the Imperial College of Science and Technology, University of London and M.S. from Northwestern University.

1 *See, e.g.*, C.E. DULL, SAFETY FIRST — AND LAST (1938).

2 *See* Halperin, *A Comparative Analysis of Six Methods for Calculating Travel Fatality Risk,* 4 RISK 15 (1993).

Here, we attempt to correct this imbalance by defining the Route Fatality Risk (RFR) as the risk of death to users posed by a particular route. For calculation of comparative RFRs, two different formulae are arrived at, the road-length specific RFR and the Average Annual Daily (automotive) Traffic (AADT) specific RFR. These are termed RFR(L) and RFR(DT), respectively.

- $\text{RFR(L)} = \dfrac{\text{F(10)/RL, deaths per mile}}{\text{PA SR mean deaths per mile}}$
- $\text{RFR(DT)} = \dfrac{\text{F(10)/PT, deaths per 100 million passenger miles}}{\text{PA Passenger Mileage Death Rate}}$

In those equations, F(10) is road fatalities for a decade, RL is the road length in miles and PT is road travel in 100 million passenger-miles. An appendix presents technical notes on the calculation of PT. Pennsylvania (PA) means have been used because national figures average-in areas with very different road systems from those studied.

We use F(10) instead of the number of fatalities per year, for the same reason that ten year averages are used in calculating the Mileage Death Rate (MDR) for public transportation. At one end, a single, multiple-fatality crash can skew the data in a particular year. At the other end, a five mile, 4,000 vehicle-a-day route should have one death every five years, based on the national average MDR. This national average roadway could be fatality free for one or even a few years, but would be less likely to remain so for an entire decade.

Study Parameters

MDR is an estimation available for large governmental units; counties are the smallest unit for which they are reported.[3] To calculate the two RFRs requires the gathering of three pieces of data for every route to be studied: (1) number of fatalities on that route, (2) length of the route, and (3) average daily traffic for the route. It thus requires a bounded area which is amenable to study.

The area we have chosen is Erie County, PA. It is a well-known test market area for new products before they are nationally released, for it has demographics similar to those for the entire industrialized northeast.

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

Roughly 40% of its 275,000 population lives in the city of Erie, and roughly 40% lives in suburbs. There are a few small towns, and the rest is farmland and wooded. The city of Erie is halfway between Buffalo and Cleveland and only slightly further from Pittsburgh. The County is served by commuter airlines, Amtrak[4] and local and national bus lines.[5] There are two interstates (I-90 East-West and I-79 North-South) and three U.S. Routes (6 and 20 East-West, and 19 North-South).

The decade 1981–90 was chosen for study. This was dictated by the ease of access of the occurrence fatality information for this time period.[6] The residence data showed 448 roadway fatalities of Erie County residents in the decade, these were studied for place of occurrence. That number of roadway fatalities works out to an Aggregate Fatality Risk (AFR) of one in 58.42.[7] This is a significantly lower risk than the U.S. AFR of one in 40.[8] This accords with the observations of Baker, Whitfield and O'Neill that urbanized, Northeastern areas have lower roadway/automobile fatality risks than do rural, Western ones.[9] A further confirmation of their findings is that for the five year period 1985–89, the latest period of data available on total deaths, one in 106.97 deaths of city of Erie residents was caused by a roadway collision. This can be compared to the rates for non-city Erie County residents: one in 39.61 deaths resulted from a roadway collision. Apparently, living outside of the city is 2.7 times riskier than living inside it, for the risk of road/car death. This sort of use for the AFR might bear further study.

4 It stops once a day going from New York to Chicago and once returning.

5 It is served by Greyhound, Lake Shore Trailways and Fullington Trailways interurban bus lines. Also, a local bus transit system serves the City of Erie and the town of Edinboro daily and some of the rest of the county once a week.

6 1981-90 ERIE COUNTY CORONER'S REPORTS (1982-91).

7 PA DEP'T HEALTH, PA VITAL STATISTICS ANN. REP. 1990 (1992). Aggregate Fatality Risk is the lifetime risk of dying from a particular cause.

8 *See* Halperin, *supra* note 2, at 26.

9 Baker, Whitfield & O'Neill, *Geographic Variations in Mortality from Motor Vehicle Crashes,* 316 NEW ENG. J. MED. 1384-87 (1987).

