SAFETY IMPACTS OF VEHICLE DESIGN AND HIGHWAY GEOMETRY

By

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ABSTRACT

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The purpose of this study is to provide insight on the relationships among automobile size, highway geometry, and traffic accidents. The curb weight was selected as the parameter to define automobile size for this study, and automobiles are classified into seven groups by their curb weight. To examine other possible factors in accident involvement, the model-year of the automobile is also considered.

Data for this study are based on police reported accidents that occurred in Michigan in 1982. Only accidents which occurred on the Interstate system or on the Michigan Trunkline system are analyzed. A total of 51,740 accidents were included in the data base.

This study uses a new exposure approach based on two hypotheses:

1. The likelihood of an automobile being an object (the second vehicle) of an accident is proportional to its exposure.
2. The likelihood of an automobile being an object of an accident is common to any design if the exposure is the same.

The validation of these hypotheses are consistently supported by data. The new exposure approach is found to be a useful tool for the quantification of exposure.

Small automobiles are found to have a unique risk of accident involvement, and are found to be more likely to be involved in an accident in the following conditions:

- single vehicle accidents
- overturned vehicle accidents
- on icy or snowy highway surfaces
- at midblocks
- in rural areas

On the other hand, large automobiles are found to be more likely to be involved in an accident in the following conditions:

- accidents with pedestrians
- accidents with parked vehicles
- accidents with other vehicles
- at intersections
- in urban areas

Results for several geometric features are obtained by examining the accident data for rural and urban areas separately. In rural areas, small automobiles are found to be more likely to be involved in an accident at the following geometric features.

- midblocks
- 2 lane-2 way highways
- no passing zones

In urban areas, large automobiles are found to be more likely to be involved in an accident at the following geometric features:

- intersections

- 6 lane-divided highways
- low posted speed limits.

Drivers in small automobiles are found to have a greater risk of being injured regardless of whether they are in the automobiles identified to be responsible for the accident or in the second automobile.

Results of analyses for vehicle classifications using wheelbase as a measure of automobile size provides very similar results, however the curb weight categories show more consistent results. The model year is also found to be an important factor in determining accident involvement. Newer model-year automobiles are found to be less likely to be involved in an accident than earlier model-year automobiles.

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1.0 INTRODUCTION

It is widely known that small automobiles are increasing in population in America. Approximately 30 million automobiles whose weight does not exceed 3000 lbs. are registered in a population of about 100 million passenger cars. The median curbweight of passenger cars is 3500 lbs. and the median wheelbase length falls in the 110-115 inch group (1). This downsizing of passenger automobiles has an effect on such vehicle design parameters as vehicle length and width, eye height, center of gravity, braking ability, horsepower and engine size.

The relationship between vehicle design and accident involvement or severity have been investigated intensively by many researchers, and a concensus has developed that occupants of small automobiles have a greater risk of injury when involved in an accident. However, it is not clear that small automobiles have a higher accident involvement rate or even a higher injury accident involvement rate than large automobiles.

There has not yet been a thorough examination of the effect of downsizing of vehicles on accident rates at various geometric features. Certainly the fact that small automobiles represent about 32 percent of registered vehicles (1) would indicate an urgency to study issues concerned not only with accident risk and vehicle design but also with accident risk and highway design.

This paper attempts to provide insight on the relationship among automobile size, highway geometry, and traffic accidents.

2.0 LITERATURE REVIEW

As early as 1963, the Division of Research and Development, New York State Department of Motor Vehicles (2) studied the extent of accident involvement of compact vehicles as compared to the overall vehicle population. The definition of compact vehicles used in this study was furnished by the U.S. Bureau of Public Roads. Any vehicle whose points totaled less than 1.0 on the following scale was considered to be a compact vehicle.

1. Wheel base, more than 112 inches - .5 points
2. Empty weight, more than 3,000 pounds - .5 points
3. Gross brake horsepower, more than 130 - 1.0 points
4. Overall length, more than 200 inches - 1.0 points

They found that in 1962, compacts accounted for 11.4 percent of all passenger vehicle registrations but represented only 10.0 percent of all passenger cars involved in accidents, 10.4 percent of all passenger cars involved in fatal accidents, 9.8 percent of all passenger cars involved in injury-producing accidents, and 10.2 percent of all passenger cars involved in property damage only accidents.

The study also included a comparison of type and location of accidents for compacts and other automobiles. The results showed a relatively smaller involvement of compact automobiles in pedestrian accidents, a higher percentage participation in collision accidents with other vehicles, a higher frequency of overturning vehicle accidents and a larger percentage of compact automobile accidents during poor weather and poor road conditions (Table 2.1).

Little comparative significance in regard to road locations was found. Nevertheless, a greater percentage of compact automobile accidents occurred on curves, both level and on grade. No statistical test was implemented to determine if this difference was statistically significant (Table 2.2).

In 1964 Solomon (3) studied accidents on main rural highways related to speed, driver and vehicle characteristics. This study was not designed specifically for evaluating small and large automobiles. However, he compared the accident involvement rate and injury rate with regard to size, age, and horsepower of passenger cars. The data base for this study consisted of 10,000 accidents which occurred on main rural highways.

The vehicle size classification used in this study was as follows:

1. Small - all foreign automobiles, Crosley, Henry J. and Willys.
2. Low priced - Ford, Chevrolet, Plymouth, Studebaker, etc.
3. Medium priced - Pontiac, Buick, Oldsmobile, Edsel, Mercury, etc.
4. High priced - Cadillac, Lincoln Continental, Chrysler Imperial, and Packard.

Comparison made by grouping passenger automobiles according to size showed that the involvement rate tended

Table 2.1. Percentage Distribution of Compact Vehicle Accidents versus All Other Accidents - 1962

Type of Accident	Total Accidents Compact	Other
Collision with:		
Pedestrian	2.5	7.8
Other Motor Vehicle	87.2	77.7
Ped. - Other M.V.	0.1	0.3
Railroad Train	0.0	0.1
Animal	0.4	0.5
Fixed Object	6.0	9.0
Bicycle	0.7	1.5
Motorcycle	0.1	0.1
Non-collision:		
Overturned on Road	1.0	0.5
Ran Off Road	1.8	1.6
Other	0.2	0.9
TOTAL	100.0	100.0
Weather Conditions		
Clear	71.6	73.3
Cloudy	--	--
Raining	16.8	14.6
Snowing	7.0	6.2
Sleeting	0.3	0.3
Fog	0.7	0.7
Not Stated	3.6	4.9
TOTAL	100.0	100.0
Road Condition		
Dry	60.5	63.3
Wet	23.0	20.0
Muddy	--	--
Snowy	12.5	11.7
Icy	0.4	0.1
Not Stated	3.6	4.9
TOTAL	100.0	100.0

Table 2.2. Percentage Distribution Of Compact Vehicle Accidents versus All Other Accidents by Road Location - 1962

	Total Accidents	
	Compact	Other
Road Location		
Not at Intersection	50.0	53.1
At Intersection	45.8	42.7
Driveway	3.4	3.3
Underpass	0.1	0.1
Railroad Crossing	0.0	0.1
Bridge Overpass	0.7	0.7
TOTAL	100.0	100.0
Road Character		
Straight, level	69.7	69.4
Curve, level	6.2	5.4
Straight, grade	9.4	8.8
Curve, grade	4.7	3.9
Straight, hillcrest	2.3	2.1
Curve, hillcrest	0.7	0.6
Not Stated	7.0	9.8
TOTAL	100.0	100.0

to decrease as the price of the automobiles increased and that there was also a tendency for the injury rate and the number of persons injured per 100 involvements to decrease as the price of the automobile increased.

Passenger automobiles were also divided into three horsepower groups, 110 or less, 111-170, and 171 or more. A comparison of accident involvement showed that drivers of automobiles having 110 horsepower or less had the highest accident involvement rate. This is the reverse of the results found in the New York study, but as in that study, no test was conducted to determine statistical significance.

Also in 1964, Jaakko K. Kihlberg, Eugene A. Narragon and B. J. Campbell (4) investigated accident injury data from 12,835 injury-producing rural motor-vehicle accidents.

Passenger automobiles were grouped in three vehicle weight categories for this study:

1. Small automobiles: 771 vehicles, under 2000 pounds.
2. Compact automobiles: 1085 vehicles, 2000-2999 pounds.
3. Standard automobiles: 10,979 vehicles, 3000 pounds and over.

This study was only concerned with injury accidents and with a comparison of the percentage of fatalities and severe injury accidents for light and heavy automobiles. The number of injury-producing vehicles was used as the exposure index.

Three major findings of this study were:

1. For all occupants, frequency of injury (to any degree) in small automobiles was about ten percent higher than in standard automobiles.

2. The frequency of dangerous and fatal injuries in small automobiles was about twenty percent higher than in standard automobiles.

3. The percentage of fatalities among small automobile occupants was about fifty percent higher than among standard automobile occupants (7.0 percent of occupants were killed in small automobiles, as compared with 6.0 and 4.6 percent in compact and standard automobiles, respectively).

It was not clear from the report if these results were statistically significant. This study also included a review of eight previously published automobile size studies. The authors characterized the findings in the reviewed literature as follows.

1. No evidence was found to suggest that small automobiles have a different accident involvement rate than that of other automobile classes.

2. Once involved in an accident, the risk of injury appears to be higher for small automobile occupants than for large automobile occupants.

In 1968, John W. Garrett and Arthur Stern (5) expanded the earlier Automotive Crash Injury Research study by Kihlberg, Narragon and Campbell, comparing the performance of the Volkswagen two door sedan "beetle" models with that of American and other imported automobiles involved in rural injury-producing accidents in 30 states.

The accident sample was divided into seven groups, with Volkswagen comprising one of these groups. The seven summary groups and the number of cases were as follows:

1.	Volkswagen	879
2.	Renault	325
3.	Foreign Sedan	391
4.	Corvair	674
5.	Light U.S.	1582
6.	Intermediate U.S.	22568
7.	Heavy U.S.	1135
	TOTAL	27552

This study compared the percentage of dangerous and fatal injuries, the percentage of rollovers, collisions and the percentage of ejection of occupants from the vehicle, using injury-producing accidents as the exposure.

Dangerous and fatal injuries were more frequent among the occupants of Volkswagen and other small automobiles than among the occupants of larger automobiles. This appeared to be more closely related to the door opening and/or the door latch design than to vehicle size. Ejection accounted for 40 percent of the Volkswagen fatalities and 32 percent of those injured to a dangerous degree. Rollover, with its high incidence of lethal ejection, occurred more frequently for Volkswagen, Renault and other small foreign sedans, than for American automobiles involved in injury accidents. These results were statistically significant.

In 1970, B. J. Campbell (6) dealt with the variation in injury to unbelted drivers involved in crashes while driving various automobile makes and models. Accident reports from 270,000 vehicles involved in crashes in North Carolina in 1966 and 1968 were analyzed.

The aggregated driver injury rate of all vehicles was calculated and compared to driver injury in each automobile make on the basis of a grouping of accident circumstances, speed, impact site and accident type. VIN data were utilized to identify automobile years and makes. Definitions of vehicle size were not given. However, each vehicle make was classified into six groups which were:

1. "The Big 3" (standard Chevrolet, Ford and Plymouth).
2. The largest automobiles (Buick Electra, Dodge Monaco, Oldsmobile 98, Pontiac Bonneville, etc.).
3. Standard size Buick, Dodge, Mercury, Oldsmobile, Pontiac.
4. Cars just smaller than standard (Buick Special, Chevrolet Chevelle, Dodge Dart, etc.).
5. Domestic compact automobiles (Chevrolet Chevy II, Chevrolet Corvair, Ford Falcon, Plymouth Valiant).
6. Other automobiles; foreign, American specialty automobiles, and a regrouping of American compact automobiles.

The two major results of this study were: 1) driver injuries were less frequent and less severe under comparable crash circumstances in the later model years than in earlier years; 2) driver injuries tended to be more severe in smaller automobiles than in large automobiles under comparable conditions. These results were statistically significant.

In 1973, James O'Day, Daniel H. Golomb, and Peter Cooley (7) made an accident study to assess the risk of injury to occupants of small and large automobiles. Accident data for Washtenaw County, Michigan during the period 1968-1970, which contained 16,360 passenger automobiles was used for this study. Small automobiles were defined as those with a licensing weight of 3,100 pounds or less, and large automobiles as those with a licensing weight of 3,300 pounds or greater. The 200 pound range in the middle of the distribution was not used.

The percentage of injury involvement in small and large automobiles for single and two automobile collisions was compared, using the numbers of small and large automobiles involved in accidents as the exposure. They found that, in single vehicle accidents, small automobile occupants were more likely to incur an injury, and in small-large collisions, small automobile occupants sustain more injuries. No statistical test was conducted.

The number of injuries per accident involvement as a function of vehicle weight was expressed in equation form as follows.

$$N = 10^{-8} W^2 - 1.32 \times 10^{-4} W + .642$$

where N = the number of injuries per accident involvement
W = the weight of the involved vehicle in pounds.

