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OVERALL FATALITY RISK TO THE PUBLIC AT LARGE RELATED TO NATIONAL WEIGHT MIX OF PASSENGER CARS

FINAL REPORT

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1 SUMMARY AND INTRODUCTION

This report addresses the question of the effect on the fatality risk to the public at large due to shifts in the weight distributions of passenger cars. For example, if the weight of the average passenger car were decreased would fatalities increase? If so, by how much? Past studies have stressed the effects on occupants. But even if heavier cars are safer for their occupants the effect on occupants of other vehicles and pedestrians may be affected differently.

In this study, fatalities are normalized by registrations in 6 passenger car weight classes. On remultiplying by hypothetical numbers of registered vehicles, fatality projections pertaining to hypothetical fleet mixes can be calculated and compared. When fatalities from various base years are used, a range of estimates can be formed in an attempt to examine the basic question.

When this program is carried out using FARS fatal accident data for the years from 1978 to 1987, the estimates indicate that the heavier hypothetical fleet (based on a 1978 mix) is probably safer for the public as a whole than the lighter hypothetical fleet (based on 1987). A quantitative estimate is hard to justify, but our results very roughly suggest a 3% advantage in safety for the heavier fleet.

When the results are broken down by accident type, they are variable: fatalities in single vehicle accidents would probably be considerably less in the heavier fleet, while pedestrian deaths may actually be less for the lighter fleet.

Because of the difficulty of the question and the inability to control confounding factors, all estimates here must be considered tentative and no great accuracy should be ascribed to them.

2 BACKGROUND

This study examines the relationship between the predicted total fatality rate and the mix of heavier and lighter vehicles in the fleet. Related topics have been addressed in previous research. However, none have addressed this particular question. Some related research examined predicted accident severity and the accident involvement rate of vehicles of different weights.

Studies of the relationship between car mass and fatality rates have been conducted at the accident level, focusing upon the individual occupants of vehicles. Although the level of analysis of this study is the fleet, and not the individual accident, many conclusions from previous work are relevant.

One result found in a previous study is that occupant fatality risk is lower in heavier cars than in of lighter cars. The occupant fatality risk in a lighter vehicle has several components. One component of this risk that has been addressed in the literature is each individual occupant's injury and fatality likelihood (driver, front seat passenger and rear seat passenger). Evans found in studies using the Fatal Accident Reporting System (FARS) data that occupants of lower weight vehicles, both passengers and drivers, are more likely to be killed in a crash than occupants of heavier vehicles.[1] Much of Evans' work concentrated upon driver fatality risk. However, he did examine other occupant fatality risks as well. In analysis of single and two-car accidents, he found that fatality likelihood decreases with weight. Among single car accidents, Evans found that drivers of a 900 kg car were 2.4 times more likely to die in an accident than were drivers of an 1800 kg car. In two-car and multiple car/vehicle accidents, he found that the driver of the lighter car was 13 times more likely to die. This relationship between car weight and fatality likelihood has been established for cases where the drivers were wearing seatbelts as well as when they were not.[2] Evans' results indicate a larger difference than we believe exists. His method used

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[1] Evans, Leonard, "Car size and safety: results from analyzing U.S. data" General Motors Research Laboratories GMR-5059, 1985

[2] Evans, Leonard, "Fatality Risk for Belted Drivers Versus Car Mass" General Motors Research Laboratories, GMR-4781, 1984

pedestrians as controls, but they may not be adequate for this purpose.

A second component that has been addressed in the literature is the predicted accident severity, as measured by the expected fatality rate, in two car crashes controlling for vehicle weight. Evans and Wasielewski have shown that in head-on collisions between two lower weight vehicles the driver is about two times as likely to be killed as in a head-on collision of two heavier vehicles[3]. This result is important to this study in that it relates to one component of the overall fleet risk as the fleet mix changes.

However, fleet risk is dependent both upon predicted accident severity and the predicted accident rate. It is assumed in this study that the absolute increase in fatalities is both a function of the number of lighter cars in the fleet and the number of accidents in which they are involved. Measures of the accident involvement rate are necessary to predict overall fleet risk.

If the rate of accident involvement and accident severity both decrease as car weight increases, the effect of fleet mix adjustment toward lighter cars would be to increase fatality rates. If the accident involvement rate increases as car weight increases the overall effect of fleet mix adjustments toward lighter cars on the fatality rate is less intuitively obvious.

In general, estimations of the accident involvement rate of cars by vehicle weight have yielded varying results. Initially, some studies indicated that small cars had a higher accident involvement rate than large cars.[4] [5] In an observational study performed in Massachusetts, Joksch found that the accident involvement rate increased with car size,

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[3] Evans, Leonard, and Wasielewski, Paul "Serious or Fatal Driver Injury Rate versus Car Mass in Head-On Crashes between cars of Similar Mass" General Motors Research Laboratories GMR-4480, 1983

[4] Reinfurt, D.W., Li L.K.,et. al. "A Comparison of the Crash Experience of Utility Vehicles, Pickup Trucks and Passenger Cars" University of North Carolina, Highway Safety Research Center, September 1981.

[5] Malliaris, A.C., Nicholson, R.M. et. al., "Problems in Crash Avoidance and in Crash Avoidance Research", SAE paper 803560, February-March 1983

when vehicle age and driver age were controlled for.[6]

Similarly, Evans[7] found that when controlling for driver age, accident involvement rates in North Carolina increased with car weight. But even if cars of a given size are overinvolved in accidents it is not known what portion of this overinvolvement is due to the allocation of drivers to vehicles, and so the implication for safety as a function of fleet mix are unclear.

The purpose of this study is to empirically test a general belief that seems to have arisen based upon this previous research. That question is: what is the effect of the adjustment of the fleet mix toward lighter cars on the severity of accidents and the resulting overall fatality rate, i.e., the fatality risk to the public in general including occupants of all vehicles and pedestrians.

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[6] Joksch, Hans C. "Small Car Accident Involvement Study" U.S. Department Of Transportation National Highway Traffic Safety Administration Final Report, October 1985

[7] Evans, Leonard, "Accident Involvement Rate and Car Size" Accident Analysis and Prevention 16, 1984, 387-405

3 APPROACH

3.1 General

The question to be addressed in this report is the comparison in terms of expected fatalities of two distinct mixes of passenger car weights. In short, what would be the effect on safety if drivers in general shifted to larger cars, all other things being held constant (including total number of cars)? Specifically we describe passenger car fleets in terms of the six weight classes in Table 3.1 (see also figure 3.1, but remember that the hypothetical distributions are defined in terms of percent distribution only and do not refer to total numbers of registrations). The two hypothetical vehicle mixes chosen to compare are based on the actual registrations in 1978 and 1987. It can be seen in Table 3.1 that these years did involve a considerable shift from heavier cars to lighter cars. The distribution based on the 1978 registrations will be called hypothetical distribution 1 and that based on the 1987 registration data will be called hypothetical distribution 2. The question to be asked is which fleet would experience more fatalities and by what percent -- all other things being equal.

Table 3.1 Car Size Definitions and Two Hypothetical Fleet Mixes

Class	Car Size	Curb Weight	1978	1987
1	Minicompact	950 - 1,949	4.4 %	4.1 %
2	Subcompact	1,950 - 2,449	9.7 %	26.7 %
3	Compact	2,450 - 2,949	11.2 %	24.9 %
4	Intermediate	2,950 - 3,449	16.3 %	23.8 %
5	Full Size	3,450 - 3,949	18.4 %	14.1 %
6	Largest	3,950 - 9,049	40.0 %	6.2 %