Traffic Routes and Lengths

Statewide, 80% of the roadway fatalities occur on state-maintained roads (SRs).[10] These SRs include roads widely referred to by number by the public, e.g. I-90 (SR 90) or Route 99 (SR 99), which is also called Edinboro Road. The SRs also include some which are known to the public only by other names, such as SR 4019, Liberty Street in the city, or SR 3017, Pont Road in Erie County. To make it more confusing, one road can carry three names: SR 4018 at the time of this study was also known as "Alternate 5" (or "5A"), or, for some parts of its length, "6th St." The SR numbers are posted on small, unobtrusive, white signs generally on lampposts, which look like mileage markers, and are unnoticed by the public. The more major routes are also posted by large signs in the familiar shapes of the Interstate, U.S. Route and State Road shapes. The state terms these traffic routes.[11]

Major traffic routes were studied.[12] These include all of the SRs with numbers of two or three digits except six short segments under five miles each, plus 6N (SR 3006) and 5A (SR 4018). Table I lists the twenty roads studied; they accounted for 300 (66%) of the roadway/automobile fatalities in Erie County between 1981 and 1990. Road lengths were determined from the Straight Line Diagram[13] and were available for all of the SRs. The passenger travel (PT) for each road was calculated from the ADTs in the Roadway Management Information System (RMS) State Roadway Summary;[14] this calculation is shown in an appendix.

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10 PENNDOT, TRAFFIC ACCIDENT FACTS & STATISTICS 1990 (1991).

11 PENNDOT ROADWAY MANAGEMENT INFORMATION SYSTEM, STATE ROADWAY SUMMARY, COUNTY NO. 25, ERIE (1989).

12 Traffic routes under 5 Mi. in length, not included:

Route	*'81-90 Deaths*	*Length, mi*	*Location & Direction*
226	0	4.861	County EW
299	0	1.324	Suburb NS
474	0	3.206	County EW
505	4	2.892	City-Suburb NS
531	0	4.288	Suburb NS
955	6	3.848	Suburb EW

13 PENNDOT, STRAIGHT LINE DIAGRAM, ERIE COUNTY (1991).

14 STATE ROADWAY SUMMARY, *supra* note 11.

Table 1
Erie County, PA Traffic Routes[15]

Route	*Deaths 1981-90*	*Length, mi*	*Deaths/ Road-mi*	*Location & Direction*
5	61	44.842	1.36	City-County EW
5A[a]	14	9.575	1.46	City-Suburb EW
6[b]	9	24.853	0.36	County EW
6N[c]	18	26.635	0.71	County EW
8	11	29.409	0.37	City-County NS
17	0	6.669	0.00	County EW
18	6	14.673	0.41	County NS
19[d]	18	18.160	0.99	City-County NS
20[e]	54	45.389	1.19	City-County EW
77	1	5.246	0.19	County NS
79[f]	7	19.576	0.36	City-County NS
89	9	27.345	0.33	County NS
90[g]	28	46.347	0.60	County EW
97	16	19.715	0.81	City-County NS
98	5	14.385	0.35	County NS
99	11	16.193	0.68	Suburb-County NS
215	1	7.874	0.13	County NS
426	4	15.065	0.27	County NS
430	9	13.722	0.66	Suburb-County NS
832	2	1.089	0.18	Suburb-County NS

Average Daily Traffic

The RMS Summary lists an "ADT Current Estimate." PennDOT[16] does not report the actual measurements. The ADTs reported are rather Current Estimates, calculated from actual measurements by an algorithm to project what is believed to be present traffic volume. They are thus not of any useful absolute accuracy.

For the purposes of the RFR(DT), however, the relative accuracy from one route to another is unaffected by this algorithm. But it leads the scientist to believe that the RFR(L) may be a more important reflection of the truth, as the lengths of the roadways are not being increased by digital computation. ADTs, measured or estimated, are not

[15] Alternative names for roads in the table are: (a) SR 4018, (b) U.S. 6, (c) SR 3006, (d) U.S. 19, (e) U.S. 20, (f) I-79, and (g) I-90. The data for Route 17 is from 1986, when the road opened, to 1990.