In 1974, Theodore E. Anderson (8) examined the influence of various accident parameters on the probability of passenger compartment intrusion. Data pertaining to one and two automobile collisions involving American made automobiles manufactured between 1969 and 1973, involved in accidents within an eight-county area surrounding Buffalo, New York were used. Only those accidents which had hospital treated injury cases were used (approximately 360 cases annually).

Automobile sizes were defined as small (0-2999 pounds), medium (3000-3900 pounds), and large (4000 pounds and over). The small automobiles had a 55.5% intrusion incidence, the medium automobiles had 57.0%, and the large automobiles 44.4%. Thus, the large vehicles were found to be less likely to experience intrusion than small or medium vehicles. This result showed a statistical significance.

In 1974, Donald W. Reinfurt and B. J. Campbell (9) presented crash rates per million vehicle miles for several makes, models, and years of automobiles. Accidents occurring in North Carolina in 1966 and 1968 were used as accident data for this study. Estimates of annual mileage for a given make-model-year combination were derived from the annual vehicle inspection program in North Carolina. VIN data were used to identify make and year for both accident and inspection data. Definition of vehicle size was not clearly given. However, automobiles were classified into big, standard and small.

Overall and single vehicle accident rates per million vehicle miles by model year, from 1960 to 1966, were calculated and compared for several makes. The results indicated that the accident rate within a given make tended to be lower for each model year than the rates for the preceding model year. The average overall accident rate of 30 makes was 8.47 per million vehicle miles for 1960 models, and 3.52 for 1966 models. On the other hand, there were no consistent differences in the overall accident rate among the various makes within a model year nor were there any clear differences according to size of vehicle. No statistical test was conducted.

In 1975, James O'Day and Richard Kaplan (10) compared fatal injury rates by vehicle size and by driver age. An equation P(F) = P(A) x P(F/A) was used to describe the probability of a driver being killed by an accident in a year. P(A) was gained from a survey conducted in 1970 (1341 accidents among 4221 individuals), and P(F/A) was obtained from the 1972 Texas accident file (1061 driver fatalities among 13,932 accidents). The definition of vehicle size was not given, but was dichotomized by designating standard model autos as "large," and compact and sports models as "small." Intermediate body styles were excluded.

The results showed that the probability of receiving a fatal injury was greater in small automobiles (P(F) = .000388) than in large automobiles (P(F) = .000183), and that the difference increased with age (.000605 for ages 55+ against .000183 for all ages). The results showed statistical significance for the difference in the fatal injury rate between large and small automobiles.

Also in 1975, P. L. Yu, C. Wrather and G. Kozmetsky (11) studied the relationship between vehicle weight and safety, using the data from the State of Texas for the year 1973. Passenger automobiles were classified into four classes.

1. Small automobiles 0-2999 pounds

2. Intermediate automobiles 3000-3999 pounds
3. Large automobiles 4000-5000 pounds
4. Super large automobiles > 5000 pounds

A sample of 1,204 accidents and 148 serious injury/or fatal accidents were broken down into weight classes along with the percentage distribution of the automobiles registered in that weight class in Texas for the year 1973.

The major findings were:

1. Larger automobiles had a much higher frequency of accident involvement.
2. Once an accident occurred, smaller automobiles had a slightly higher frequency of getting into a serious or fatal accident.
3. Overall, larger automobiles had a much higher frequency of getting into a serious injury, or fatal accident.

The results of 1 and 3 were found to be statistically significant.

Also in 1975, Leon S. Robertson and Susan P. Baker (12) examined motor vehicle related fatalities by vehicle size. Accident records of all reported fatalities in Maryland involving a motor vehicle during 1970 and 1971 were used.

Automobiles were classified by automobile-wheelbase in inches into five groups (105 or less, 106-110, 111-115, 116-120, and 121 or more). Fatal crash involvement rates per 100,000 registered vehicles were calculated by dividing the number of involved vehicles by the number registered for those five groups.

In single vehicle crashes, the smallest vehicles (105 inches or less) were involved at a rate almost three times the rate of the largest vehicles (121 inches or more), 12.0 compared to 4.1 per 100,000 registered vehicles.

In multiple vehicle crashes, the smallest vehicles were involved at a rate 12.6 compared to 7.2 for the largest. However, these results were not examined statistically.

In 1977, Amitabh K. Dutt, Donald W. Reinfurt, and Jance C. Stutts (13) investigated accident involvement and crash injury rate per million miles of vehicle travel by make, model and year of automobile. The accident and injury information was obtained from the North Carolina accident file over the period October 1973 through October 1974. The exposure data, derived from paired odometer readings recorded on a statewide sample of motor vehicle inspection receipts (approximately 300,000), were also obtained over the same period.

Passenger automobiles were classified into three major groups by make-model.

1. Full size automobiles (luxury, medium, and standard)
   Buick, Cadillac, Standard Ford, etc.

2 Middle-sized automobiles (intermediate, compact)
   Chevrolet Chevelle, Intermediate Ford, Ford Mustang, etc.

3. Small-sized automobiles (subcompact)
   Ford Pinto, Datsun, Toyota, VW Beetle, etc.

Calculations were given by:

$$\lambda_i = n_i/(M_i N_i) \times 10^6$$

where n_i = number of involvements of group i.

M_i = estimated annual mileage for group i.

N_i = estimated registration frequency for group i.

The overall or total accident rate showed a steady decline with newer model years (6.24 for 1960 models against 3.56 accidents per million vehicle miles for 1974 models for full-sized automobiles). Injury rates also showed a steady decline with newer model years (0.92 against 0.22). Full-sized automobiles showed far better rates than middle or small-sized automobiles for accident involvement and injury. This was particularly true for the newer model year (injury rate: 0.22 for full, 0.32 for middle and 0.57 for small for 1974 models). These results proved to be statistically significant.

In 1979, G. Grime and T. P. Hutchinson (14) studied relationships between fatal rates, injury severities and mass ratio of the vehicles involved in collisions. Accidents involving injury occurring in England during the years 1969 to 1972 were analyzed.

Vehicle weights were decoded into ten classes. Severities of injury were judged by comparing the percentages of fatal, serious and slight injury and of uninjured drivers. Analyses were separated for head-on and intersection, and for rural (speed limit more than 40 miles) and urban (elsewhere) areas.

They found that the mass ratio had the greatest effect on deaths. For example, the percentage of deaths in light vehicles was seven times that in heavier vehicles when there was a collision involving two vehicles with a mass ratio of 2. On the other hand, little or no effect of vehicle weight was found in single-vehicle accidents. No statistical test was conducted in this study.

In 1980, J. Richard Steward and Carol Lederhaus Carroll (15) updated and extended the previous study by A. K. Dutt and D. W. Reinfurt (1977). As in the previous study, this study estimated average annual mileage by automobile make and model year based on paired odometer readings obtained from motor vehicle inspection receipts. 1979 data obtained in North Carolina were studied and compared with previous results. Automobiles were classified into four automobile size categories - full sized, intermediate, compact, and subcompact.

Comparison with the previous study showed a much higher average annual mileage for relatively new subcompacts (under five years old) in 1979 than in 1974 or in 1975. Comparisons of accident rates averaged over the entire span of fourteen model years showed full sized automobiles to have significantly lower rates than intermediates and compacts. Rates for subcompacts were also significantly lower than those for intermediate and compacts. However, when averaged over the newer nine model years, full sized automobiles still had a lower rate than the other three classes, but those three did not differ significantly from one another. These results were examined statistically.

In 1982, Leonard Evans (16) estimated the relationship between vehicle mass and the likelihood of an occupany fatality. Data from the Fatal Accident Reporting System for 1978 (28687 occupants) were used to study both non-two automobile and two automobile accidents. Another set of data were prepared to determine the number of registered vehicles of the same mass having owners of the same age, using 1980 registration data from the State of Michigan and R. L. Polk.

Vehicle mass ranges were 500-900 kg, 900-1100 kg, 1100-1300 kg, 1300-1500 kg, 1500-1800 kg, and 1800-2400 kg. For non-two automobile accidents, numbers of fatalities by driver age and vehicle mass were divided by the estimated percentage of vehicles registered to obtain the likelihoods. To get the likelihood of an occupant fatality of two car accidents, the number of occupant fatalities in automobiles of mass M_1 in collisions with vehicles of mass M_2 was divided by assumed exposures which were derived from the results of non-two car accident data.

This study showed that the likelihood of a fatality in small vehicles (900 kg) was 1.5 times (non-two automobile accidents) or 3.4 times (two-automobile accidents) greater than that in large vehicles (1800 kg). The statistical significance was not examined.

In 1983, Leonard Evans (17) also studied the likelihood of involvement in a potentially fatal accident using a new method to account for exposure. He hypothesized that the likelihood of a pedestrian or a motorcyclist being killed in an accident does not depend on the mass of the automobile, and if a vehicle has more exposure, it has a greater probability of hitting a pedestrian or a motorcyclist. Thus, the number of pedestrians or motorcyclists killed in accidentes with vehicles of mass m can be used as the measure of exposure. Data from the Fatal Accident Reporting System for 1975 through 1980 combined were used to account for those fatalities. The likelihood of a driver fatality for small automobiles (900 kg) was 2.60 times that for large automobiles (1800 kg) with 99 percent confidence.

The aforementioned studies represent 20 years of attempting to advance the understanding of the relationship between vehicle size and accidents. Table 2.3 shows a summary of data elements from these studies. Seven out of 16 studies used vehicle weight as the definition of size. Another 7 studies used the make and model of automobiles while the remainder used the wheelbase and point system. Table 2.4 summarizes the contents of the studies. Related to these tables, Table 2.5 shows a summary of the results of 16 studies.

Nine reports are (in varying degree) related to the problem of injury and death resulting from an accident. These reports, without exception, conclude that the injury and death rate or severity of injury are higher in small

Table 2.3. Summary of Literature Review (Data Elements)

Year	Study Author	Sample Size	Data Year	Analyzed Data	Definition of Car Size
1963	N.Y. DMV	a	1962	N.Y.	Point System
1964	Solomon	10,000	1952-57	Rural	Make, Price, Year
1964	Kihlberg	12,835	1956-63	Inj. Rural	Weight
1969	Garrett	27,552	1952-66	Inj. Rural	V.W., Make, Model
1970	Compbell	270,000	1966, 68	N.C.	Make, Model
1973	O'Day	16,360	1968-70	Mich.	Weight
1974	Anderson	360	1973	Inj. N.Y.	Weight
1974	Reinfurt	a	1966, 68	N.C.	Make, Model, Year
1975	O'Day	1,061	1972	Fatal Tex.	Make, Model
1975	Yu	148	1973	Fatal Tex.	Weight
1975	Robertson	885	1970-71	Fatal Md.	Wheelbase
1977	Dutt	a	1973-74	N.C.	Make, Model, Year
1979	Grime	a	1969-72	England	Weight
1980	Steward	a	1979	N.C.	Make, Model, Year
1982	Evans	28,687	1978	Fatal	Weight
1983	Evans	a	1975-80	Fatal	Weight

a) Not provided in the article.

Table 2.4. Summary of Literature Review (Contents of Studies)

Author	Exposure Used	P(A)	P(F/A) or P(I/A)	P(F) or P(I)	Geometry
N.Y. DMV	Percentage Registered	No	No	No	(2)
Solomon	Veh-miles	Yes	No	Yes	No
Kihlberg	Inj. acc	No	Yes	No	No
Garrett	Inj. acc	No	Yes	No	No
Compbell	Acc	No	Yes	No	No
O'Day	Acc	No	Yes	No	No
Anderson	Acc	No	Yes	No	No
Reinfurt	Veh-miles	Yes	No	Yes	No
O'Day	Drivers	No	No	Yes	No
Yu	Registration	Yes	Yes	Yes	No
Robertson	Registration	No	No	Yes	No
Dutt	Veh-miles	Yes	No	Yes	No
Grime	Inj. acc	No	Yes	No	(3)
Stewart	Veh-miles	Yes	No	No	No
Evans	Registration	No	Yes	No	No
Evans	(1)	No	Yes	No	No

P(A) - Accident Involvement
P(F/A), P(I/A) - Fatality, Injury Rate by Accident
P(F), P(I) - Fatal, Injury Accident Involvement

(1) Pedestrian and motorcyclist killed.
(2) Percentages of accidents involving compact cars for various geometric design conditions compared to percentage of compact car registration.
(3) Urban, rural only.

Table 2.5. Summary of Literature Review (Results of Studies: Small cars were found to have the following characteristics)

		P(A)	P(F/A) or P(I/A)	P(F) or P(I)		Statistically Significant
N.Y. DMV	Accident Involvement Not Significant	N.S.				
Solomon	More injury, more accident involved, the newer the lower crash rate	Yes		Yes	1	
Kihlberg	Once involved accident, more injuries		Yes			
Garrett	Fatalities frequent among Volkswagen		Yes			Yes
Campbell	Severe injury, the newer model the less sever		Yes			Yes
O'Day	Once involved accident, more injuries		Yes			
Anderson	More intrusion		Yes			Yes
Reinfurt	Not significant, the newer model the lower crash rate	N.S.			1	
O'Day	Higher fatal injury rate			Yes		
Yu	Lower accident involvement higher injury or fatal rate	No	Yes	No		Yes
Robertson	Higher fatal injury rate			Yes		
Dutt	More injury, more accident involved the newer the less injury accident involved	Yes		Yes	1	Yes
Grime	More fatal injury, not significant for single accidents		Yes			
Stewart	Small, full size lower accident rate than intermediate, compact	No/ Yes			1	Yes
Evans	Higher fatal injury rate		Yes			
Evans	Higher fatal injury rate					Yes

N.S. - Not Significant

1 - Yes for Older Model

automobiles once involved in an accident.