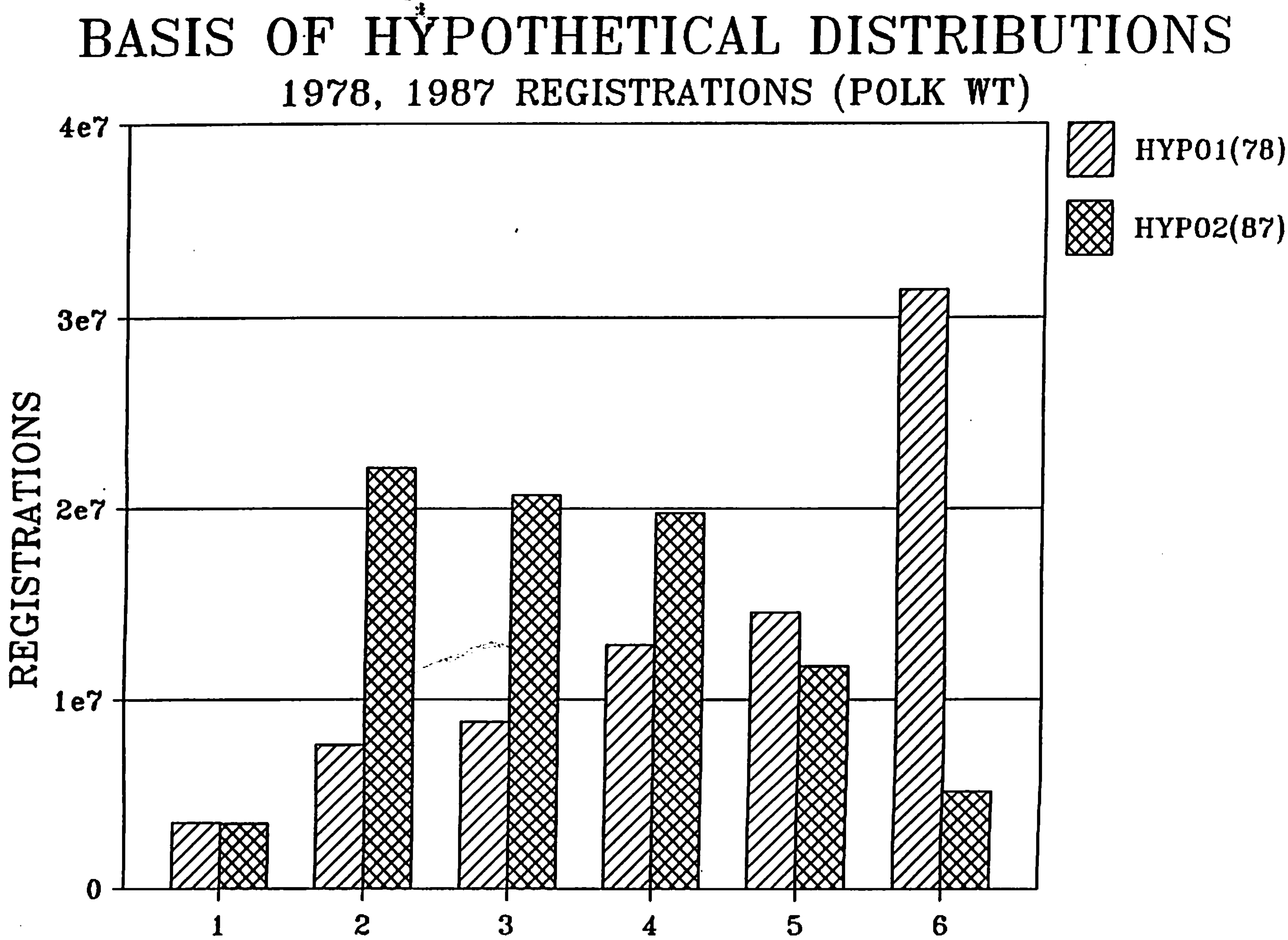
(source R.J. Polk National Vehicle Population Profile for 1978 and 1987)

3.2 Specific Method

The fatalities involving passenger cars in a specific year (as "base" year) are broken down into 4 categories. The fatalities in these categories are broken down into the passenger car weight categories with which they are associated:

1. Fatalities in single car crashes of passenger cars: A_i is the number of fatalities in cars in weight class i in single car crashes. Here i ranges from 1 to 6

Fig 3.1


BASIS OF HYPOTHETICAL DISTRIBUTIONS
1978, 1987 REGISTRATIONS (POLK WT)
REGISTRATIONS
4e7
3e7
2e7
1e7
0
1
2
3
4
5
6
HYP01(78)
HYP02(87)

corresponding to the weight classes defined in Table 1.

2. Fatalities in two car crashes involving a passenger car and a vehicle not a passenger car: B_i is the number of fatalities in collisions involving a car in weight class i and other vehicles.

3. Pedestrian fatalities caused by cars in weight class i: C_i is the number of the pedestrian fatalities involving cars in weight class i.

4. Fatalities in crashes where one car was in size category i and the other in size category j: D_{ij} is the total number of such fatalities.

(All fatality counts pertain to a single "base" year and were obtained from FARS.)

Having defined the fatality categories, the fatalities per registered vehicle within each weight class (using the same year's registration as the accidents are from) can be calculated:

3.1) $$U_i = A_i/R_i,\ V_i = B_i/Ri,\ W_i = Ci/R_i,\ X_{ij} = D_{ij}/(R_iR_j).$$

Here R_i is the number of registered passenger cars in car size category i (as recorded in the Polk data for the specified base year). (See Section 4 for the method of determining these quantities.) Now we can compare the expected fatalities in the hypothetical distributions if the fatalities per registered vehicle in each class did not change. This requires the assumptions:

1. The vehicles constituting each weight class do not change (only the total number in each class changes).

2. The quantity of driving for each vehicle is the same as for the vehicles in the base year.

3. The same assumption about the kind of driving - i.e. the driver, the roads, etc.

If these assumptions held then we could predict the relative safety of vehicle mix 1 and 2 as follows. Let h_{1i} be the fraction of cars in class i in hypothetical mix 1, (note that $\sum h_i = 1$). Then if this mix were reflected in a fleet of the same total size as the base year fleet we would have H_{1i} vehicles in class i where $H_{1i} = h_{1i} (\sum R_j)$. Then the expected number of fatalities for fleet mix 1 would be estimated by

3.2) $$T_1 = \sum H_{1i}U_i + \sum H_{1i}V_i + \sum H_{1i}W_i + \sum H_{1i}H_{1j}X_{ij}$$

Then the relative safety of fleet mix 1 to fleet mix 2 would be estimated as $Q_{12} = T_1/T_2$. This measure can be calculated for each base year for which data is available. It answers the question "what is the ratio of passenger car fatalities associated with fleet mix 1 compared to fleet mix 2 ?" if:

1. Both fleet mixes had just as many total vehicles as there were in the base year;

2. All the cars in each weight class were just like the cars in that weight class in the base year (i.e. were distributed the same in all qualities).

3. All the cars in each weight class were driven the same amount and the same way as the cars in that weight class in the base year.

The quantities needed to calculate Q_{12} are:

1. The two hypothetical distributions (these are given in Table 1 and are based on Polk registrations in 1978 and 1987)

2. The actual fatalities in the base year y (from FARS)

3. The actual registrations in the base year y (from Polk)

4 DATA AND METHODS

This section describes the input data and manipulations used to create the data sets for the car mass analysis. Raw data sources, methods of selecting cases, and the programs that count the frequencies of fatalities are described.

4.1 Input Data

Two types of input data were used. The first was automobile registration data, the other fatal accident data. These two data sets were required to estimate fatality rates per registrations in each year. Registration and fatality data are not included on the same data set, therefore two data sets were used.

Automobile registrations were provided by the R.L. Polk National Vehicle Population Profile for the years 1978-1987 inclusive. These data are national level and provide information on all registered vehicles in the United States.

Since weight data on vehicles with model years 10 years or more before the accident year were not always available, these older cars were not included in this analysis.

The second set of input data was the Fatal Accident Reporting System (FARS) data maintained by the U.S. Department of Transportation National Highway Traffic Safety Administration (NHTSA). These data report accident, vehicle and person-level data on fatal accidents in the United States. Data for 1978-1987 inclusive were used for this report.

The initial step in preparation of the input data for this analysis involved assignment of each vehicle to a car "class" based upon the vehicle weight. This required a reconciliation between the FARS and the POLK data sets because their reported vehicle weights differed systematically, on average by about 200 lbs. Two methods of correcting for weight discrepancies were used. Both data sets report a VIN Weight and a Make Model for vehicles. The two reconciliation methods make use of these variables to accomplish class assignment.

4.2 Method I: Estimation based upon FARS Weight

This method made use of the VIN Weight in FARS to assign vehicles to car classes. VIN Weights were reported in the POLK data sets but differed from the FARS reported VIN Weight. An estimated FARS weight was created using a regression to calculate a FARS weight based upon the reported POLK weight in the POLK data set. The regression equation was calculated by regressing known average FARS weight for each make/model and model year combination vs. average POLK weight for the same subset of vehicle types. The regression was run over all make/model/model year combinations which appeared in both data sets. The transformation below was used to assign a new weight to each vehicle observation in the POLK data set, thereby creating a uniform weight in both POLK and FARS. Using the calculated FARS weight, total registrations by car class are calculated.

Under this methodology a non-linear transformation from POLK to FARS weights was created by estimating the following equation:

$FAVWT = B_0 + B_1*WT + B_2*WT^2 + B_3*WT^3 + B_4*YEAR$ where:

FAVWT = FARS Average Weight

WT = POLK weight

WT^2 = POLK weight squared

WT^3 = POLK weight cubed

YEAR = Model year (78-87)

(The model fit the data with an R^2 of .989.)