[16] PENNDOT, TRAFFIC COUNTING PROGRAM CONTROL COUNT ANN. REP. (1990).

available for non-SR roadways in Erie County. Table 2 lists the mean ADTs values for the Erie County major traffic routes.

Table 2

Erie County, PA Traffic Route
Mean Estimated Current Average Daily Traffic[17]

Route	*Deaths 1981-90*	*ADT(Mean) # vehicles*	*Std Dev. on ADT*	*Deaths/ 100 million passenger-mi*
5	61	8574	6246	3.10
5A	14	9571	4492	2.99
6	9	4521	2247	1.57
6N	18	2744	1181	5.09
8	11	4395	2378	1.67
17	0	4463	407	0
18	6	2963	1040	2.70
19	18	5139	2037	3.77
20	54	5719	2963	4.07
77	1	2771	756	1.35
79	7	7026	1510	1.00
89	9	2736	998	2.35
90	28	9060	2480	1.30
97	16	6909	3076	2.30
98	5	3022	1895	2.25
99	11	4482	3329	2.97
215	1	966	0	2.57
426	4	2833	2413	1.83
430	9	5683	1843	2.26
832	2	6154	4822	0.57

Risk Results

Figure 1 shows roadway deaths per road mile and the RFR values based on length, RFR(L), for the major traffic routes of Erie County for the decade 1981-90. They are arranged in descending order.

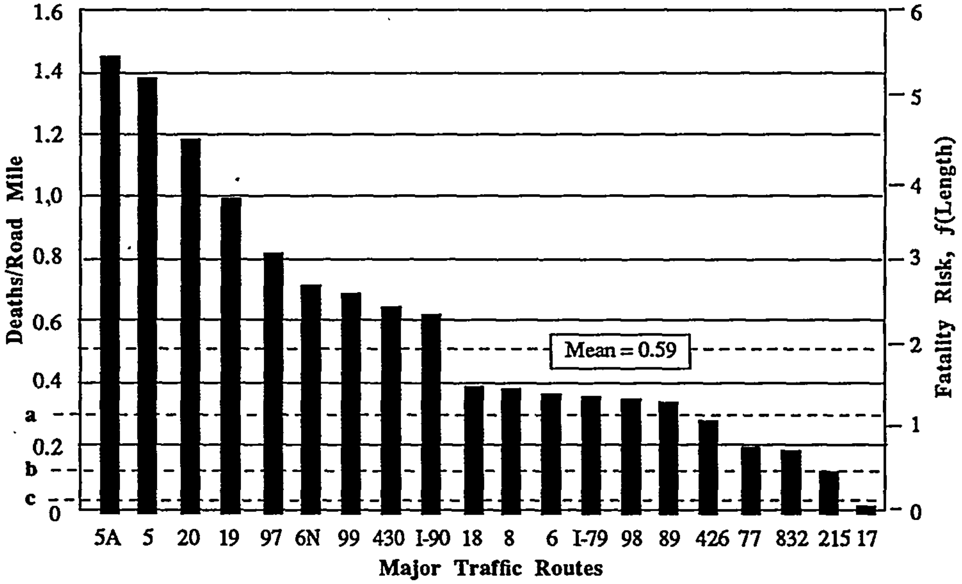
Figure 2 shows roadway deaths per 100 million passenger miles and the RFR values based on traffic volume, RFR(DT), for the same routes. The data are arranged in descending order based on this measure.

Each graph shows the mean for that measure for the roads studied. For comparison to the transportation system as a whole, mean appropriate measures from larger geographical units are included. The

[17] As mentioned above, the data for Route 17 is from 1986, when the road opened, to 1990.

mean measures on Figure 1 are for 1990. The most obvious feature of the two graphs is the range of values. Not including SR 17, which opened in two sections, partly in 1986 and partly in 1988 and by 1990 had had no fatalities, the RFR(L) varies from 0.4 to 4.9 and the RFR(DT) from 0.3 to 3.