The other reports are mainly relevant to the question of how often small automobiles are involved in an accident, or in an injury or fatal accident. These studies tended to disagree with each other. For accident involvement, two studies found small automobiles have a higher rate than larger automobiles, while one study found the opposite result, and two studies did not find any significant difference. For the injury or fatal accident involvement, four studies found small automobiles have a higher rate, while one study found the opposite result.

Four studies also examined the accident involvement rate for various model years. These studies found a consistant result, which is that older model year automobiles have the higher accident involvement rate.

The reviewer feels that the question of accident involvement requires a measure of exposure to the risk of an accident or injury accident, and because various measures have been used to quantify exposure, the results have been inconsistant. Little research was found which would contribute to an understanding of the effects of geometric design on vehicle size and accidents. The studies reviewed did not address the full range of geometric features.

3.0 PROBLEM STATEMENT

Previous analyses about the relationship between automobile design and accidents were associated mainly with crashworthiness during a collision. These studies genereally agree on the inferiority of small automobiles in relation to driver injury or death.

However, little information was given about the likelihood of small vehicles being involved in an accident. There is some argument about whether higher maneuverability and lower aggressivity of small vehicle drivers could offset the inferiority of their crashworthiness.

To determine the impact on highway safety caused by the increasing share of small automobiles, it must be determined if they have a unique risk of accident involvement. This problem necessitates a quantification of exposure. Various measurements have been used, including estimated vehicle miles, number of registered vehicles, and number of drivers. Nevertheless, none of these is available or appropriate when trying to examine accident rates under specific circumstances, such as on rainy days or by day of week; or at specific locations such as at intersections or in parking lots; or on roads with certain geometric design characteristics.

Traditional definitions of small automobiles are given by several criteria, although curbweight and wheelbase length are the two most commonly used. It has not yet been determined which is the most suitable indicator of characteristics of small automobiles.

Although a study to identify the relationship between vehicle design and accidents is important it is of equal importance to understand the relationship between highway geometry, vehicle design and accidents. In the past, little has been done in regards to highway design, partially because this relationship may be subtle and partially because appropriate measures of exposure were not available.

This study provides not only quantitative information on the impact of the changing population of small automobiles on highway safety, but also insight on the impact of small automobiles on accidents at selected highway geometric design features.

4.0 METHODOLOGY

The central theme of this study is the analysis of the relationship between highway geometric design and related automobile parameters with accidents being a measure of performance. The methodology consists of two parts.

The first part of the methodology involves an investigation of the variation in accident involvement and in injury accident involvement as related to these parameters. The second part extends the investigation to an examination of the relationship between automobile design, highway geometric design and accidents.

The methodology consists of the following steps.

1. Definition of vehicle parameters to be studied. The curb weight and the wheelbase were selected as the two parameters to define automobile size. To examine other possible factors in accident involvement, the model-year is also used.

2. Identification of information on automobile design. In the United States, each new vehicle sold is required to automobilery a Vehicle Identification Number (VIN). VIN's consist of unique alphanumeric strings of up to 17 characters assigned by manufacturers. VINs from the accident file of the Michigan Department of State Police (MSP Accident File) are utilized to obtain information on vehicle make, series, model, curb weight, wheelbase, and year of production. The VINDICATOR 83 program (18) is used

to decode VINs. Table 4.1 lists the make and model year span the VINDICATOR 83 handles. Examples of the output of VINDICATOR 83 are given in Figure 4.1.

3. Development of a new accident file (File 1). A standard accident report form has been used for many years to report accidents that occur in Michigan. Figure 4.2 is an example of the form that has been used since 1979 by all state and local agencies in Michigan. With this report, information on accident location, conditions, vehicles and drivers are put on record. The VIN numbers for the vehicles are also indicated. Vehicle number one is identified as the vehicle designated as responsible for initiating the accident and vehicle number two is the second vehicle in the accident.

When a copy of the accident report is sent to the Michigan Department of State Police (MSP), each report is given a unique number, called the Accident Report Number (AR). This number is attached to any accident file of the Department of State Police or the Department of Transportation to identify the accident.

As mentioned in step 2, VIN is extracted from the MSP Accident File. Figure 4.3 shows a description of this file. The necessary accident information is extracted from the Highway Accident Master Data of the Department of Transportation. Figure 4.4 shows the data file description of this file. These two pieces of information are combined by matching the AR and a new file is created (File 1) that has information for both accident data and vehicle design.