This resulted in the following transformation from POLK weight to an estimated equivalent FARS weight referred to as FAVWT.

$$FAVWT = -531.05126461 + 1.80432484 * WT - 0.00014152 * WT^2 + 1.65182E{-}08 * WT^3 + 3.66827 * YEAR$$

The six weight classes are defined for the following weights:

CLASS	FROM	TO
#1	100 lbs	1949 lbs
#2	1950 lbs	2449 lbs
#3	2450 lbs	2949 lbs
#4	2950 lbs	3449 lbs
#5	3450 lbs	3949 lbs
#6	3950 lbs	9049 lbs

4.3 Method II: Using the VIN Weight to Assign a Make Model to a weight class.

This methodology also made use of the VIN Weight to accomplish class assignments, but used the Make/Model codes in POLK to make a translation from POLK to FARS.

Under this methodology an entire Make/Model/model year category was assigned to a class (1-6) within the POLK data set based upon the reported VIN Weight in POLK. These class assignments were then merged onto the FARS file for each year (1978-1987) matching on the reported make/model/model year of the vehicle in the FARS file. Registrations by class were calculated in the POLK data set based upon the assigned classes in POLK. Similarly, fatalities in the FARS data set were assigned to the same weight classes based upon make model/model year category, or strictly speaking on the weight class that the category was assigned in Polk.

4.4 Counting Fatalities

Differences in the vehicle class assignment methodologies resulted in differences in the methods of assembling fatality counts. The following are descriptions of how fatality counts were obtained using the methods one and two. Definitions of categories of fatalities and accident circumstances do not differ between the two methods. Case selection and handling missing observations do differ among the two methods. These differences are discussed below.

4.5 Method I: Vehicle Classification using the FARS Weight

Fatalities were counted based upon information about the vehicle. A vehicle was selected for assignment to a weight class if that vehicle's weight was available from FARS and the make/model code indicated that the vehicle was a passenger car.

In addition to classifications of accidents based upon vehicle weight class, the circumstances of the accident were of interest in this study. Four categories were created for classified vehicles. These categories included single vehicle accidents, two-car accidents, pedestrian accidents and accidents involving one passenger car and one non-classified vehicle which was either a non-passenger car (such as a truck or motorcycle), or possibly motor car which could not be classified.

The fourth category was constructed because some vehicles failed assignment to one of the six classes. This may have occurred because the vehicle was not considered a passenger car, or because necessary weight data were missing. These data on fatal accidents were included in this analysis if one of the unclassified vehicles (e.g. truck, motorcycle or car with unknown weight) was involved in an accident with a classified vehicle. Fatalities of occupants of the unclassified vehicle were counted in the analysis as well as fatalities in the classified vehicle. These observations were classified into four other classes. A class "7" referred to motorcycles, class "8" to light trucks and vans, class "9" heavy trucks, and class "10" for all others or missing VIN Weights. For the purposes of the analysis, however, all unclassified vehicle fatalities were summed together. (However, if an unclassified vehicle was in collision with a classified vehicle, the fatalities were kept disaggregated by the weight class of the classified vehicle.)

After vehicle class assignments were made, records in the FARS Vehicle File were sorted by their accident identifier (State Case Number). The total occupant fatalities in the first car in an accident were counted, and similarly the total occupant fatalities in the second car (if there was one) were counted. A total of these two counts was kept. Finally, if more than two cars were involved, a third count was kept of all fatalities in the accident (Accidents involving 3 or more cars were not included in further analyses.) If the case had only one vehicle, the case was counted as a single car accident.

Pedestrian fatality counts were treated differently because they had to be identified from a separate FARS file. Pedestrian deaths were counted by selecting cases of pedestrian fatalities from the FARS Person File, and constructing the vehicle class assignments using the vehicle file. The person and vehicle files are merged to identify the class of the vehicle involved in the pedestrian accident.

This operation resulted in the creation of a data set that had observations for all fatal accident cases for each year, including a vehicle class assignment (1-10) and a category assignment, single, two-car, unclassified or pedestrian.

Fatality rates were estimated for each year by including the calculated registrations from the POLK file in the analysis. Arrays of these four rates were calculated in the following way:

$U_i = A_i / R_i$	Single Vehicle Fatality Rate
$V_i = B_i / R_i$	Pedestrian Fatality Rate
$W_{ij} = C_{ij} / (R_i R_j)$	Two-car Fatality Rate
$X_i = D_i / R_i$	Two Vehicle Fatality Rate (one vehicle a car the other unclassified)

Where:

R_i = Registrations for class i in a base year

A_i = Single vehicle fatalities weight class i

B_i = Pedestrian fatalities weight class i

C_{ij} = Two-car crash fatalities - weight classes i and j

D_i = Two vehicle fatalities - weight class i with unclassified vehicle (e.g. truck etc.)

After creation of these fatality rates for the four arrays of accidents, the data were converted into a spread-sheet format to calculate the effects of varying fleet mixes on expected fatality rates.

4.6 Method II: Vehicle Classification Using Polk Weight

Registration counts using the POLK data on VIN Weights and Make Models were constructed. Employing this process, an output data set was created that contained an observation for each make, model and model year for vehicles that had an occupant fatality during the study period. This data set contained a vehicle classification for weight classes "1-6" corresponding to the same weight classes used in method I, or class "7" if the vehicle could not be classified into one of these categories. This data set (named FARSNEW) was used as a "dictionary" of make model classes containing a weight class assignment for each make-model/model-year category it contained. This assignment was based upon the average POLK Vin Weight within this class. When the fatality count program was run on the FARS vehicle file, vehicle classification assignments were made using this dictionary.

After a make model reconciliation was conducted on the FARS data set, FARS vehicle file information was merged with the output data set (FARSNEW) described above. The result was to assign a class (1-9) to each vehicle observation based upon its make model. Initially, all make models in the FARS were assigned an 8. After merging with the FARSNEW data set, any passenger car that had a corresponding make model class in FARSNEW was reassigned a class value of 1 through 7. Any vehicle that was missing from the FARSNEW data set was assigned the value "9" for its class. The remaining value "8" by default represented non-passenger cars that had a classification in the FARSNEW data set. (As before all vehicles in classes 7, 8 and 9 were treated as one group of vehicles, which are not classified passenger cars.

Once the classification assignment was complete, the steps in counting fatalities and forming fatality rates were exactly as described above in the Method I methodology.

4.7 Creating Hypothetical Distributions

The final step in this process was to estimate the expected fatality rates for the years 1978 - 1987 using the calculated fatality rates from above, and hypothetical fleet mix distributions. The actual fleet mixes in these two years were each scaled to total to the total number of classified cars in the "base year" i.e. the year for which the rates were calculated.

The result of each step above was a matrix representing fatality rates for two-car accidents, two-vehicle accidents involving one passenger car, single vehicle accidents and pedestrian accidents. This yielded a matrix of 60 cells (ten years times six weight clases). These cells were input to a spreadsheet program. The fatality rates in these 60 cells were multiplied by the alternative hypothetical registration counts. These counts represented a fleet mix weighted toward heavy cars, and a fleet mix weighted toward light cars. These fleet mixes were based upon actual registrations for the earliest and latest years in the estimation period (1978 and 1987). In addition, these fatality rates were multiplied by the actual fleet mix for the year of estimation to apply an accuracy check.
The resulting fatality counts for the heavy and light fleet mixes were divided to form a ratio. These ratios for the total analysis, and sub-parts of the analysis (single

vehicles, pedestrians, etc.) appear in the results tables.

4.7 Example

Calculations were performed using fatality rates created by both Methods I and II. Results for each method appear in the results. The following example will help to illustrate how the ratio in equation 3.2 (Section 3.2) is calculated. In that equation we calculate

$$T_1 = \sum H_{1i}U_i + \sum H_{1i}V_i + \sum H_1 W_i + \sum H_{1i}H_{1j}X_{ij}$$

$$T_2 = \sum H^1_i U_i + \sum H_{2i}V_i + \sum H_2 W_i + \sum H_{2i}H_{2j}X_{ij}$$

The four terms U_i, V_i, W_i and X_{ij} refer to the single car fatal accident rate, the two vehicle fatal accident rate when one vehicle is a passenger car and the other is not, the pedestrian fatal accident rate and the two passenger car fatal accident rate. In this example we will illustrate calculation of the U_i only, and apply the hypothetical distributions H_{1i} and H_{2i} in the formulae to calculate T_1 and T_2.

In this section we have discussed different methods for counting the number of registered vehicles in each class, and the number of fatalities in each class of registered vehicles. These counts are used to produce the initial value U_i. Recall (Eqn 3.1), that U_i is equal to A_i (the number of single car fatalities in class i) divided by R_i (the number of registered vehicles in class i) for a given year. R_i in this example is calculated using what we have previously referred to as Method II. In Method II we use a regression equation to reconcile differences in the reported vehicle weights in FARS and POLK to create uniform categories of vehicle classes between the two. All input values in this example, including fatality counts, base year registrations, and hypothetical distribution inputs were calculated using method II. (They could as well have been calculated using method I.)