Figure 1
Deaths/Mile & RFR(L)
Erie County, PA Traffic Routes > 5 Mi, 1981–90

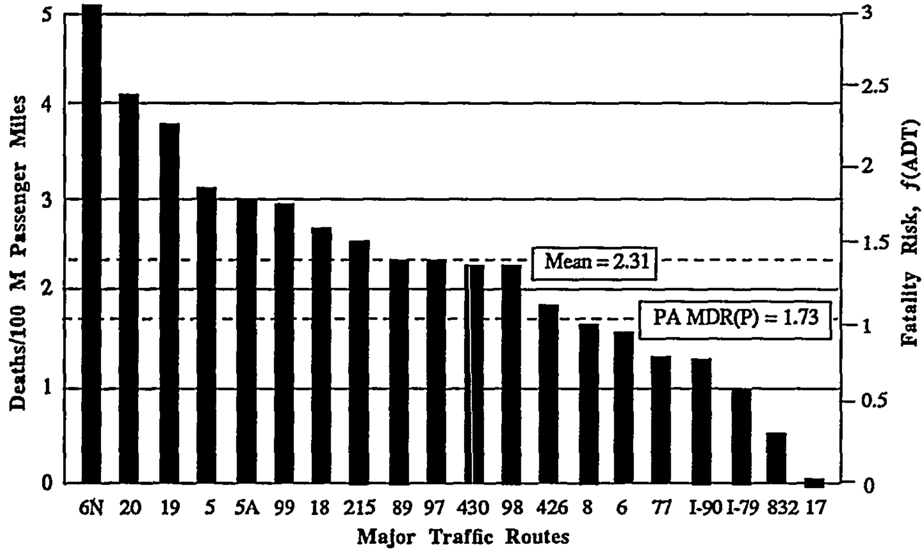


a PA SR Mean = 0.32
b PA Overall Mean = 0.14
c PA Non-SR Mean = 0.044

By either method, there is an order of magnitude difference between the lowest risk major traffic route in Erie County and the highest risk one. Even though the mean risk for these roads is high, there are roads included in the study which have the same risk as the average risk road in PA. And at the other end, there are roads which are three times more fatal than average.

Figure 2

Deaths/100 M Passenger Miles & RFR(DT)[18]
Erie County, PA Traffic Routes, 1981–90



On each graph, the risks fall into three categories. The low-risk roadways are those which have fewer deaths per roadway mile or passenger mile than does the average of PA roadways. For RFR(DT) this was taken to be the MDR(P)[19] for the state, 1.73 deaths per 100 million passenger miles average for the decade, with the caveat that this number is only an estimation. For RFR(L) this was taken to be the PA SR Mean, 0.32 roadway deaths per road mile per decade.

Middle-risk roadways are those with a risk between that of the average road in PA and that of the average of the twenty roads in this study. And the high-risk roads are those with fatality risks above the mean for the roads included in this study.

Table 3 lists the roadways by each method grouped into the three categories by each method.

The RFR method can be applied to the one passenger rail line in Erie County. Amtrak carries 600 passengers daily over the 45 miles of track

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18 MDR(P) is the MDR per passenger mile.

19 *Id.*

on the Lake Shore Limited route. There were no Amtrak fatalities in the approximately 100 million passenger miles travelled by train in Erie County in the ten year period. There were also no fatalities on the various bus lines serving the County.

Table 3
Comparative Roadway Fatality Risks[20]
by Two Methods of Calculation

Roadway	*Risk Rank by RFR(L) Method*	*Class*	*Risk Rank by RFR(DT) Method*	*Class*
5A	1	High	5	High
5	2	High	4	High
20	3	High	2	High
19	4	High	3	High
97	5	High	10	Mid
6N	6	High	1	High
99	7	High	6	High
430	8	High	11	Mid
90	9	High	17	Low
18	10	Mid	7	High
8	11	Mid	14	Low
6	12	Mid	15	Low
79	13	Mid	18	Low
98	14	Mid	12	Mid
89	15	Low	9	High
426	16	Low	13	Mid
77	17	Low	16	Low
832	18	Low	19	Low
215	19	Low	8	High
17	20	Low	20	Low

Correlation of Risks and Measured Variables

By the length method, RFR(L), nine of the roadways were high-risk, five were mid-risk, and six were low-risk. By the ADT method, nine were high-risk, four were mid-risk and seven were low-risk. The correlation between the two methods was good. The six highest risk roadways by the RFR(DT) method were all among the seven riskiest by the RFR(L) method. Of the ten lowest risk roads by the RFR(L)

20 For risk rankings, 1 is the highest, and 20 the lowest.
For risk classes, "high" indicates risk above the mean for these routes; "mid" indicates risk below the mean for the routes, but above the PA state mean; and "low" indicates risk below the PA state mean.

method, eight are among the ten lowest by the RFR(DT) method. There is no correlation between the rank order of the risk factors and either of the independent variables: road length or mean estimated ADT. Thus, RFR is not an artifice of either traffic volume or road length and is thus independent of importance of the road, however defined. Brodsky and Hakkert found highway accident rates to be independent of the travel densities on rural highways;[21] the same appears to be true for death rates for roads urban and rural.