Table 4.1. VINDICATOR Data Available

MAKE VALUES	MAKE NAME	MODEL YEAR SPAN
1	Chevrolet	1967-1983
2	Ford	1967-1983
3	Pontiac	1967-1983
4	Buick	1967-1983
5	Plymouth	1967-1983
6	Oldsmobile	1967-1983
7	Dodge	1967-1983
8	Volkswagen	1967-1983
9	Mercury	1967-1983
10	Cadillac	1967-1983
11	American	1967-1983
12	Chrysler	1967-1983
13	Lincoln	1967-1983
14	Opel/Isuzu	1967-1979, 1981-1983
15	Datsun/Nissan	1967-1983
16	Toyota	1967-1983
17	Capri	1972-1977
18	Mazda	1967-1983
19	Fiat	1972-1983
20	Volvo	1972-1983
21	Audi	1972-1983
22	Dodge/Mitsubishi	1972-1983
23	Honda	1973-1983
24	Porsche	1972-1983
25	MG	1970-1980
26	Subaru	1972-1983
27	Plymouth/Mitsubishi	1976-1983
28	GM of Canada	1968-1983
29	Chevrolet Truck	1973-1983
30	GMC Truck	1972-1983
31	Ford Truck	1973-1983
32	Dodge Truck	1973-1983
33	Plymouth Truck	1975-1983
34	Jeep	1973-1983
35	International	1975-1983
36	Mercedes Benz	1981-1983
37	BMW	1981-1983
38	Renault	1981-1983
39	Saab	1981-1983
40	Peugeot	1981-1983
41	Triumph	1981
42	Ferrari	1981-1983
43	Lancia	1981-1982
44	Jaguar	1981-1983
45	Alfa Romeo	1981-1983
46	Rolls Royce	1981-1983
47	Bentley	1981-1983
48	Aston Martin	1981-1983
49	Delorean	1981-1982
50	Avanti	1981-1983
51	Mitsubishi	1983
52	Lotus	1981-1983

```
........................................................................................................

 INPUT: 75  31749 1  4  1D37H5140943G      (NO INYEAR SUPPLIED)
  IERR  AMBSW  ALTSW  MAKE  YEARF  YEARL SERIES  MODEL  BODY  RSTN ENGINE  TRANS WEIGHT  WHLBS  MINHP  MAXHP  MAXR  MINR
    0      0      0      1   1975   1975     19      6    34     0     28      0   3642    112    145    145  2511  2511
REMARK: NO ERRORS
  YEAR: 1975-1975              MODEL: MALIBU                    TRANS: NO DATA              WEIGHT: 3642
  MAKE: CHEVROLET               BODY: 2 DOOR HDTP  4-6 PSGR     WHLBS: 112                      HP: 145-145
SERIES: CHEVELLE 2D            ENGINE: 8-350-2V                RESTRN: NO DATA              WGT/HP: 25.11-25.11

........................................................................................................

 INPUT: 78  31749 2  7  8W82L237726        (NO INYEAR SUPPLIED)
  IERR  AMBSW  ALTSW  MAKE  YEARF  YEARL SERIES  MODEL  BODY  RSTN ENGINE  TRANS WEIGHT  WHLBS  MINHP  MAXHP  MAXR  MINR
    0      0      0      2   1978   1978     21      0    68     0      9      0   3122    110     97     97  3218  3218
REMARK: NO ERRORS
  YEAR: 1978-1978              MODEL: NO DATA                   TRANS: NO DATA              WEIGHT: 3122
  MAKE: FORD                    BODY: 4+DOOR SEDAN              WHLBS: 110                      HP:  97- 97
SERIES: GRANADA 4D             ENGINE: 6-250-1V 4.1L           RESTRN: NO DATA              WGT/HP: 32.18-32.18

........................................................................................................

 INPUT: 70  31750 1 12  354390M223935      (NO INYEAR SUPPLIED)
  IERR  AMBSW  ALTSW  MAKE  YEARF  YEARL SERIES  MODEL  BODY  RSTN ENGINE  TRANS WEIGHT  WHLBS  MINHP  MAXHP  MAXR  MINR
    0      0      0      6   1970   1970     14      0    72     0      4      0   4034    124    250    390  1613  1034
REMARK: NO ERRORS
  YEAR: 1970-1970              MODEL: NO DATA                   TRANS: NO DATA              WEIGHT: 4034
  MAKE: OLDSMOBILE              BODY: 4+DOOR HDTP               WHLBS: 124                      HP: 250-390
SERIES: DELTA-88 4D            ENGINE: 8-350/455-2/4V          RESTRN: NO DATA              WGT/HP: 10.34-16.13

........................................................................................................

 INPUT: 73  31750 2 12  3N69H3M513076      (NO INYEAR SUPPLIED)
  IERR  AMBSW  ALTSW  MAKE  YEARF  YEARL SERIES  MODEL  BODY  RSTN ENGINE  TRANS WEIGHT  WHLBS  MINHP  MAXHP  MAXR  MINR
    0      0      0      6   1973   1973     14      8    68     0     13      0   4313    124    160    160  2695  2695
REMARK: NO ERRORS
  YEAR: 1973-1973              MODEL: ROYALE                    TRANS: NO DATA              WEIGHT: 4313
  MAKE: OLDSMOBILE              BODY: 4+DOOR SEDAN              WHLBS: 124                      HP: 160-160
SERIES: DELTA-88 4D            ENGINE: 8-350-2V                RESTRN: NO DATA              WGT/HP: 26.95-26.95

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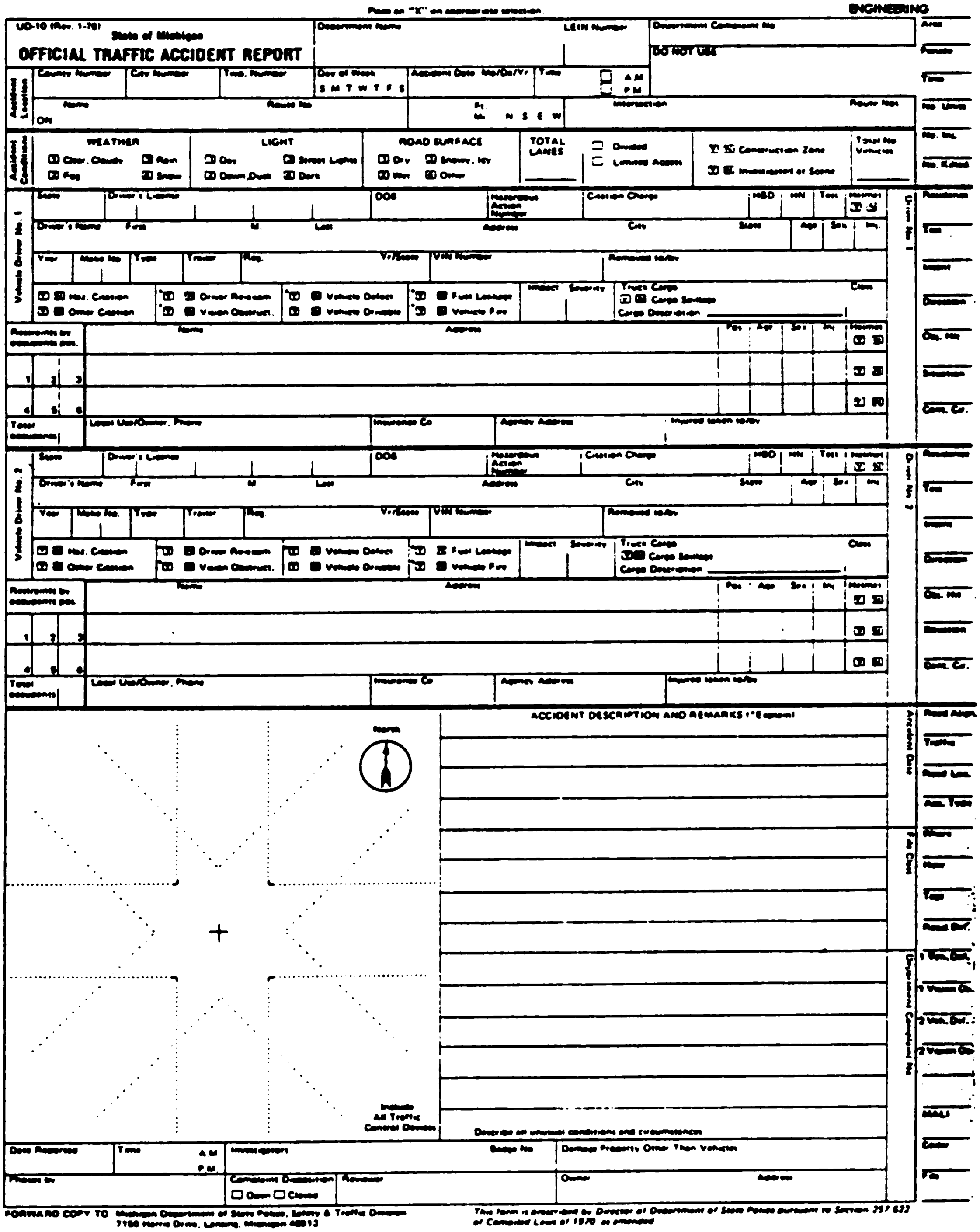
Figure 4.1. Sample Output from VINDICATOR 83



ENGINEERING

UD-10 (Rev. 1-78)

State of Michigan

OFFICIAL TRAFFIC ACCIDENT REPORT

DO NOT USE

S M T W T F S

AM

PM

ON

N S E W

WEATHER

LIGHT

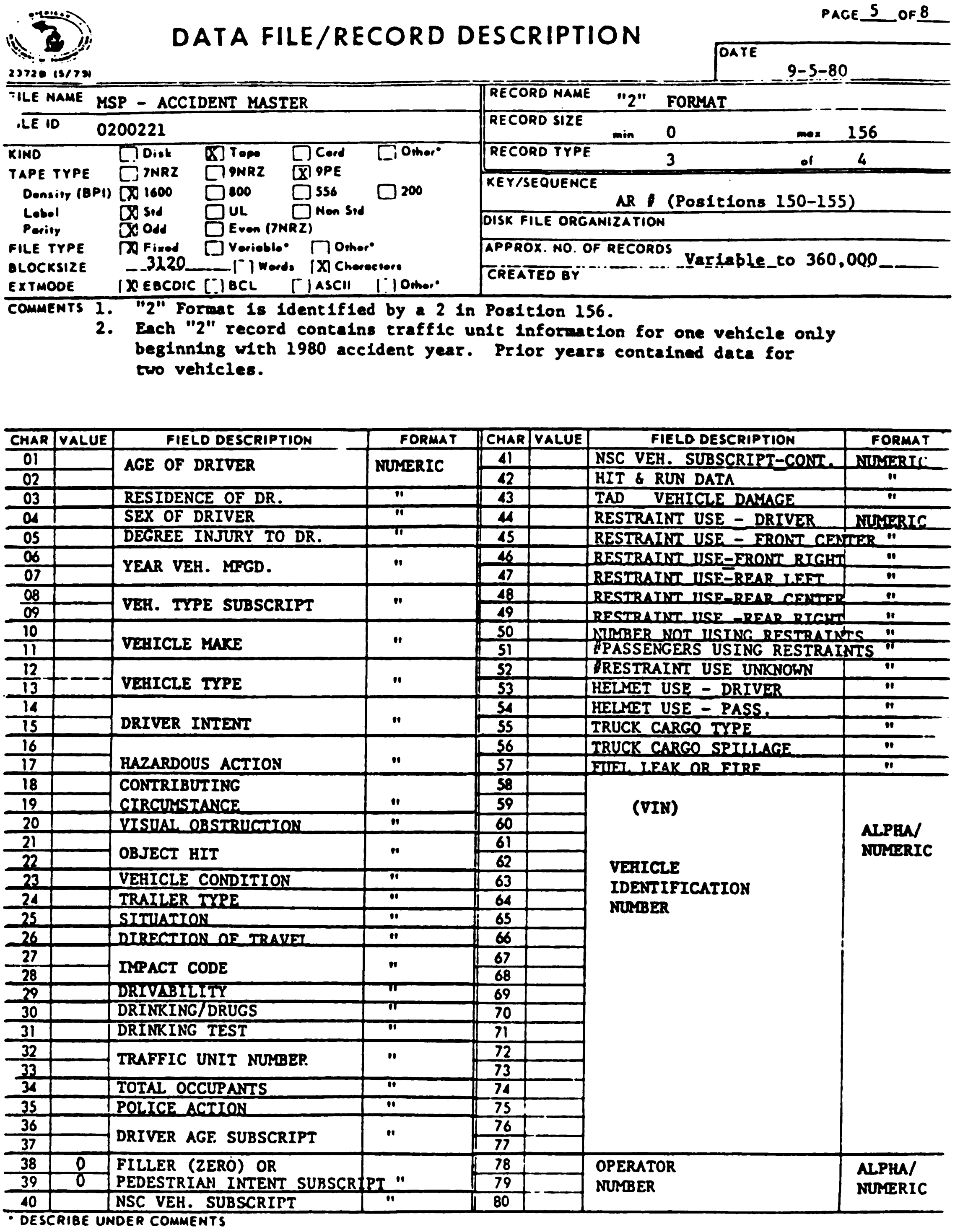
ROAD SURFACE

TOTAL LANES

DOB

ACCIDENT DESCRIPTION AND REMARKS

Figure 4.2. Accident Report Form used by Michigan Police Agencies



PAGE 5 OF 8

DATA FILE/RECORD DESCRIPTION

23728 (5/79)

DATE 9-5-80

FILE NAME MSP - ACCIDENT MASTER

FILE ID 0200221

KIND ☐ Disk ☒ Tape ☐ Card ☐ Other*

TAPE TYPE ☐ 7NRZ ☐ 9NRZ ☒ 9PE

Density (BPI) ☒ 1600 ☐ 800 ☐ 556 ☐ 200

Label ☒ Std ☐ UL ☐ Non Std

Parity ☒ Odd ☐ Even (7NRZ)

FILE TYPE ☒ Fixed ☐ Variable* ☐ Other*

BLOCKSIZE 3120 ☐ Words ☒ Characters

EXTMODE ☒ EBCDIC ☐ BCL ☐ ASCII ☐ Other*

RECORD NAME "2" FORMAT

RECORD SIZE min 0 max 156

RECORD TYPE 3 of 4

KEY/SEQUENCE AR # (Positions 150-155)

DISK FILE ORGANIZATION

APPROX. NO. OF RECORDS Variable to 360,000

CREATED BY

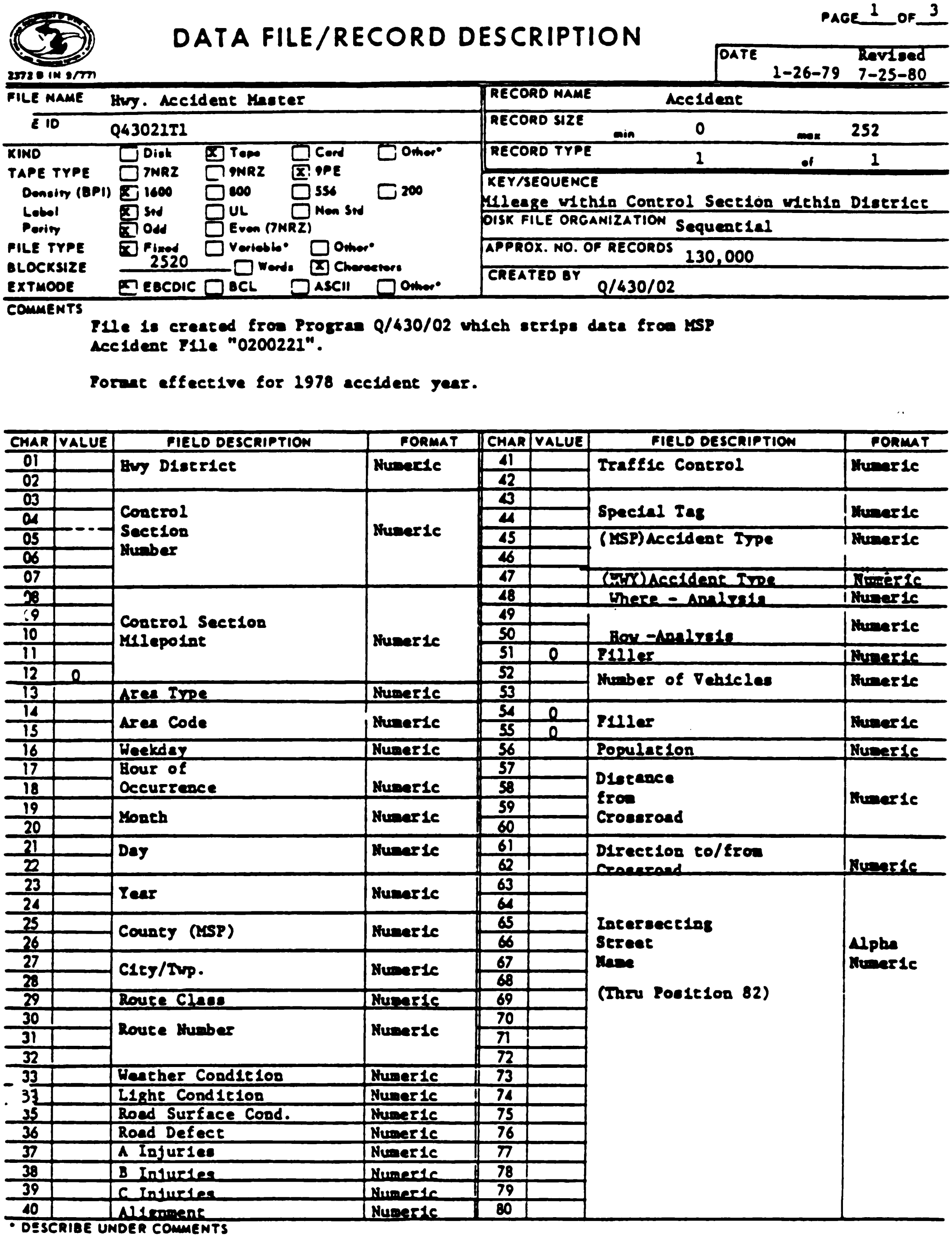
COMMENTS 1. "2" Format is identified by a 2 in Position 156.

2. Each "2" record contains traffic unit information for one vehicle only beginning with 1980 accident year. Prior years contained data for two vehicles.

CHAR	VALUE	FIELD DESCRIPTION	FORMAT	CHAR	VALUE	FIELD DESCRIPTION	FORMAT
01		AGE OF DRIVER	NUMERIC	41		NSC VEH. SUBSCRIPT-CONT.	NUMERIC
02				42		HIT & RUN DATA	"
03		RESIDENCE OF DR.	"	43		TAD VEHICLE DAMAGE	"
04		SEX OF DRIVER	"	44		RESTRAINT USE - DRIVER	NUMERIC
05		DEGREE INJURY TO DR.	"	45		RESTRAINT USE - FRONT CENTER	"
06		YEAR VEH. MFGD.	"	46		RESTRAINT USE-FRONT RIGHT	"
07				47		RESTRAINT USE-REAR LEFT	"
08		VEH. TYPE SUBSCRIPT	"	48		RESTRAINT USE-REAR CENTER	"
09				49		RESTRAINT USE -REAR RIGHT	"
10		VEHICLE MAKE	"	50		NUMBER NOT USING RESTRAINTS	"
11				51		#PASSENGERS USING RESTRAINTS	"
12	----	VEHICLE TYPE	"	52		#RESTRAINT USE UNKNOWN	"
13				53		HELMET USE - DRIVER	"
14		DRIVER INTENT	"	54		HELMET USE - PASS.	"
15				55		TRUCK CARGO TYPE	"
16		HAZARDOUS ACTION	"	56		TRUCK CARGO SPILLAGE	"
17				57		FUEL LEAK OR FIRE	"
18		CONTRIBUTING CIRCUMSTANCE	"	58		(VIN) VEHICLE IDENTIFICATION NUMBER	ALPHA/ NUMERIC
19				59			
20		VISUAL OBSTRUCTION	"	60			
21		OBJECT HIT	"	61			
22				62			
23		VEHICLE CONDITION	"	63			
24		TRAILER TYPE	"	64			
25		SITUATION	"	65			
26		DIRECTION OF TRAVEL	"	66			
27		IMPACT CODE	"	67			
28				68			
29		DRIVABILITY	"	69			
30		DRINKING/DRUGS	"	70			
31		DRINKING TEST	"	71			
32		TRAFFIC UNIT NUMBER	"	72			
33				73			
34		TOTAL OCCUPANTS	"	74			
35		POLICE ACTION	"	75			
36		DRIVER AGE SUBSCRIPT	"	76			
37				77			
38	0	FILLER (ZERO) OR PEDESTRIAN INTENT SUBSCRIPT	"	78		OPERATOR NUMBER	ALPHA/ NUMERIC
39	0			79			
40		NSC VEH. SUBSCRIPT	"	80			

* DESCRIBE UNDER COMMENTS

Figure 4.3. Accident File from Michigan Department of Transportation



2372 B IN 9/77

PAGE 1 OF 3

DATA FILE/RECORD DESCRIPTION