Column I in the example contains R_i the total base year vehicle registrations. As noted earlier this includes vehicles of the base year model year through those up to 10 years old. In this example the base year is 1982, so registered vehicles from model years 1973 to 1982 are included in the total. In the second column, the number of fatalities in the base year by car class in single vehicle accidents (A_i) is shown. Column 3 shows the calculated fatality rate in single car accidents in the base year. This rate is calculated by dividing the number of fatalities (A_i) by the number of registrations (R_i).

The second block in the example illustrates calculation of one of the Hypothetical Vehicle Registration Distributions (H_{1i}) to be used to create our estimate of projected fatalities. The basis of this hypothetical distribution is the actual 1978 distribution of registered vehicles by class. Column 4 shows this 1978 registration distribution.

The fraction of the total distribution that each class represents is shown in column 5. For instance, Column 5 value #1 is 0.0436253. This is equal to the total registered vehicles in class #1 in 1978 (3431659) divided by the total of all vehicles in all classes in 1978 (78661978). These ratios are used to reapportion the total number of registered vehicles in 1982 (77139541) to coincide with the 1978 fleet mix. Thus 0.043625384 is multiplied by 77139541 to create the hypothetical distribution's first value 3365242.1012. The new hypothetical distribution in column 6 contains the same total number of registered vehicles as column #1, but with a different mix of cars in each weight class.

The last step in this section is to calculate projected fatalities. This is accomplished by multiplying the fatality rate U_i in column 3 by the new hypothetical distribution in column 6 (H_{1i}). The result is shown in column 7. The sum of column 7 is equal to T_1.

The third block in this example illustrates creation of the second hypothetical distribution. The basis for this distribution is the 1987 fleet mix shown in column 8. Column 9 is the result of dividing each of the entries for total registrations in classes 1 through 6 by the total number of registrations for that year. Again, 0.041136182, the first entry in column 9, is the result of dividing 3407643 by 82883559. These ratios are multiplied by the total registrations in column #1 (77139541) to create the second hypothetical distribution H_{2i}. The total number of registrations in column 10 is equal to the registrations in the base year (1982). Then, projected fatalities are estimated by multiplying the fatality rate U_i by the number of registrations in each class shown in column 10. The results are shown in column 11. The total of column 11 is T_2.

Finally, Q_{12} is calculated by dividing T_1 by T_2. The result, .894920647, represents the single vehicle ratio of estimated fatalities for lighter and heavier fleet mixes based upon the 1982 fatality rate.

EXAMPLE: Calculation of Q_{12} For Single Car Accidents
Base Year 1982

(1) Base Year Registrations R_i	(2) Single Car Fatalities A_i	(3) Ratio R_i/A_i U_i
2679706	342.0001579	0.000127626
12147170	1634.9969348	0.000134599
13256308	1606.0017142	0.00012115
16539881	1722.9924835	0.000104172
12621855	1335.0009815	0.000105769
19894621	1783.9904543	0.000089672
77139541	8424.9827263	

(4) 1978 Registrations	(5) Ratio $Class_i$ Total Regst.	(6) H_{1i} Hypo Dist #1	(7) $H1_iU_i$ Proj. Fatals.
3431659	0.043625384	3365242.1012	429.49238846
7627825	0.0969696567	7480194.8068	1006.8267408
8843834	0.1124283196	8672668.9665	1050.6938453
12811357	0.1628659401	12563403.8667	1308.7549076
14506446	0.184414966	14225685.8324	1504.6365648
31440857	0.3996957336	30832345.426	2764.7980791
78661978		77139541	8065.202526

	(8) 1987 Registrations	(9) Ratio $Class_i$ Total Regist.	(10) H_{2i} Hypo Dist #2	(11) $H_{2i}U_i$ Proj. Fatals.
	3407643	0.0411136182	3171485.637	404.76402591
	22161876	0.2673856705	20626007.895	2776.2400367
	20678245	0.249485486	19245195.878	2331.5554806
	19741120	0.2381789614	18373015.758	1913.9537976
	11724026	0.1414517685	10911524.4956	1154.1010344
	5170649	0.0623844953	4812311.3359	431.52958211
Total	82883559		77139541	9012.1439573

Q_{12}
(Ratio T_1/T_2) = 0.8949260647

5 RESULTS

When the fatality rates for the base years are calculated as specified in Sections 3 and 4, the resulting values of Q_{12} are as shown in figure 5.1. Recall that Q_{12} is the ratio of projected fatalities of the heavy hypothetical fleet to that for the light hypothetical fleet. These hypothetical fleets are in the proportions by weight of the actual 1987 and 1978 fleets respectively, but are both scaled to the same total number of vehicles (which is the total number of cars in the base year). A different value of Q_{12} is calculated for each year in the range 1978 to 1987 as base year. This means that each year is used in turn to calculate the rates specified in (3.1) which are then used to reconstitute fatality projections using (3.2) using both hypothetical fleets. (The results for each year are shown in tables in the appendix.) These projections are then used to form an estimated fatality ratio for each year as base year. These ratios are what are plotted in figure 5.1. Since there were two ways of classifying fatalities and registrations into weight class we end up with two separate estimates of each of the fatality ratios. These fatality ratios are estimated considerably differently using the two methods but some overall observations can be made:

1. All the ratios are less than 1 indicating that in all cases based on these ratios one would predict that the heavier fleet would be safer.

2. All but one of the ratios are in the range .93 to 1. This suggests that .97 could be used as a very tentative preliminary estimate of the ratio of fatalities to be expected for the heavier fleet compared to the lighter fleet.

5.1 Interpretation

Below we shall discuss the corresponding ratios of the 4 component types of fatalities (i.e. fatalities in fatal accidents) to see how the aggregate ratios are determined by the component quantities but first we should say more about the meaning of this overall ratio Q_{12}.

We are seeking to compare the estimated fatalities that would occur with a fleet with predominantly heavier cars to those that would occur with a fleet of predominantly lighter cars. The comparison being sought is difficult to specify precisely. For example

1. What precisely is the nature of the excess heavy cars in the heavy fleet compared to the light fleet and what is the nature of the excess light cars in the light fleet? For example are the excess heavy cars brand new Cadillacs or old broken down Chevrolets?

2. Which drivers drive the excess heavy cars in the heavy fleet and which drive the excess light cars in the light fleet?

3. What kind of driving do the cars which are different between the two fleets get -- where are they driven, under what circumstances and how?

We may assume that the total driving population is the same for the two fleets and the total trip population the same (with respect to route, time, speed, traffic, distance, etc.). However, the drivers distribute themselves over cars in an unknown manner. (The fact that the heavier cars carry more passengers and hence can be used in some circumstances, where a lighter car won't do, will be ignored here.)

When we calculate fatalities per registered vehicle in a weight class, we don't expect that ratio to hold when the distribution of the fleet over weight classes changes. Since we have the same total numbers of good drivers and of bad drivers, for example, these drivers must distribute themselves in different proportions over the weight classes in the two hypothetical fleets. We do not control directly for driver factors, vehicle factors and trip factors which, though the same in total, must change in their distribution over weight classes. However, we do have a means of addressing the problem at least partially. What we have is the opportunity to make an estimate based on the fatality rates for a sequence of ten years. During these years the actual fleet mix changed from a relatively heavy fleet in 1978 to a much lighter fleet in 1987. The change was continuous, as seen in figure 5.2 (The averages in figure 5.2 are actually averages of the nominal weights for the six classes - they are presumably close to actual average weights.) Consequently the base years represent a wide range of vehicle weight distributions and also the base years varied in many other ways.