Comparison of RFR(L) to RFR(DT)

RFR(L) and RFR(DT) are reasonably similar measures of the same variable, the relative risk of using a particular route. RFR(L) is the more accurate, as it depends only on number of deaths and length of road surface, both of which are readily available. The ADT on which RFR(DT) depends is only measured sporadically, strictly applicable only to the site at which it is measured, annually inflated by a computer algorithm, and difficult to apply to the entire route. These complications would become even more important if one was attempting an analysis of the transportation network of a larger area. Since RFR(L) adequately measures the same variable, it is much more cost effective.

Usefulness of the Route Fatality Risk Approach for Lowering the Risk of Roadway/Automotive Travel

The usefulness of the RFR approach is in risk amelioration. Once the analysis has been done, it is a simple matter to identify the high risk routes. These then must be redesigned for greater safety. The basic technique to do so is known, and consists principally of enforcing the speed limit by methods of geometric design.[22] Dramatic improvements

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21 Brodsky & Hakkert, *Highway Accident Rates and Rural Travel Densities*, 15 ACCID. ANAL. & PREV. 73 (1983).

22 The most recent and thorough source for engineering techniques to lower crash rates is C. HASS-KLAU, I. NOLD, G. BOCKER & G. CRAMPTON, CIVILISED STREETS: A GUIDE TO TRAFFIC CALMING, ENVIRONMENTAL AND TRANSPORT PLANNING (1992), which not only discusses techniques but also presents data that quantifies the success of the approach. For a less quantified analysis one could consult D. APPLEYARD, LIVABLE STREETS (1981), or W. HOMBURGER ET AL., RESIDENTIAL STREET DESIGN

in population death rates and therefore AFRs have been achieved in Europe through the application of such techniques.[23]

The National Safety Council has stated that every collision is a result of a confluence of driver, vehicle and roadway.[24] Of the three, much attention has been paid in the U.S. to the driver and to the vehicle.[25] Safety efforts involving the roadway have been sorely neglected. The application of the RFR method could aid in solving the roadway leg of the fatal triangle.

5A and 6N are the two highest risk roadways, one by each of the methods. There is no reason to believe the drivers or vehicles are different on SR 6N than on SR 6, two rural roads which connect with each other, yet the fatality risk of one of them is two times (RFR(L)) or three times (RFR(DT)) the other one. Similarly the fatality risk on 5A, a city street for most of its length, is many times that of its neighboring streets, and of roadways in general. Thus, either method is a feasible starting place for trying to reduce transportation fatalities.

From 1981-90, SR 6 had nine fatalities and 6N had eighteen. If 6N were lowered to the same RFR(L) as SR 6, there would have been nine fatalities on 6N, a saving of nine lives. If 6N could be lowered to the same RFR(DT) as SR 6, twelve lives could be saved per decade.

A similar analysis can be done for 5A. SR 8 can be chosen for a comparison, as it is the lowest RFR state route among those in the city of Erie. In the decade, 5A had fourteen fatalities and SR 8 (a much longer road) had eleven. If the RFR(DT) of 5A were lowered to that of SR 8, seven lives could be saved in ten years. If the RFR(L) of 5A were lowered to that of SR 8, eleven lives could be saved.

It should be noted that, by either RFR method, both SR 6 and SR 8 are considerably riskier than the average roadway in PA. So, room for further improvement is possible. Yet, even if only six of the highest risk roads, e.g., SRs 5, 5A, 6N, 19, 20, and 99, were improved, and only

AND TRAFFIC CONTROL (1989).