DATE 1-26-79 Revised 7-25-80

FILE NAME	Hwy. Accident Master
E ID	Q43021T1
KIND	☐ Disk ☒ Tape ☐ Card ☐ Other*
TAPE TYPE	☐ 7NRZ ☐ 9NRZ ☒ 9PE
Density (BPI)	☒ 1600 ☐ 800 ☐ 556 ☐ 200
Label	☒ Std ☐ UL ☐ Non Std
Parity	☒ Odd ☐ Even (7NRZ)
FILE TYPE	☒ Fixed ☐ Variable* ☐ Other*
BLOCKSIZE	2520 ☐ Words ☒ Characters
EXTMODE	☒ EBCDIC ☐ BCL ☐ ASCII ☐ Other*
RECORD NAME	Accident
RECORD SIZE	min 0 max 252
RECORD TYPE	1 of 1
KEY/SEQUENCE	Mileage within Control Section within District
DISK FILE ORGANIZATION	Sequential
APPROX. NO. OF RECORDS	130,000
CREATED BY	Q/430/02

COMMENTS

File is created from Program Q/430/02 which strips data from MSP Accident File "0200221".

Format effective for 1978 accident year.

CHAR	VALUE	FIELD DESCRIPTION	FORMAT	CHAR	VALUE	FIELD DESCRIPTION	FORMAT
01		Hwy District	Numeric	41		Traffic Control	Numeric
02				42			
03		Control Section Number	Numeric	43		Special Tag	Numeric
04	---			44			
05				45		(MSP)Accident Type	Numeric
06				46			
07				47		(HWY)Accident Type	Numeric
08		Control Section Milepoint	Numeric	48		Where - Analysis	Numeric
09				49		How -Analysis	Numeric
10				50			
11				51	0	Filler	Numeric
12	0			52		Number of Vehicles	Numeric
13		Area Type	Numeric	53			
14		Area Code	Numeric	54	0	Filler	Numeric
15				55	0		
16		Weekday	Numeric	56		Population	Numeric
17		Hour of Occurrence	Numeric	57		Distance from Crossroad	Numeric
18				58			
19		Month	Numeric	59			
20				60			
21		Day	Numeric	61		Direction to/from Crossroad	Numeric
22				62			
23		Year	Numeric	63		Intersecting Street Name (Thru Position 82)	Alpha Numeric
24				64			
25		County (MSP)	Numeric	65			
26				66			
27		City/Twp.	Numeric	67			
28				68			
29		Route Class	Numeric	69			
30		Route Number	Numeric	70			
31				71			
32				72			
33		Weather Condition	Numeric	73			
34		Light Condition	Numeric	74			
35		Road Surface Cond.	Numeric	75			
36		Road Defect	Numeric	76			
37		A Injuries	Numeric	77			
38		B Injuries	Numeric	78			
39		C Injuries	Numeric	79			
40		Alignment	Numeric	80			

* DESCRIBE UNDER COMMENTS

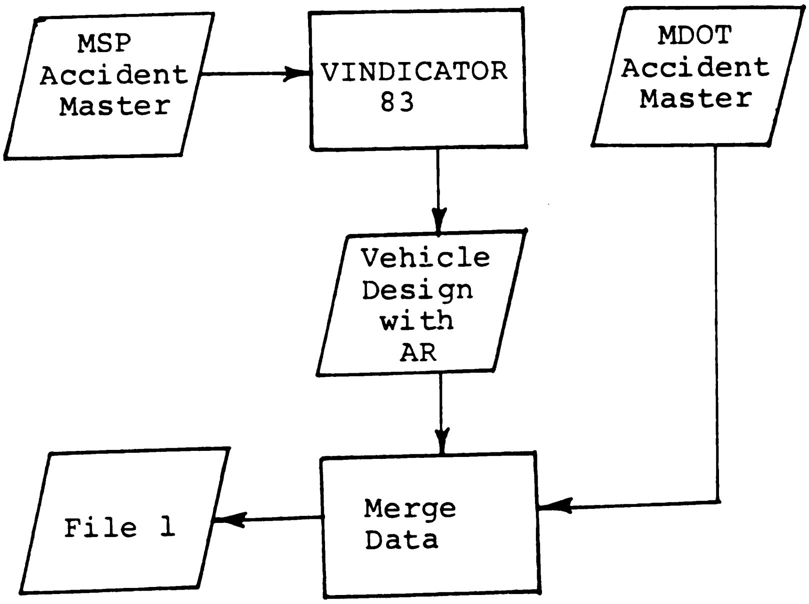
Figure 4.4. Michigan Department of Transportation Master Accident File

2372 B-R (9/77) *Not on all files PAGE 2 OF 3

CHAR	VALUE	FIELD DESCRIPTION	FORMAT	CHAR	VALUE	FIELD DESCRIPTION	FORMAT
81		-continued-	Alpha Numeric	141	0	Filler	Numeric
82				142	0		
83		No. of "0" Injuries	Numeric	143		Vehicle #3-Subscript	Numeric
84				144			
85		Vehicle #1-Subscript	Numeric	145		Vehicle #3-Make	Numeric
86				146			
87		Vehicle #1-Make	Numeric	147		Driver #3-Age	Numeric
88				148			
89		Driver #1-Age	Numeric	149		Driver #3-Residence	Numeric
90				150		Driver #3-Sex	Numeric
91		Driver #1-Residence	Numeric	151		Driver #3-Injury	Numeric
92		Driver #1-Sex	Numeric	152		Driver #3-Intent	Numeric
93		Driver #1-Injury	Numeric	153			
94		Driver #1-Intent	Numeric	154		Violation #3	Numeric
95				155			
96		Violation #1	Numeric	156		Circumstance #3	Numeric
97				157			
98		Circumstance #1	Numeric	158		Restraint Usage #3	Numeric
99				159		Vision Obstruction #3	
100		Restraint Usage #1	Numeric	160		Vehicle #3-Direction	Numeric
101		Vision Obstruction #1		161		Driver #3-Drinking	Numeric
102		Vehicle #1-Direction	Numeric	162		Vehicle #3-Object Hit	Numeric
103		Driver #1-Drinking	Numeric	163			
104		Vehicle #1-Object Hit	Numeric	164		Situation #3	Numeric
105				165		Vehicle #3-Type	Numeric
106		Situation #1	Numeric	166			
107		Vehicle #1-Type	Numeric	167		Impact Code #3	Numeric
108				168		Vehicle #3-Condition	Numeric
109		Impact Code #1	Numeric	169		Trailer #3	Numeric
110		Vehicle #1-Condition	Numeric	170	0	Filler	Numeric
111		Trailer #1	Numeric	171	0		
112	0	Filler	Numeric	172	0		
113	0			173		*Road Type	Numeric
114		Vehicle #2-Subscript	Numeric	174		*Number Lanes	Numeric
115				175		*Average Daily Traffic (T.V.M.)	Numeric
116		Vehicle #2-Make	Numeric	176			
117				177			
118		Driver #2-Age	Numeric	178			
119				179			
120		Driver #2-Residence	Numeric	180			
121		Driver #2-Sex	Numeric	181		Number of Fatalities	Numeric
122		Driver #2-Injury	Numeric	182			
123		Driver #2-Intent	Numeric	183		Number of Injuries	Numeric
124				184			
125		Violation #2	Numeric	185	0	Filler	Numeric
126				186		Number of Occupants	Numeric
127		Circumstance #2	Numeric	187			
128				188		Location	Numeric
129		Restraint Usage #2	Numeric	189	0	Filler	Numeric
130		Vision Obstruction #2		190	0		
131		Vehicle #2-Direction	Numeric	191	0		
132		Driver #2-Drinking	Numeric	192	0		
133		Vehicle #2-Object Hit	Numeric	193	0		
134				194	0	Reserved/Future AR	Numeric
135		Situation #2	Numeric	195		Accident Report Number	Numeric
136		Vehicle #2-Type	Numeric	196			
137				197			
138		Impact Code #2	Numeric	198			
139		Vehicle #2-Condition	Numeric	199			
140		Trailer #2	Numeric	200			

PNH 1-26-79 MDOT

Figure 4.4. (continued)



This study considers vehicle number one (VEH #1) and vehicle number two (VEH #2) only.

4. <u>Classification of passenger automobiles by design</u>. The curb weight, wheelbase, and model year of passenger automobiles involved in accidents in 1982, were first examined using the accident file for Calhoun County. Fig. 4.5 shows the relationship of the curb weight and the wheelbase for these automobiles.

Passenger automobiles are classified into seven classes by their curb weights or by the wheelbase.

CURB WEIGHT

(1) less than 2000 lbs.
(2) 2000-2499 lbs.
(3) 2500-2999 lbs.
(4) 3000-3499 lbs.
(5) 3500-3999 lbs.
(6) 4000-4499 lbs.
(7) 4500 lbs. or more

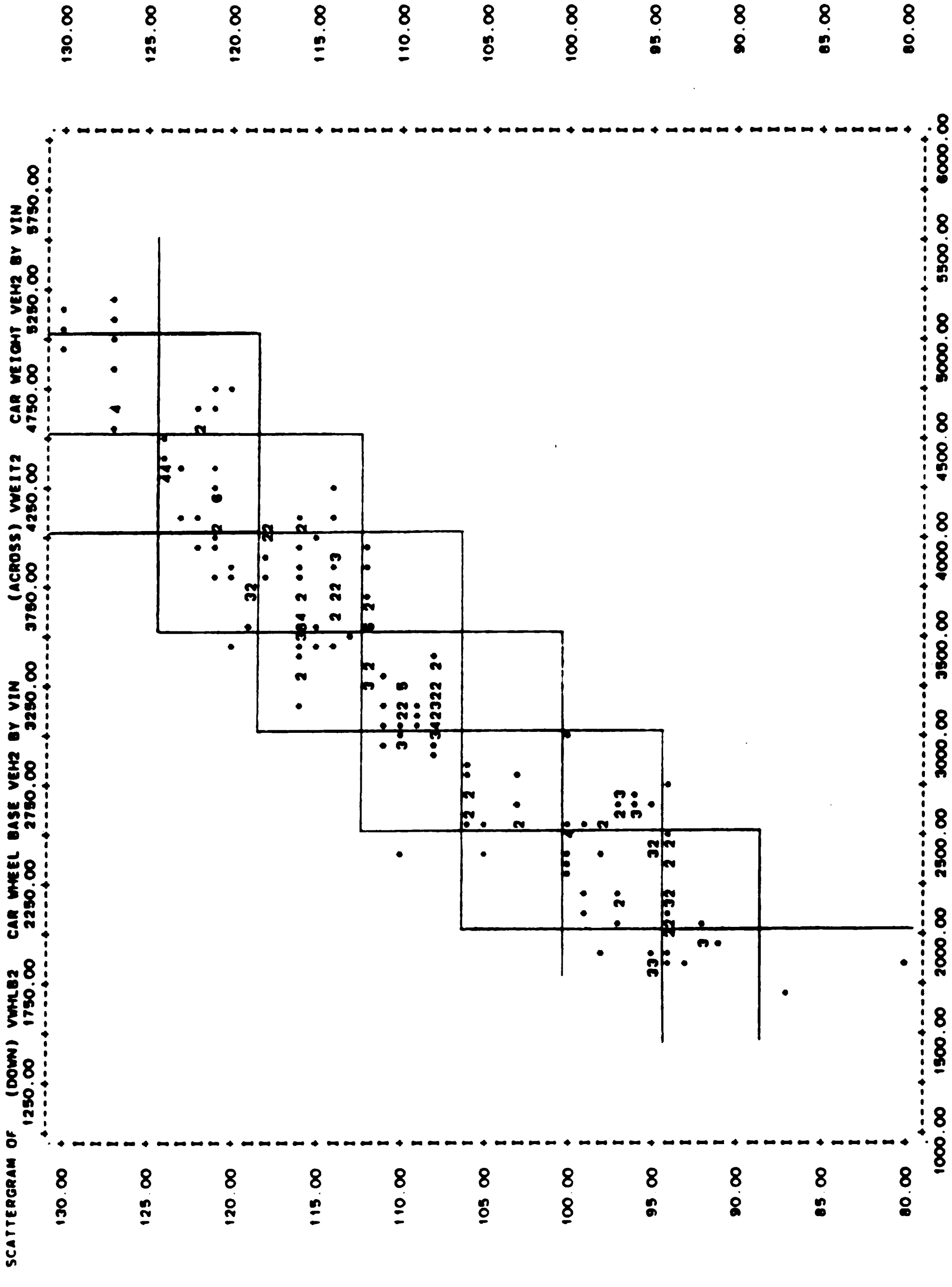


Figure 4.5. Relationship between Vehicle Weight and Wheelbase

WHEELBASE

(8) less than 95 inches
(9) 95-100 inches
(10) 101-106 inches
(11) 107-112 inches
(12) 113-118 inches
(13) 119-124 inches
(14) 125 inches or more

MODEL YEAR

(15) 1972 or older
(16) 1973
(17) 1974
(18) 1975
(19) 1976
(20) 1977
(21) 1978
(22) 1979
(23) 1980
(24) 1981
(25) 1982

The model year is used to classify vehicles into 11 groups (1972-1982). Those automobiles older than 1972 are classified as 1972. Fig. 4.6 shows the relationship of the model year and the curb weight of automobiles involved in accidents in Calhoun County.

5. Acquisition of the number of accidents and injury accidents associated with automobile design. Only accidents which involved passenger automobiles are used in the analyses. The passenger automobile data is then broken down by curb weight, wheelbase, and model year. The accidents are cross tabulated by location, weather condition, age, sex of driver, road surface condition, and accident type for each classification category.

To eliminate problems due to a difference in the number of occupants by different automobile designs, only

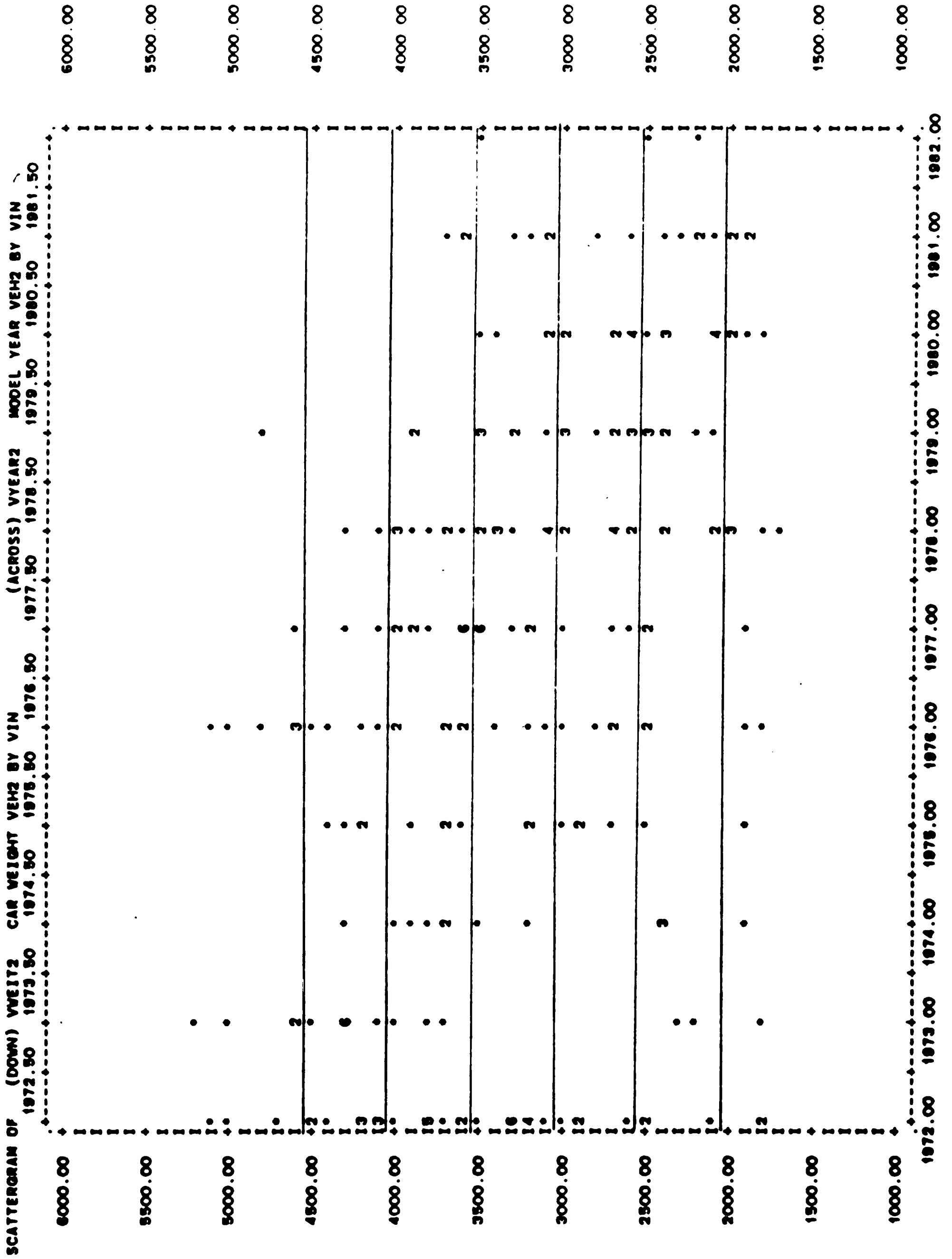


Figure 4.6. Relationship between Model Year and Vehicle Weight

the drivers are considered when recording injuries.

Fatal, incapacitating, non-incapacitating, and possible injury of drivers are considered as the injury classifications.

6. Determination of the exposure associated with automobile design. In the present study a new exposure approach is used. Hypotheses are made as follows:

1. The likelihood of being an object (the second vehicle) of an accident is proportional to the exposure.
2. The likelihood of being an object of an accident is common to any design if the exposure is the same.