The variation in the estimated fatality ratio Q_{12} with base year will reflect variation in the types of drivers which are paired with vehicles in the various weight classes. For example if a relatively heavy fleet implies better drivers in heavier cars than a relatively light fleet, then this phenomenon has the opportunity to be realized in the

Fig. 5.1

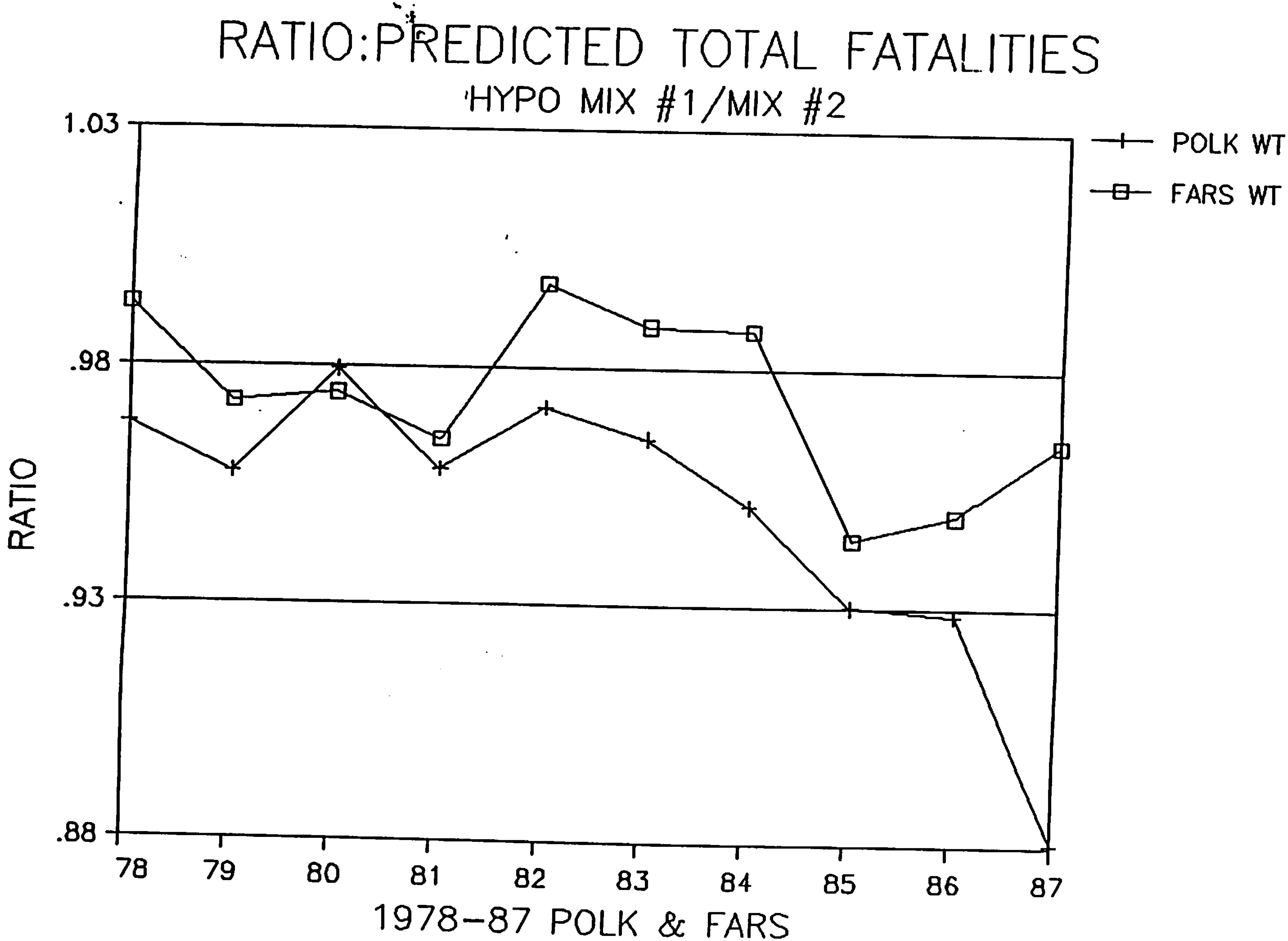
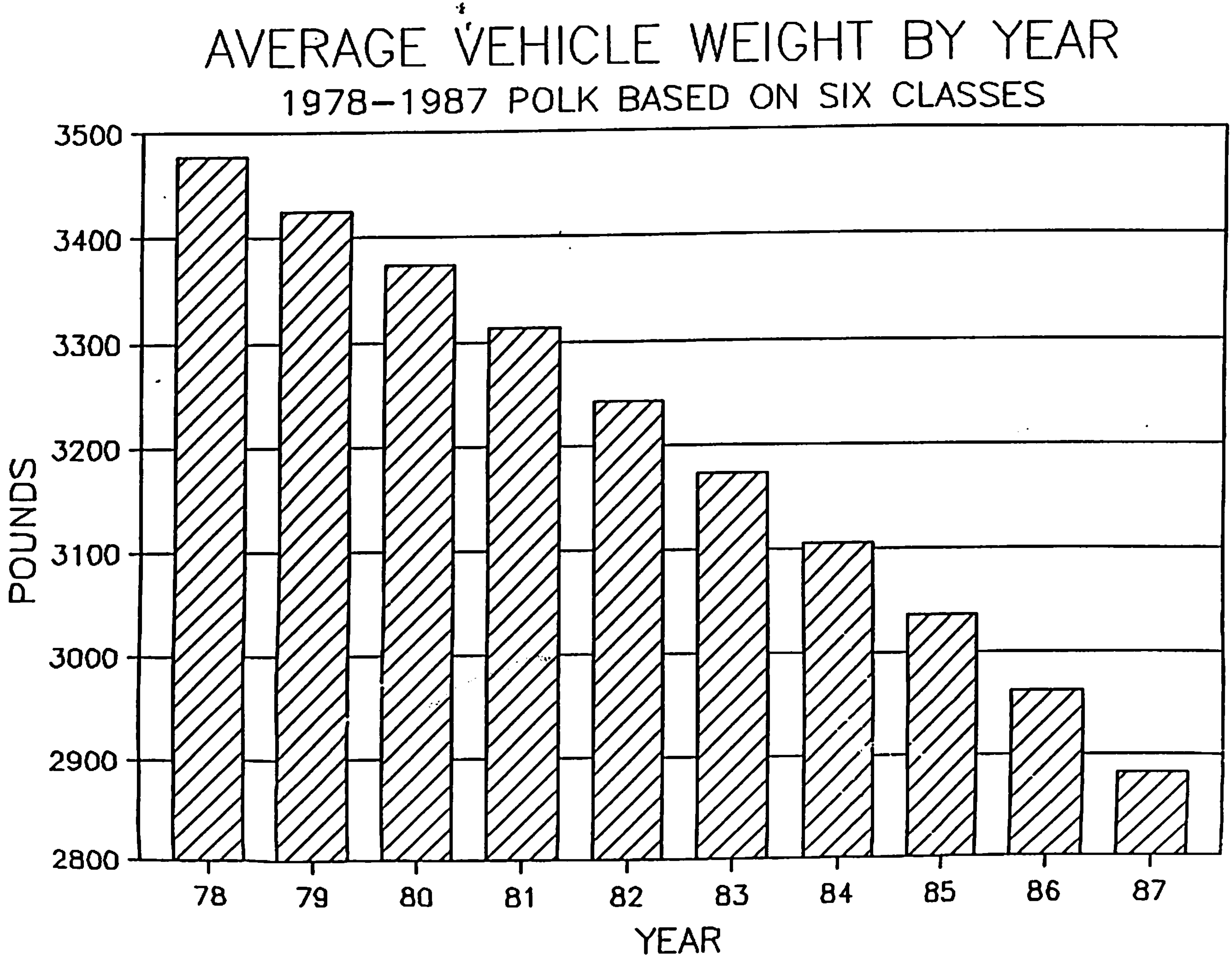

RATIO:PREDICTED TOTAL FATALITIES
HYPO MIX #1/MIX #2
1.03
.98
.93
.88
RATIO
78
79
80
81
82
83
84
85
86
87
1978-87 POLK & FARS
POLK WT
FARS WT

Fig 5.2


AVERAGE VEHICLE WEIGHT BY YEAR
1978–1987 POLK BASED ON SIX CLASSES
POUNDS
3500
3400
3300
3200
3100
3000
2900
2800
78
79
80
81
82
83
84
85
86
87
YEAR

earlier base years with heavier fleets and similarly any effect associated with lighter fleets should be reflected in the later base years.