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

24 NATIONAL SAFETY COUNCIL, ACCIDENT FACTS (1989).

25 G.C. BLOMQUIST, THE REGULATION OF MOTOR VEHICLE AND TRAFFIC SAFETY (1988) (reviews much of the important work done to that time).

to the levels of SR 6 and SR 8, the number of fatalities in Erie County in a ten year period could be lowered by at least one seventh, from 448 to 400. Extrapolated nationally, this suggests that 6,000 lives could be saved annually.

Conclusions

RFR(L) and RFR(DT) appear to be equivalent. While a particular problem may be highlighted by one method over the other, it will still be made evident by the second method. Thus, as RFR(L) is both more accurate and less time-consuming and thus less costly, it would be preferred. However, as long as MDR continues to be widely used in the transportation field, RFR(DT) analysis may be necessary for inter-disciplinary communication.

That aside, RFR values can be used to map the safest route to a destination. Thus, RFRs might be posted on street signs. The society interested in improving the longevity of its population would obviously want to begin by improving the safety records of the deadliest corridors. That the RFR for the one rail passageway in the study area is zero[26] is significant. Governmental units attempting to meet increasing transportation needs could build rail right-of-ways or convert existing automotive right-of-ways to rail, thereby enormously decreasing fatality risk and legal liability. Baltimore's Howard Street conversion and the downtown Buffalo light rail line are examples of such conversions.

Those involved in lowering the legal liability of state departments of transportation would have an obvious interest in demonstration projects in lowering accident rates along the higher-risk routes. In PA, in particular, 80% of the fatalities occur on the state routes. In places where the roadway officials were not ameliorating known risks, an RFR analysis could conceivably affect tort liability of various parties. In any event, roadway officials should actively consider rail projects as a means of reducing transportation risk.

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26 *See* discussion *supra*, at 8.

APPENDIX
Calculation of PT,
Passenger Travel in 100 M passenger miles

The passenger road miles per decade for a particular road is calculated by the formula:[27]

• PT = ADT(Mean) * Road Length * 365 * 10 * 1.4

ADT(Mean) is the mean of all independent observations of ADT (cars/day) recorded in the RMS summary for that road since 1981.[28] An independent observation is any ADT reported for that roadway the first time it appears. Differences of one digit were considered to mean separate observations.

The ADT figures had been adjusted automatically according to an algorithm called the yearly growth factors. This algorithm averages the changes recorded at 61 sites throughout PA, the continuous traffic recorder stations.[29] If 60 of these were to remain flat for one year, and the other one to register an increase, the traffic on all state routes in PA would be calculated as increasing. Three of the continuous traffic recorder stations are in Erie County: one recorded no change in 1986–90, one recorded a slight overall decrease and one recorded an increase, slight in four years and peaked in a year in which a major bridge nearby it was closed for repair. As all ADTs for all roads had been adjusted to estimated current values, the values were assumed useful for the purposes of comparing the relative risks of various roadways.

Road length was taken from the straight line diagram.[30] Different segments of the same road, particularly a long one that goes through rural, suburban and urban areas, will obviously have different traffic volumes. No satisfactory method for handling this difference was found, and thus the first order linear approximation, in which the mean

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27 Factors on the right side of the equation are: Cars/day, miles, days/year, years/decade and passengers/car.

28 STATE ROADWAY SUMMARY, *supra* note 11.

29 1990 PENNDOT ANN. REP., *supra* note 16.

30 STRAIGHT LINE DIAGRAM, *supra* note 13.

ADT was assumed applicable to the entire route, was used.

The RMS survey does not state on which days of the week the measurements were taken. In general, Sundays have lower traffic volumes than do weekdays. ADT was multiplied by 365 to give total cars for the year, but this is probably a high approximation. For comparison of the relative risks of various roadways, this should present no problem. The multiplicative factor of ten for the decade should add no inaccuracies.

The factor of 1.4 for average number of passengers per vehicle is a national figure. No local data were available. Again, it should not add to the problems inherent in the analysis.

Finally, dividing the number of fatalities on a road by the PT calculated above would give the fatalities per passenger mile. Multiplying this by a factor of 100 million places the data on a per 100 million passenger miles basis, for the particular roadway. This enables comparison to mileage death rates based on passenger miles. For comparison to the familiar vehicle mileage death rates, simply multiply by 1.4.