The basis of the first hypothesis is if an automobile is driven for a longer time or a longer distance, it will have a larger risk of being involved as the VEH #2. For example, any automobile, regardless of its design characteristics, could be hit by another vehicle while stopping on a red signal at an intersection. The number of times a vehicle must stop on a red signal is proportional to the number of miles driven (and on what roads the driving takes place) in that vehicle. Thus, the number of times a vehicle is involved in an accident as the VEH #2 is a direct measure of exposure.

The basis of the second hypothesis is since this study is concerned with passenger automobiles only, we infer that there would be no difference in the likelihood of being hit regardless of whether the automobile is small or large.

We assume, for instance, when a vehicle is involved in a rear-end accident with an automobile which has stopped on red, the risk of the automobile being hit would not be related to its size. These two hypotheses imply that the number of VEH #2 accidents of automobiles with some design (D1) should be proportional to the exposure of these automobiles. All accidents in which a passenger automobile was involved as VEH #2 are considered for the exposures.

The likelihood of a VEH #1 accident for an automobile with design (D1) is equal to the total accidents multiplied by VEH #2 class D1 relative to all VEH #2 accidents:

$$E[\text{VEH \#1, Class D1}] = \text{Total Accidents} \times \frac{\text{VEH \#2, Class D1}}{\text{Total VEH \#2}} \tag{1}$$

Dividing the number of VEH #1, Class D1 accidents by both sides of equation 1, we have the following.

$$\frac{\text{VEH \#1, Class D1}}{E[\text{VEH \#1, Class D1}]} = \frac{\text{Total VEH \#2}}{\text{Total Accidents}} \times \frac{\text{VEH \#1, Class D1}}{\text{VEH \#2, Class D1}} \tag{2}$$

Equation 2 is the ratio of the actual number of accidents to the expected number of accidents for automobiles of class D1. This ratio will be referred to as the A/E ratio in this paper. Likewise, the expected number of injury accidents is equal to the total injury accidents multiplied by VEH #2 Class D1 relative to all VEH #2 accidents.

$$E[\text{Injury Acc. Class D1}] = \text{Total Injury Acc.} \times \frac{\text{VEH \#2, Class D1}}{\text{Total VEH \#2}} \tag{3}$$

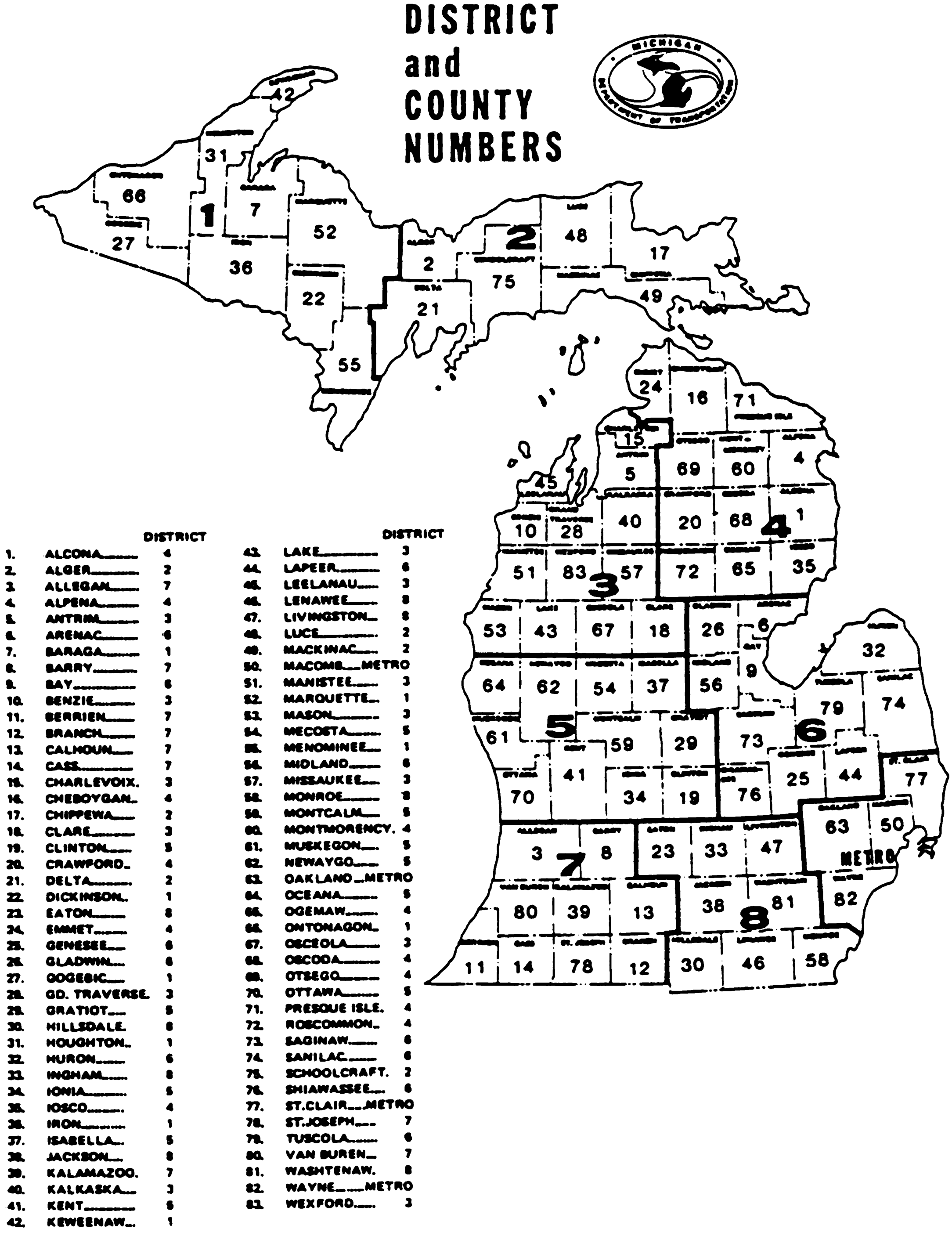
Dividing the number of injury accidents of Class D1 by both sides of the equation 3, the ratio of the actual number of injury accidents to the expected number of injury accidents for automobiles of Class D1 is expressed as follows.

$$\frac{\text{Injury Acc. Class D1}}{\text{E[Injury Acc. Class D1]}} = \frac{\text{Total VEH \#2}}{\text{Total Injury Acc.}} \times \frac{\text{Injury Acc. Class D1}}{\text{VEH \#2, Class D1}} \tag{4}$$

The accident file used in this study includes the information for both VEH #1 and VEH #2. This permits the analysis of accident rates and injury accident rates by various automobile designs for various kinds of accidents.

This same analysis can be used to compare the actual and expected number of accidents for any given geometric characteristic, vehicle characteristic or location, by defining Class D1 to be the parameter to be studied.

7. <u>Development of accident File 2</u>. The Michigan Department of Transportation has divided 83 counties into nine districts. Figure 4.7 is a map of Michigan illustrating the location of each county and the nine districts. Each state trunkline in each county is assigned a unique number and mileage point (distance in miles along the route from the point of origin of the control section to the point in question). Figure 4.8 is an example of a control section map. This control section is further divided into segments with respect to the geometric



		DISTRICT
1.	ALCONA	4
2.	ALGER	2
3.	ALLEGAN	7
4.	ALPENA	4
5.	ANTRIM	3
6.	ARENAC	6
7.	BARAGA	1
8.	BARRY	7
9.	BAY	6
10.	BENZIE	3
11.	BERRIEN	7
12.	BRANCH	7
13.	CALHOUN	7
14.	CASS	7
15.	CHARLEVOIX.	3
16.	CHEBOYGAN	4
17.	CHIPPEWA	2
18.	CLARE	3
19.	CLINTON	5
20.	CRAWFORD	4
21.	DELTA	2
22.	DICKINSON.	1
23.	EATON	8
24.	EMMET	4
25.	GENESEE	6
26.	GLADWIN	6
27.	GOGEBIC	1
28.	GD. TRAVERSE.	3
29.	GRATIOT	5
30.	HILLSDALE.	8
31.	HOUGHTON	1
32.	HURON	6
33.	INGHAM	8
34.	IONIA	5
35.	IOSCO	4
36.	IRON	1
37.	ISABELLA	5
38.	JACKSON	8
39.	KALAMAZOO.	7
40.	KALKASKA	3
41.	KENT	5
42.	KEWEENAW	1
43.	LAKE	3
44.	LAPEER	6
45.	LEELANAU	3
46.	LENAWEE	8
47.	LIVINGSTON	8
48.	LUCE	2
49.	MACKINAC	2
50.	MACOMB	METRO
51.	MANISTEE	3
52.	MARQUETTE	1
53.	MASON	3
54.	MECOSTA	5
55.	MENOMINEE	1
56.	MIDLAND	6
57.	MISSAUKEE	3
58.	MONROE	8
59.	MONTCALM	5
60.	MONTMORENCY.	4
61.	MUSKEGON	5
62.	NEWAYGO	5
63.	OAKLAND	METRO
64.	OCEANA	5
65.	OGEMAW	4
66.	ONTONAGON	1
67.	OSCEOLA	3
68.	OSCODA	4
69.	OTSEGO	4
70.	OTTAWA	5
71.	PRESQUE ISLE.	4
72.	ROSCOMMON	4
73.	SAGINAW	6
74.	SANILAC	6
75.	SCHOOLCRAFT.	2
76.	SHIAWASSEE	6
77.	ST.CLAIR	METRO
78.	ST.JOSEPH	7
79.	TUSCOLA	6
80.	VAN BUREN	7
81.	WASHTENAW.	8
82.	WAYNE	METRO
83.	WEXFORD	3

Figure 4.7. Michigan Highway Districts

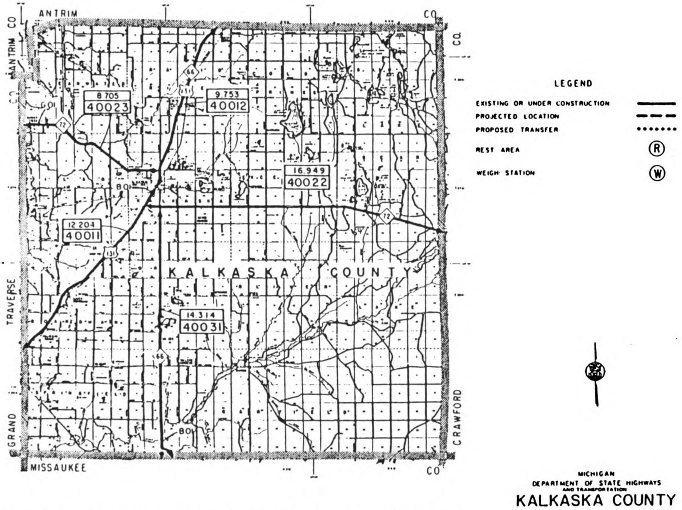
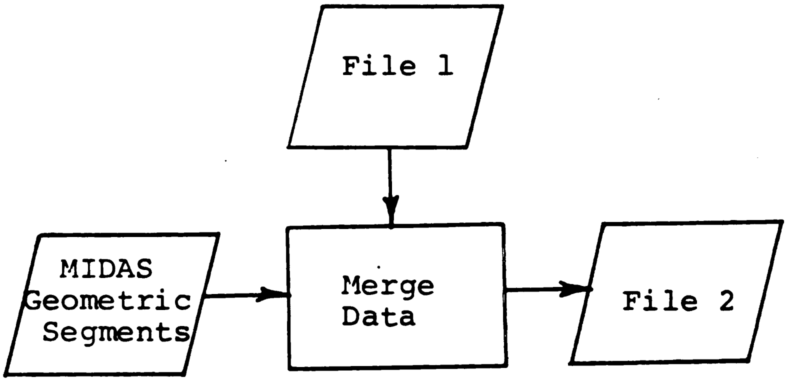


Figure 4.8. Control Section Map for Kalkaska Co. Michigan

elements. There are 28,213 segments for trunklines in Michigan.

Information on geometric features and operational controls of the at-grade trunkline system in the State of Michigan are available on the MIDAS Segment File of the Michigan Department of Transportation. Figure 4.9 shows the data file description of a MIDAS Segment File. This file has the beginning milepoint and the ending milepoint of a segment.

File 1 developed in step 3 and the MIDAS Segment File are combined by matching the milepoint of the accident site and the milepoint of the highway segment.



This file provides not only information on the accident but also information on the geometric features and operational control for each accident occurring on the trunkline system.

8. <u>Determination of the relationship between vehicle design, geometric design of the highway, and accidents.</u>

DATA FILE RECORD DESCRIPTION
MIDASII/SEGMENT

			BEGIN COL	FORMAT
	REFERENCE SYSTEM DATA SET			
01	HIGHWAY DISTRICT		01	I1
02	HIGHWAY CONTROL SECTION NUMBER		02	I5
03	SEGMENT NUMBER		07	I6
04	DATA FLAG		13	I2
05	BEGIN MILEPOINT of SEGMENT	(PHOTOLOG)	15	I4
	or MILEPOINT of INTERSECTION	(PHOTOLOG)		
06	END MILEPOINT of SEGMENT	(PHOTOLOG)	19	I4
	or MILEPOINT of INTERSECTION	(PHOTOLOG)		
07	BEGIN MILEPOINT of SEGMENT	(MALI)	23	I4
	or MILEPOINT of INTERSECTION	(MALI)		
08	END MILEPOINT of SEGMENT	(MALI)	27	I4
	or MILEPOINT of INTERSECTION	(MALI)		
	SEGMENT FEATURES DATA SET			
09	LANEAGE CODE		31	I2
10	LANE WIDTH		33	I2
11	SHOULDER WIDTH CODE		35	I2
12	POSTED SPEED LIMIT		37	I1
13	ROADSIDE DEVELOPMENT CODE		39	I1
14	NO PASSING ZONE CODE		40	I1
15	TRUCK CLIMBING LANE CODE		41	I1
16	DELTA ANGLE (DEGREES, MINUTES)		42	I3, I2
17	CURVE CODE		47	I1
18	DEGREE OF CURVE (DEGREES, MINUTES)		48	I2, I2
19	BEARING (DIR., DEGREES, MINUTES, DIR.)		52	I1, 2I2, I1
20	DIRECTION : TRUNKLINE APPROACH LEG		58	I1
21	DIRECTION : TRUNKLINE DEPARTURE LEG		59	I1
	INTERSECTION DATA SET			
22	BEGIN MILEPOINT INFLUENCE AREA	(PHOTOLOG)	60	I4