5.2 The Four Types of Accident Ratios

So far in this section we have been discussing Q_{12} as a function of base year, where Q_{12} is the ratio of fatalities projected for the heavier hypothetical mix (distributed the same as the actual 1978 fleet of passenger cars) to that for the lighter hypothetical mix (ditto 1987). The fatalities in question are all the fatalities in which a passenger car (in one of six weight classes) was involved. We now examine similar ratios, but of components of the total fatalities. The four types of fatalities which involve passenger cars have been described in Section 3. They are:

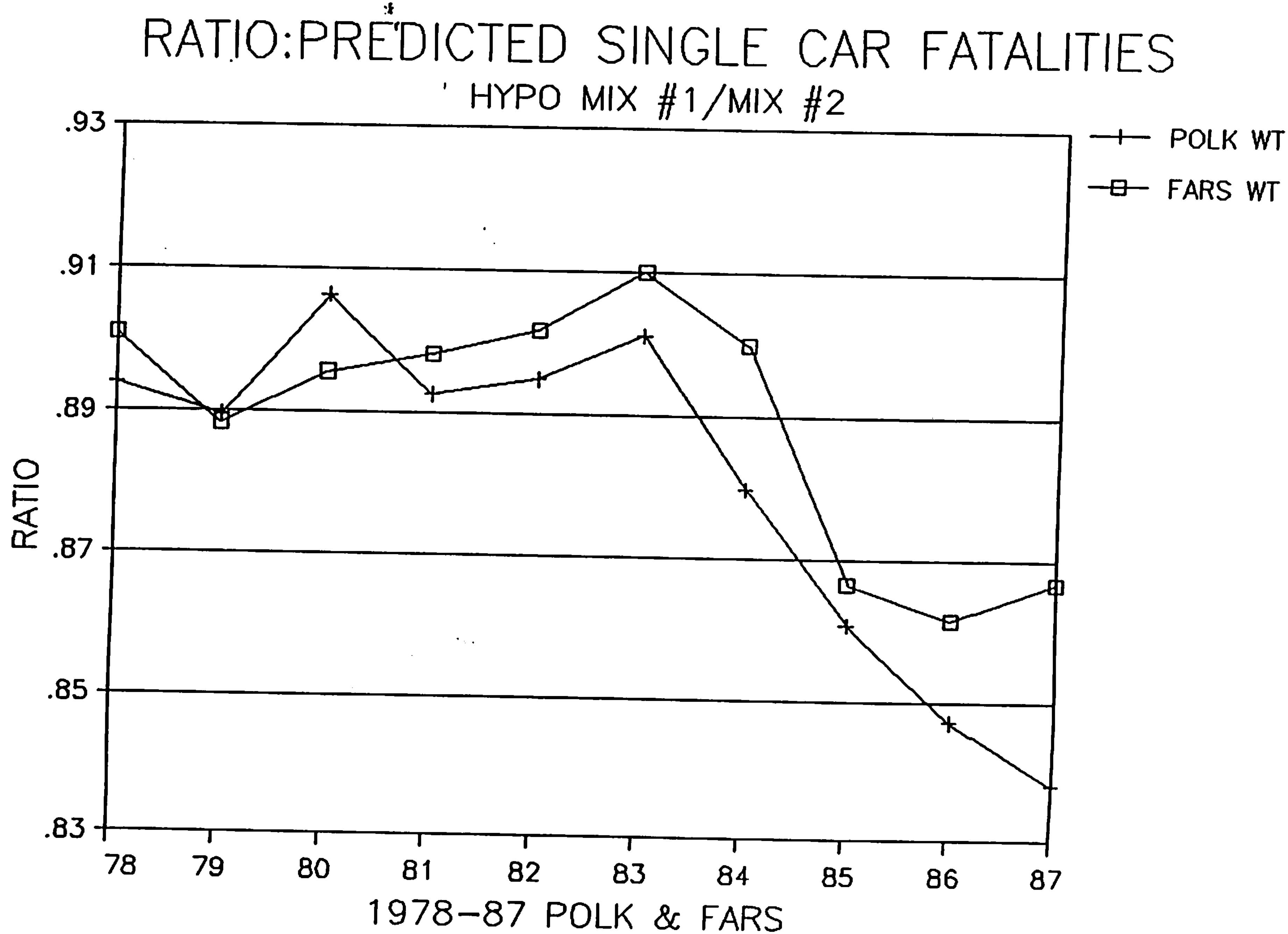
1. Fatalities in single car crashes
2. Fatalities in either car in crashes between two passenger cars (both classified into our 6 weight classes)
3. Fatalities in either car in crashes involving a classified passenger car and a non-classified vehicle (e.g. truck)
4. Pedestrian fatalities caused by classified passenger cars

First we examine the ratio of projected single car fatalities (figure 5.3). Here the ratio strongly favors the heavy fleet ranging from about .90 to .85. Not surprisingly when attention focuses on single car crashes, the conclusion is that heavier cars are safer for the public in general (since all fatalities are occupant fatalities in this case).

When we examine the ratio for the case of a collision of a passenger car with an unclassified vehicle, the results are similar but not so strong (see figure 5.4). The ratio ranges from about .99 to about .93 (one estimate goes as low as .89). This is also not surprising, as collisions with trucks should favor large cars while collisions with motorcycles may favor small cars (remember that <u>all</u> fatalities are counted (including those on the motorcycle) as we are investigating the risk to the public at large).

When we examine crashes involving two classified passenger cars the results are perhaps somewhat surprising (see figure 5.5). Here the ratio is mostly above one (and hence favors the lighter fleet). It is not easy to explain this observation. It

Fig 5.3



RATIO:PREDICTED SINGLE CAR FATALITIES
HYPO MIX #1/MIX #2
.93
.91
.89
.87
.85
.83
RATIO
78
79
80
81
82
83
84
85
86
87
1978-87 POLK & FARS
POLK WT
FARS WT

Fig 5.4

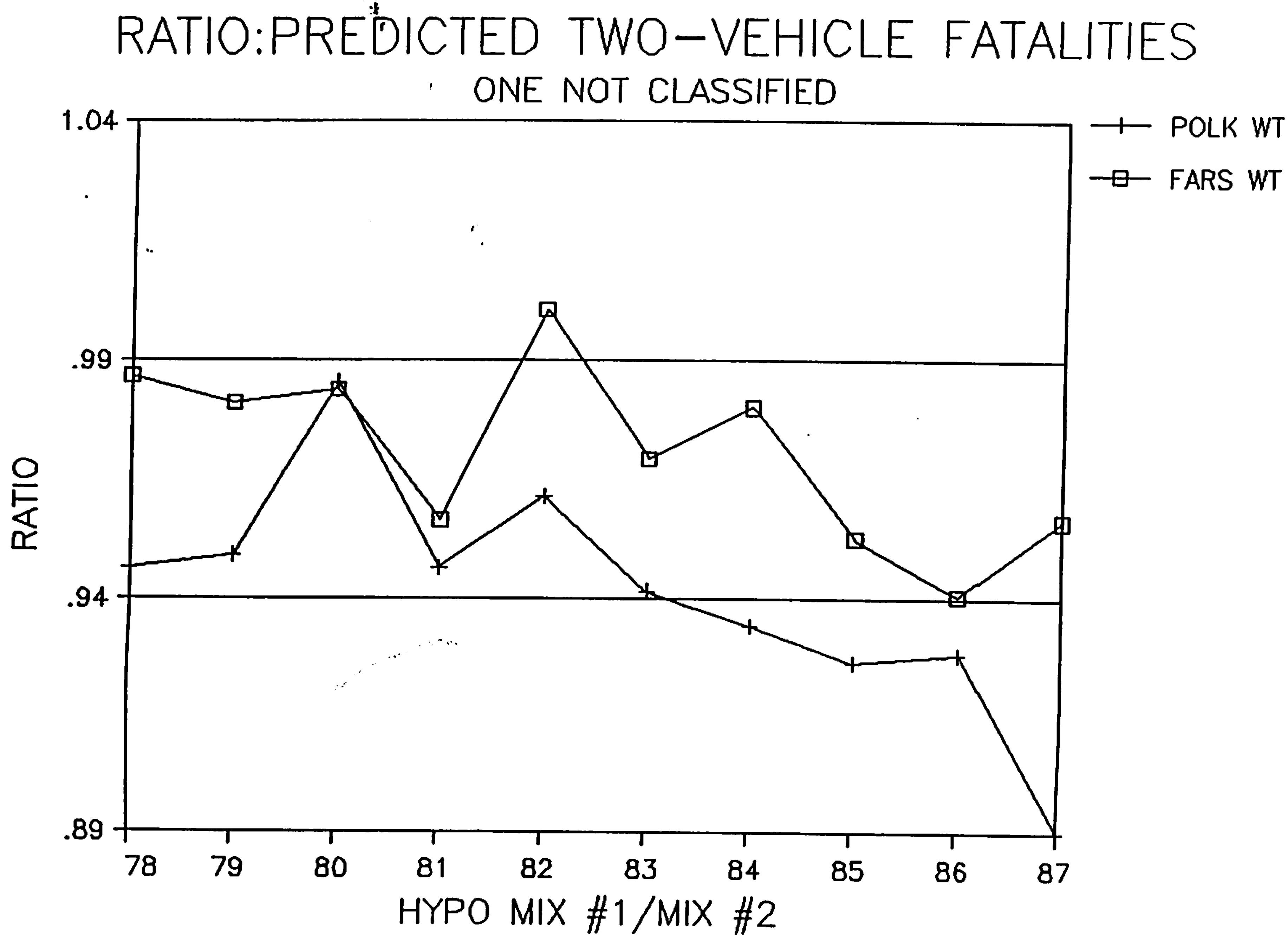
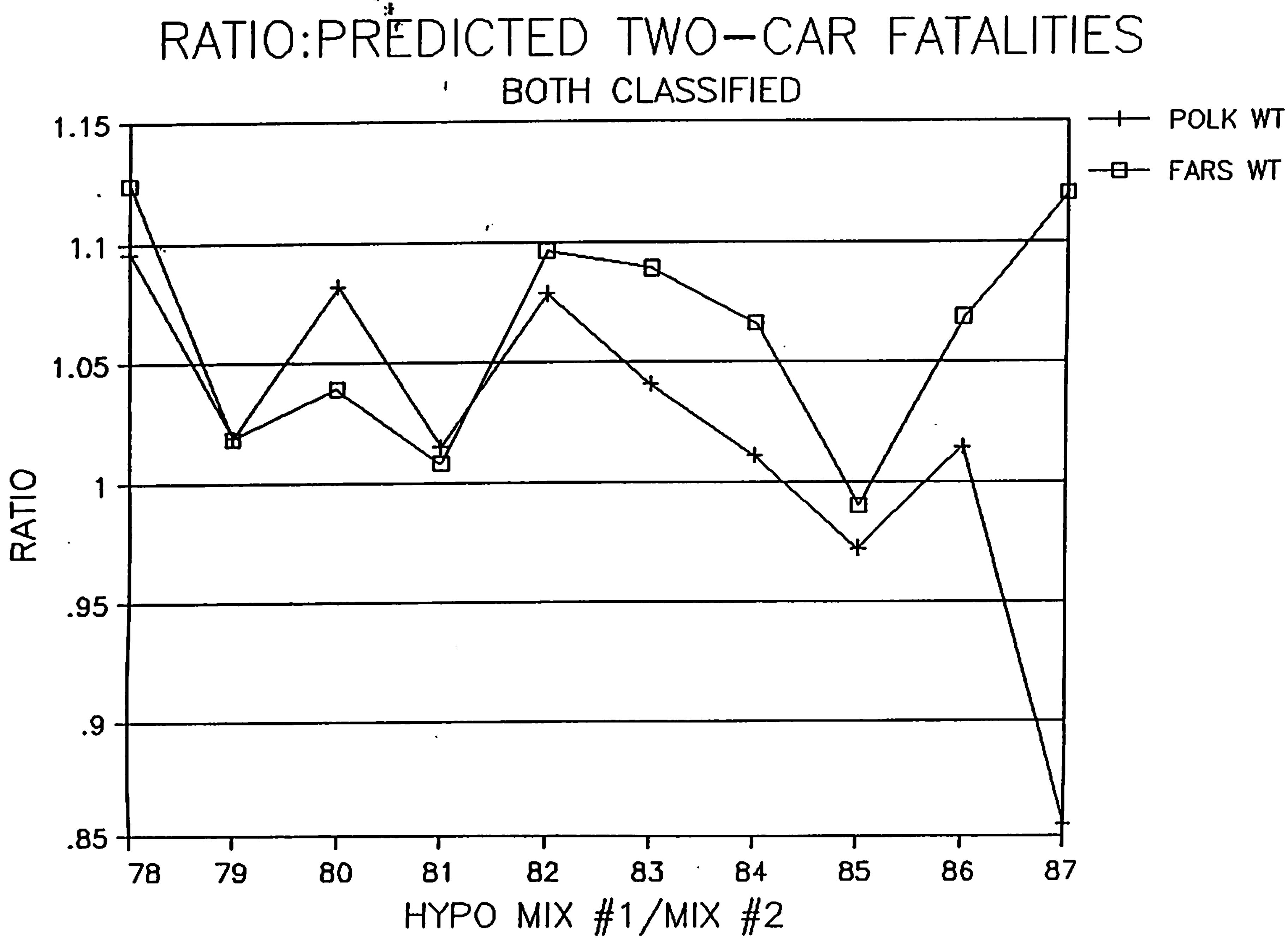
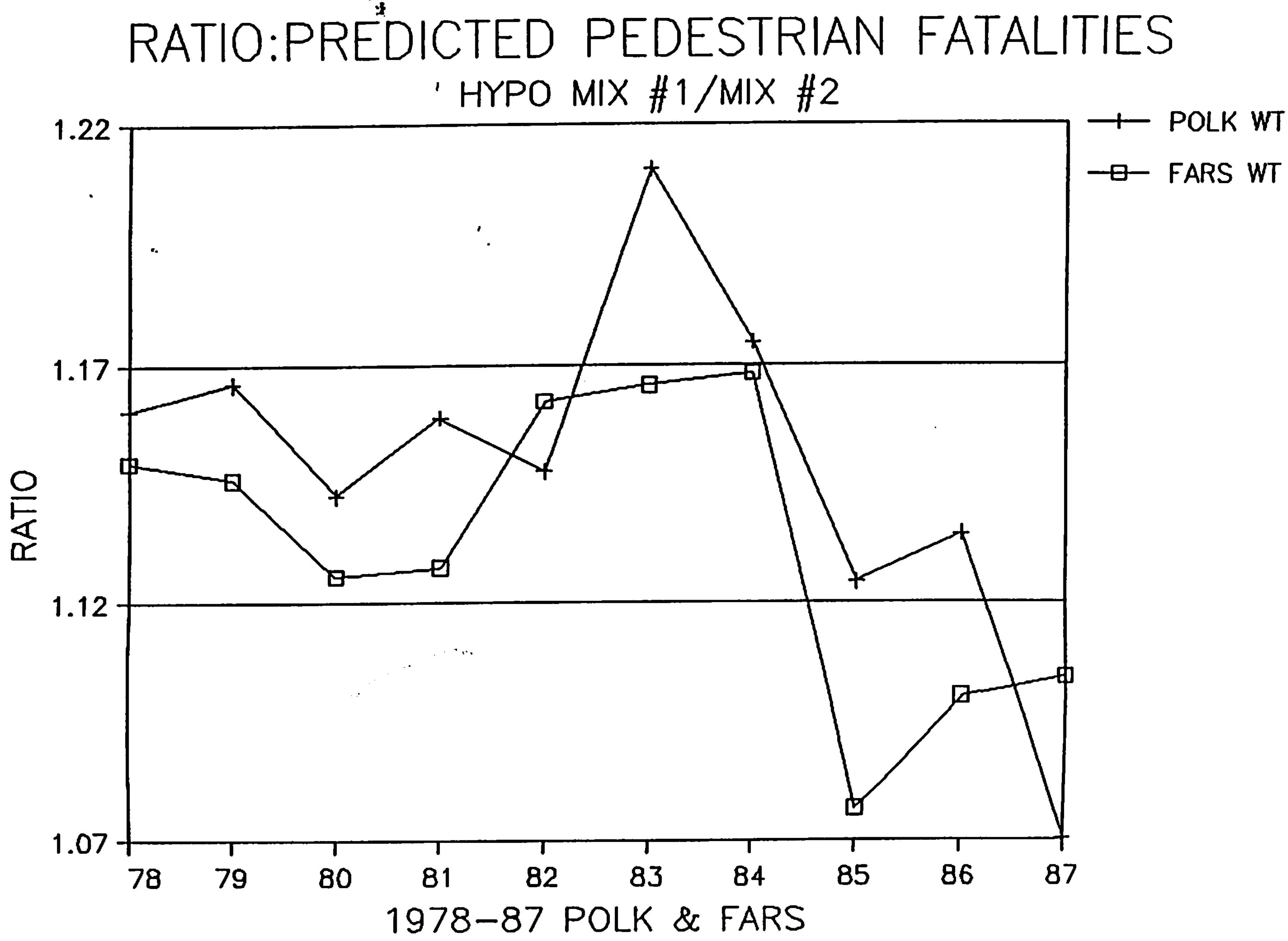

RATIO:PREDICTED TWO-VEHICLE FATALITIES
ONE NOT CLASSIFIED
POLK WT
FARS WT
1.04
.99
.94
.89
RATIO
78
79
80
81
82
83
84
85
86
87
HYPO MIX #1/MIX #2

Fig 5.5



RATIO:PREDICTED TWO-CAR FATALITIES
BOTH CLASSIFIED
POLK WT
FARS WT
RATIO
1.15
1.1
1.05
1
.95
.9
.85
78
79
80
81
82
83
84
85
86
87
HYPO MIX #1/MIX #2

Fig 5.6


RATIO:PREDICTED PEDESTRIAN FATALITIES
HYPO MIX #1/MIX #2
POLK WT
FARS WT
RATIO
1.22
1.17
1.12
1.07
78
79
80
81
82
83
84
85
86
87
1978-87 POLK & FARS

may reflect higher total fatality risk in collisions involving cars of greatly different weights. It would contradict some previous work if collisions of light cars with similar light cars had lower fatality risk than similar collisions of heavy cars (see Evans, and Wasielewski 1983 loc. cit.).

Finally, figure 5.6 shows the ratios of projected pedestrian fatalities. These ratios clearly favor small cars. They seem to indicate that a smaller fleet would be safer for pedestrians.