23	END MILEPOINT INFLUENCE AREA	(PHOTOLOG)	64	I4
24	BEGIN MILEPOINT INFLUENCE AREA	(MALI)	68	I4
25	END MILEPOINT INFLUENCE AREA	(MALI)	72	I4
26	SIGNAL CODE		76	I1
27	INTERSECTION TYPE CODE		77	I1
28	NUMBER OF LEGS		78	I1
29	NUMBER OF AUXILIARY LANES - RIGHT		79	I1
30	NUMBER OF AUXILIARY LANES - LEFT		80	I1
31	NO TURN ON RED CODE		81	I1
32	ALL RED CLEARANCE PHASE CODE		82	I1
33	LEFT TURN CODE		83	I1
34	LEFT TURN CONTROL - BY APPROACH		84	3I1 x 4

Figure 4.9. MIDAS Segment Record

DATA FILE RECORD DESCRIPTION
MIDASII/SEGMENT

		BEGIN COL	FORMAT
	ROUTE DATA SET		
35	TRUNKLINE ENGLISH DESCRIPTION	96	X12
36	CROSSROAD ENGLISH DESCRIPTION	108	X18
37	TOWNSHIP ENGLISH DESCRIPTION	126	X12
38	ROUTE HOURLY CAPACITY, 10's	138	I4
39	ROUTE AVERAGE DAILY TRAFFIC (ADT), 10's	142	I5
	ACCIDENT SUMMARY DATA SET		
	ALL - ACCIDENTS		
40	No. TOTAL ACCIDENTS	147	I3
41	No. INJURY ACCIDENTS	151	I3
42	No. FATAL ACCIDENTS	154	I3
43	No. WET ACCIDENTS	157	I3
44	No. ICY ACCIDENTS	160	I3
45	No. DARK ACCIDENTS	163	I3
46	No. DAWN/DUSK ACCIDENTS	156	I3
	MULTIPLE - VEHICLE - ACCIDENTS		
47	No. HEAD-ON ACCIDENTS	169	I3
48	No. SIDESWIPE - MEETING ACCIDENTS	172	I3
49	No. SIDESWIPE - PASSING ACCIDENTS	175	I3
50	No. RIGHT ANGLE ACCIDENTS	178	I3
51	No. LEFT TURN ACCIDENTS	181	I3
52	No. RIGHT TURN ACCIDENTS	184	I3
53	No. REAR-END ACCIDENTS	187	I3
54	No. BACKED-INTO ACCIDENTS	190	I3
55	No. PARKING ACCIDENTS	193	I3
56	No. OTHER ACCIDENTS	196	I3
	SINGLE - VEHICLE - ACCIDENTS		
57	No. PEDESTRIAN ACCIDENTS	199	I3
58	No. FIXED/OTHER OBJECT ACCIDENTS	202	I3
59	No. BICYCLE/PEDALCYCLE ACCIDENTS	205	I3
60	No. PARKED VEHICLE ACCIDENTS	208	I3
61	No. OTHER ACCIDENTS	211	I3
62	STATISTICAL OUTLIER CODE	214	I1

Figure 4.9. (continued)

Steps 4 through 6 are implemented again for File 2. This procedure enables us to obtain the ratio of the actual number of accidents to the expected number of accidents for automobiles of Class D1 at a specific geometric design or at a specific operational control.

The expected number of accidents involving VEH #1, Class D1 at a geometric feature (G1) is equal to the total accidents multiplied by VEH #2, Class D1 or G1 relative to all VEH #2 accidents on G1.

$$E[\text{VEH \#1, Class D1 on G1}] = (\text{Total Accidents on G1}) \times \frac{\text{VEH \#2, Class D1 on G1}}{\text{Total VEH \#2 on G1}} \qquad (5)$$

Dividing the number of VEH #1, Class D1 accidents on G1 by both sides of the equation 5, we have the following.

$$\frac{\text{VEH \#1, Class D1}}{E[\text{VEH \#1, Class D1}]}_{\text{on G1}} = \frac{\text{Total VEH \#2 on G1}}{\text{Total Acc. on G1}} \times \frac{\text{VEH \#1, Class D1 on G1}}{\text{VEH \#2, Class D1 on G1}} \qquad (6)$$

Vehicles of design D1 are over represented at location G1 if the A/E ratio from equation 6 is no greater than 1.0. This ratio is the measure used to determine the relationship between automobile size and both location and highway geometric features.

5.0 DATA BASE

Data for this study are based on police reported accidents that occured in Michigan in 1982. An accident file of the Michigan Department of State Police (MSP Accident File) and the Highway Accident Master Data File of the Michigan Department of Transportation were used to gain accident information. An accident report is submitted by the police agencies if someone is injured or killed, or if property damage exceeds $100.00.

The Michigan Department of State Police keeps all reported accident data, and the Michigan Department of Transportation keeps reported accident data for those accidents which occurred on the Interstate system and the Michigan Trunkline system. This study obtains the VIN number from the MSP Accident File and the other accident information from the Highway Accident Master Data File. Only accidents which occurred on the Interstate system or on the Michigan trunkline system in 1982 were studied.

In 1982, 101,663 total accidents occurred on the Michigan trunkline and Interstate systems. Of this total, only accidents involving at least one passenger car are analyzed in this study with truck and motorcycle accidents discarded. A total of 77,306 accidents involve an automobile as VEH #1 and 55,978 accidents involve an automobile as VEH #2 while some accidents involve more than two vehicles, this study considers VEH #1 and VEH #2 only.

VINDICATOR 83 decodes the VINs. Three specific design characteristics were extracted - curb weight, wheelbase, and model year of automobile. More than 70 percent of the automobiles involved as VEH #1 and VEH #2 were decoded by the VINDICATOR 83. The remaining 30 percent could not be decoded because of missing or incorrect data.

The 70 percent provides a data base for curb weight grouping of 51,740 automobiles identified as VEH #1 and 38,284 automobiles identified as VEH #2. The data base includes 51,830 VEH #1 and 38,340 VEH #2 entries for wheelbase grouping, and 54,896 VEH #1 and 40,526 VEH #2 entries for the model year grouping. This data is used to examine the relationship between automobile design and accidents.

Accidents which occurred on the trunkline system are utilized to study the relationship between the geometric design of the highway, vehicle design, and accidents. The MIDAS Segment File of the Michigan Department of Transportation is used to obtain information on geometric features and operational controls of the trunkline system. There were 75,314 accidents which occurred on the trunkline system. Among these, 38,828 identified as VEH #1, and 29,996 identified as VEH #2 were decoded.

This study counts a VEH #1 accident if VEH #1 is identified as a passenger automobile regardless of the type of VEH #2. Single automobile accidents are counted as VEH #1 accidents also. The same concept is used to count VEH #2 accidents, except there are no single vehicle accidents in this category.

6.0 VALIDATION OF THE NEW EXPOSURE APPROACH

The present study uses a new exposure approach based on two hypotheses:

1. The likelihood of being an object (the second vehicle) of an accident is proportional to the exposure of that vehicle..
2. The likelihood of being an object of an accident is common to any vehicle design if the exposure is the same.

These hypotheses imply that the number of VEH #2 accidents should be proportional to the exposure of any class of automobile. This exposure approach permits an estimate of the exposure of various classes of automobiles if the accident data are available. For instance, having the number of VEH #2 accidents for female drivers and male drivers, a comparison of the exposure between female and male drivers can be determined. Other examples would be a comparison of exposure among driver age groups, and a comparison of the exposure among different sizes of automobiles by age of driver or sex..

Figure 6.1 shows the number of VEH #2 accidents by sex of driver which occurred in Calhoun County in 1982. The exposure between female and male drivers as 154 to 225, respectively. Figure 6.2 shows a similar distribution of the number of VEH #1 accidents by curb weight.

The first hypothesis implicit in the new exposure approach is that the exposure of automobiles for any design (D1) is proportional to the likelihood of VEH #2 being