There is a broad range of possible estimates of the fatality ratio in each of the cases just described and the true fatality ratio does not necessarily lie within our range; but in order to summarize the results of this study we attempt very approximate estimates of the percentage by which the large car fleet or small car fleet may be safer with regard to each component type of accident:

1. Single car accident - large fleet 10% fewer fatalities

2. Collision with truck or the unclassified vehicle - large cars 5% few fatalities

3. Collision of two passengers cars - small car fleet safer by 5% (that is the result of the numbers in this study not necessarily in accord with our overall judgment)

4. Pedestrian accident - small car fleet safer by 10%.

Overall - large car fleet safer by 3%.

These estimates are given only to summarize the wide range of estimates suggested in this study. It is not possible to determine their accuracies. These estimates should ideally be used in conjunction with the independent estimates to gain confidence in them.

APPENDIX

This appendix contains numerical tabulations of the projected fatalities leading to the plots of ratios of projected fatalities discussed in Section 5.

Table A-1 shows projected fatalities by:

a. Method (1 or 2)

b. Hypothetical fleet mix (1 or 2)

c. Types of accident (single vehicle, pedestrian, cars/unclassified, two cars(?)

d. Accident year (1978-1987)

Also given are fatalities summed over accident type and the ratio of fatalities in each category by hypothetical fleet mix -- i.e. the ratio of projected fatalities for hypothetical fleet mix 1 (based on the actual 1978 mix) to those for hypothetical fleet mix 2 (based on the actual 1987 mix).

RESULTS: 1978 - 1987 METHODS I AND II

YEAR 1978/METHOD I	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	24083.008038	8143.0076209	3541.0006057	8877.9991379	3521.0006736
HYPOTHETICALS 2	24249.639832	9038.6121778	3080.2729884	8998.4986278	3132.2558383
RATIO	0.9931284837	0.9009134877	1.1495736316	0.986608912	1.1241101798

YEAR 1978/ METHOD II	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	22922.991654	9857.9925174	3392.0004746	6279.9990441	3392.9996174
HYPOTHETICALS 2	23680.64624	11027.4016249	2922.8969798	6634.5836879	3095.7639472
RATIO	0.9680053247	0.8939542471	1.1604926544	0.9465551027	1.0960136739

YEAR 1979/MAKE MODEL	RATIO	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	24622.344823	8358.1521801	3679.1204462	8993.2361771	3591.8360192
HYPOTHETICALS 2	25315.786287	9408.8720988	3210.4241267	9169.0919401	3527.3981211
RATIO	0.9726083379	0.888326687	1.1459920251	0.9808208093	1.0182678269

YEAR 1979 FARS/REG	RATIO	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	23134.973747	10064.5383951	3456.5478564	6170.5190917	3442.0568812
HYPOTHETICALS 2	24159.192889	11314.7074613	2963.9067938	6501.7893289	3378.789305
RATIO	0.9576054073	0.8895093779	1.1662134125	0.9490493739	1.018724925

YEAR 1980/MAKE MODEL	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	24947.710723	9049.0974874	3635.2615474	8637.2209434	3626.130745
HYPOTHETICALS 2	25600.898853	10103.1449457	3229.8459528	8779.2563701	3488.6515839
RATIO	0.9744857345	0.8956713514	1.1255216504	0.9838214741	1.0394075355

YEAR 1980 FARS/REG	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	23446.043176	10565.6667323	3426.5420192	6020.2857677	3433.5486567
HYPOTHETICALS 2	23939.007932	11656.8052685	2999.074962	6109.9645157	3173.1631858
RATIO	0.9794074693	0.9063947187	1.1425329685	0.9853225419	1.0820586448

YEAR 1981/MAKE MODEL	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	24719.016462	8296.1233163	3636.419365	8418.8251709	3481.8058754
HYPOTHETICALS 2	24091.991376	9236.0879339	3225.3628971	8803.249435	3454.3161958
RATIO	0.9648482407	0.8982291394	1.127445029	0.9563315493	1.007958067

YEAR 1981 FARS/REG	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	23216.754416	9693.0865296	3439.53932	5848.3392743	3259.2596066
HYPOTHETICALS 2	22489.99187	10859.3998478	2967.36152	6178.4428844	3211.5501643
RATIO	0.9584417782	0.8925987316	1.1591237862	0.9465717145	1.0148555806

Table A.1

RESULTS: 1978 - 1987 METHODS I AND II

DATA (CON'T)

	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
YEAR 1982/MAKE MODEL					
HYPOTHETICALS 1	20716.719571	6774.2450087	3448.1383248	7609.6020239	2888.1513267
HYPOTHETICALS 2	20756.999385	7512.2694839	2965.7574706	7604.0861246	2634.6064919
RATIO	0.9976637644	0.9017574547	1.1626501354	1.0007253862	1.0962363205

	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
YEAR 1982 FARS/REG					
HYPOTHETICALS 1	19112.891393	8065.202526	3159.5860225	5225.9373957	2638.6457361
HYPOTHETICALS 2	19669.915444	9012.1439573	2752.8963365	5437.1887539	3083.4786825
RATIO	0.9716814212	0.8949260647	1.1477315657	0.9611469515	0.8557366558

	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
YEAR 1983/ MAKE MODEL					
HYPOTHETICALS 1	19066.659434	6215.1842383	3003.1405493	7327.5595118	2520.7751346
HYPOTHETICALS 2	19281.17162	6829.8246261	2575.7214876	7561.3519851	2314.2735209
RATIO	0.9888745254	0.9100064172	1.1659414901	0.9690805991	1.0892295625

	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
YEAR 1983 FARS/REG					
HYPOTHETICALS 1	17806.752583	7587.8872558	2933.1449631	5066.0614515	2317.9954882
HYPOTHETICALS 2	18448.889816	8419.9793826	2422.6176906	5379.8931579	2226.3995851
RATIO	0.9651937195	0.901176465	1.2107337342	0.9416658106	1.0411408193

	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
YEAR 1984/MAKE MODEL					
HYPOTHETICALS 1	19726.707362	6263.5584625	3199.0459268	7721.0275767	2543.0753955
HYPOTHETICALS 2	19961.378264	6959.0842825	2738.1503432	7879.7690016	2384.3746363
RATIO	0.9882437526	0.9000549797	1.1683236952	0.9798545586	1.066558651

	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
YEAR 1984 FARS/REG					
HYPOTHETICALS 1	18297.219248	7694.1897531	3029.2677194	5201.976196	2371.7855799
HYPOTHETICALS 2	19238.00101	8745.3717262	2578.7501984	5568.0585869	2345.8204987
RATIO	0.9510977382	0.8798013388	1.1747038241	0.934253136	1.0110686565

Table A.1 (cont'd)

YEAR 1985/MAKE MODEL	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	19726.707362	5846.4624644	2771.1817003	7735.0129184	2480.1809641
HYPOTHETICALS 2	19646.992366	6746.7786581	2573.269468	8121.0122779	2505.0589969
RATIO	0.9441855666	0.866556139	1.0769108074	0.9524690585	0.9900688835

YEAR 1985 FARS/REG	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	17750.181952	7401.9708404	2716.8909159	5204.6811799	2436.0009368
HYPOTHETICALS 2	19080.53557	8600.3686597	2416.4956419	5616.9606717	2446.7105963
RATIO	0.9302769247	0.8606573896	1.12431029	0.9266009652	0.9956228336

YEAR 1986/MAKE MODEL	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	19667.001598	6286.7147543	2909.0798262	7669.1991993	2802.0078181
HYPOTHETICALS 2	20715.900733	7298.0205278	2643.2146833	8153.3889181	2621.2766039
RATIO	0.9493674377	0.8614273871	1.100584014	0.9406149119	1.0689477844

YEAR 1986 FARS/REG	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	18417.78965	7581.5702458	2840.1288048	5452.4221747	2543.6684246
HYPOTHETICALS 2	19834.213661	8949.5277754	2503.6283165	5873.2545894	2507.80298
RATIO	0.9285868331	0.8471475184	1.1344051296	0.9283476634	1.01430154

YEAR 1987/ MAKE MODEL	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	20352.007693	6031.9894559	2761.0777987	7949.1458473	2887.3576718
HYPOTHETICALS 2	20352.007693	6960.0058808	2500.0018897	8313.999364	2578.0005586
RATIO	0.9645029164	0.8666644194	1.1044302847	0.9561157632	1.1199988542

YEAR 1987 FARS/REG	TOTAL	SINGLS	PEDS	UNCLSS	TWO CAR ONLY
HYPOTHETICALS 1	17179.480161	7201.3343776	2489.8788178	5406.0005806	2149.5111447
HYPOTHETICALS 2	19503.988733	8590.9863068	2326.0005948	6074.0012613	2513.0005699
RATIO	0.8808188108	0.8382430283	1.070454936	0.8900229598	0.8553564095

Table A.1 (cont'd)