```
SEX2       SEX OF DRIVER VEH2
      CODE
            I
        1.  ************************ (    225)
            I  MALE
            I
            I
        2.  **************** (    154)
            I  FEMALE
            I
            I.........I.........I.........I.........I.........I
            0        100       200       300       400       500
            FREQUENCY

VALID CASES      379
```

Figure 6.1. Accidents in Calhoun Co. by Sex of Driver of VEH #2

```
VWEIT2     CAR WEIGHT VEH1 BY VIN

            I
        2.  ****** (    19)
            I  1500-1999 LBS
            I
            I
        3.  ********* (    31)
            I  2000-2499 LBS
            I
            I
        4.  *********** (    41)
            I  2500-2999 LBS
            I
            I
        5.  ************* (    47)
            I  3000-3499 LBS
            I
            I
        6.  **************** (    59)
            I  3500-3999 LBS
            I
            I
        7.  ******** (    29)
            I  4000-4499 LBS
            I
            I
        8.  ****** (    20)
            I  4500 LBS OR MORE
            I
            I.........I.........I.........I
            0        40        80       120
            FREQUENCY

VALID CASES      379
```

Figure 6.2. Accidents in Calhoun Co. by Weight of VEH #1

involved in an accident. The difference between this exposure measure and the commonly used measure which assumes the exposure is proportional to the number of automobiles registered was investigated.

Table 6.1 shows the distribution of automobiles registered by curb weight in Ingham County in 1981.

Table 6.1. Distribution of Automobiles Registered in Ingham County (1981).

Curb Weight	Number of Cars Registered	Relative Frequency (%)
under 2000 lb	17,269	6.8
2000 - 2499 lb	27,774	10.9
2500 - 2999 lb	34,731	13.7
3000 - 3499 lb	51,317	20.2
3500 - 3999 lb	60,079	23.6
4000 - 4499 lb	41,062	16.2
4500 lb or more	21,978	8.6
Total	254,210	100.0

A distribution of the number of VEH #1 and VEH #2 accidents by curb weight is shown in Table 6.2. Figure 6.3 compares the relative frequencies of the number of automobiles registered and the number of VEH #2 accidents.

Table 6.2. Distribution of VEH #1 and VEH #2 Accidents in Ingham County (1982).

Curb Weight	Number of VEH #1 Accidents	Number of VEH #2 Accidents	Relative Frequency (VEH #2) (%)
under 2000 lb	160	158	8.3
2000 - 2499 lb	397	328	17.2
2500 - 2999 lb	463	346	18.1
3000 - 3699 lb.	579	454	23.8
3500 - 3999 lb	452	350	18.5
4000 - 4499 lb	260	195	10.2
4500 lb or more	92	75	3.9
Total	2403	1905	100.0

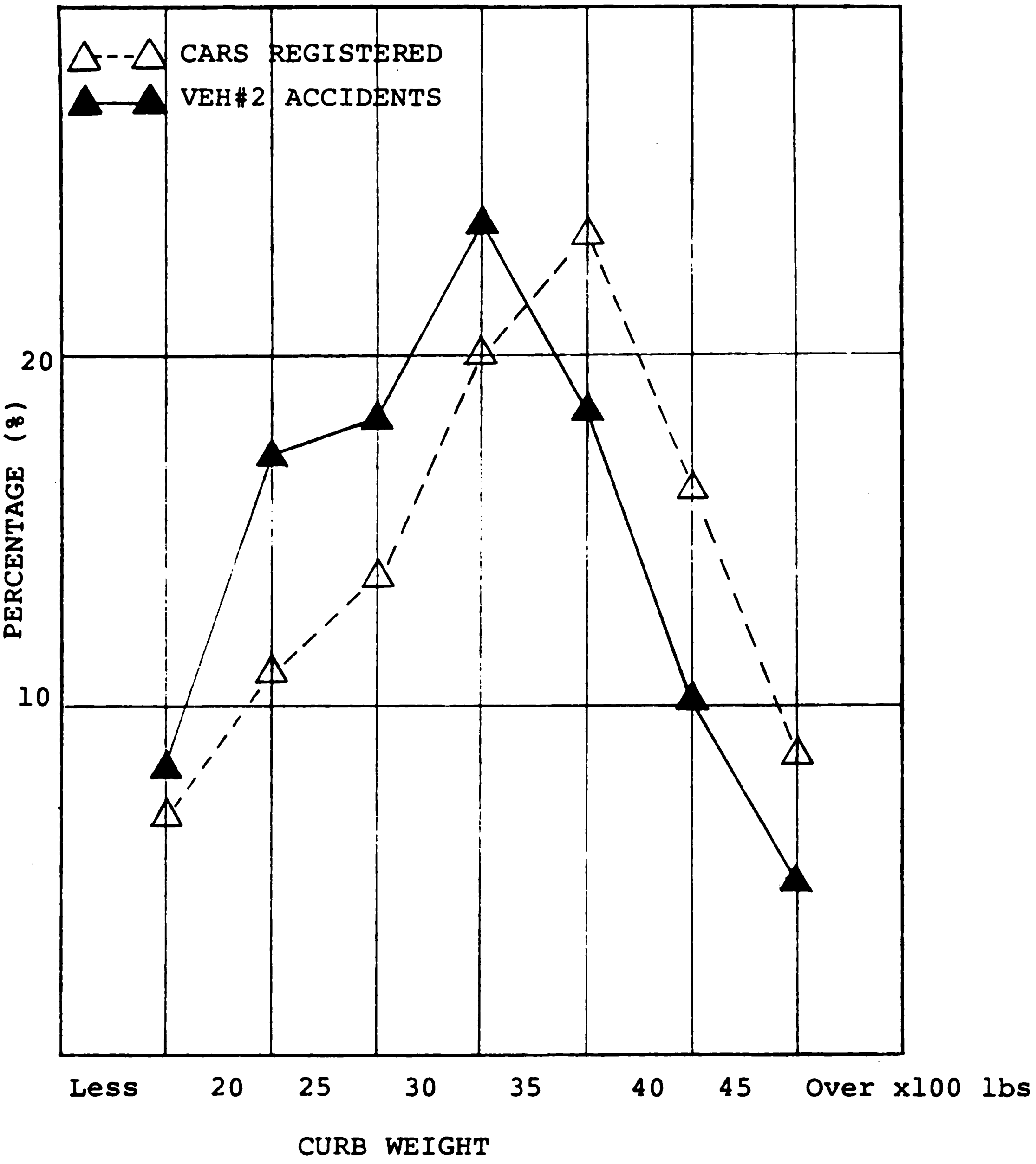


Figure 6.3. Difference between Exposure Measures

In 1980, J. Richard Steward and Carol Lederhaus Carroll (19) obtained estimates of average annual mileage for automobiles of model year 1966 to 1979 by size categories. They found that subcompacts had a higher average annual mileage than full size automobiles for all model years except 1979. Another finding was that newer automobiles had a higher average annual mileage than older automobiles.

These findings suggest that using the distribution of registered automobiles would produce a biased result. This bias could explain the difference in the distributions shown in Figure 6.3. In addition, it should also be remembered that the registration data are for 1981 and the accident data are for 1982. The number of small vehicles are increasing year by year, and the newer model automobiles are driven higher average annual mileage. This could also explain part of the difference.

Figure 6.4 compares the results of the traditional and the new exposure approaches. If the exposure measure was perfect (without bias), the results in Figure 6.4 would be a line along the 1.0 horizontal axis. The traditional approach indicates that the highest accident rate, .01429 accidents per vehicle registered, occurs for the second lightest weight class. This value is more than three times as high as the value of the heaviest weight class. On the other hand, the result of the new exposure approach shows the highest A/E ratio, 1.064 is for the second heaviest

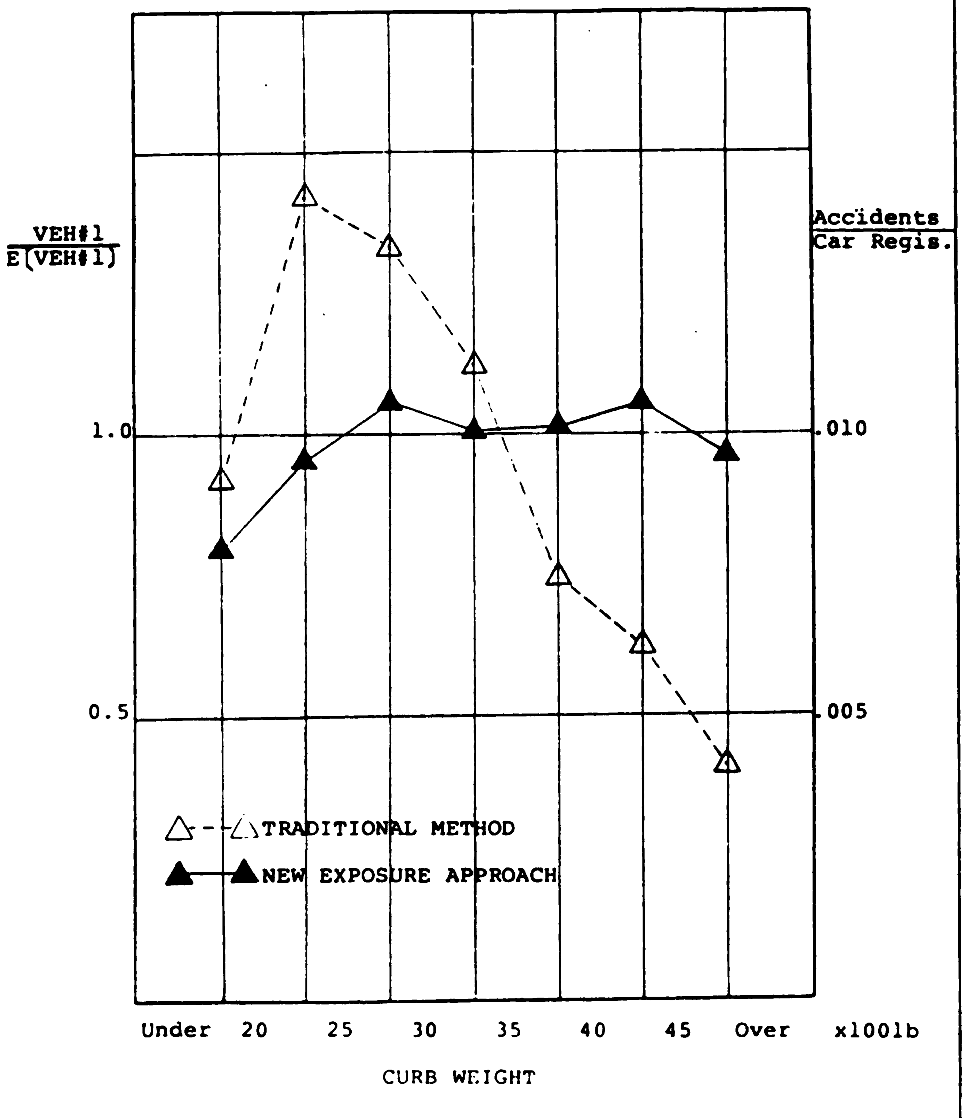


Figure 6.4. Exposure Methods

weight class. This approach indicates a slightly lower rate for small automobiles than for large ones.

The second hypothesis implicit in the approach is that the likelihood of being an object of an accident is common to any vehicle design if the exposure is the same. This means, for instance, when an automobile is involved in a left-turn accident as a VEH #1 with an automobile which intended to go straight, the risk of being hit would not be related to the size of VEH #2.

This assumption suggests if the risk of an automobile being involved in an accident as VEH #2 is not related to the size of the vehicle, the distribution of VEH #2 accidents by size should be similar among different types of accidents. The distribution of VEH #2 accidents for "angle" accidents should be similar to that of "left-turn" accidents, or "rear-end" accidents, because these types of accidents mainly occur at intersections and the exposure of automobiles is the same while they are at intersections.

Figure 6.5 shows population distributions of VEH #2 accidents by weight class for "angle," "left-turn," and "rear-end" accidents which occured in Michigan in 1982. Figure 6.6 shows the distributions by wheelbase class. Statistical tests were conducted with the null hypothesis: "There is no difference between any two distributions," and this hypothesis is accepted at α = .975 for all tests. Thus, we conclude that the distributions in Figures 6.5 and 6.6 are identical, and the exposure measure is reasonable. The results of the statistical test are shown in Table 6.3

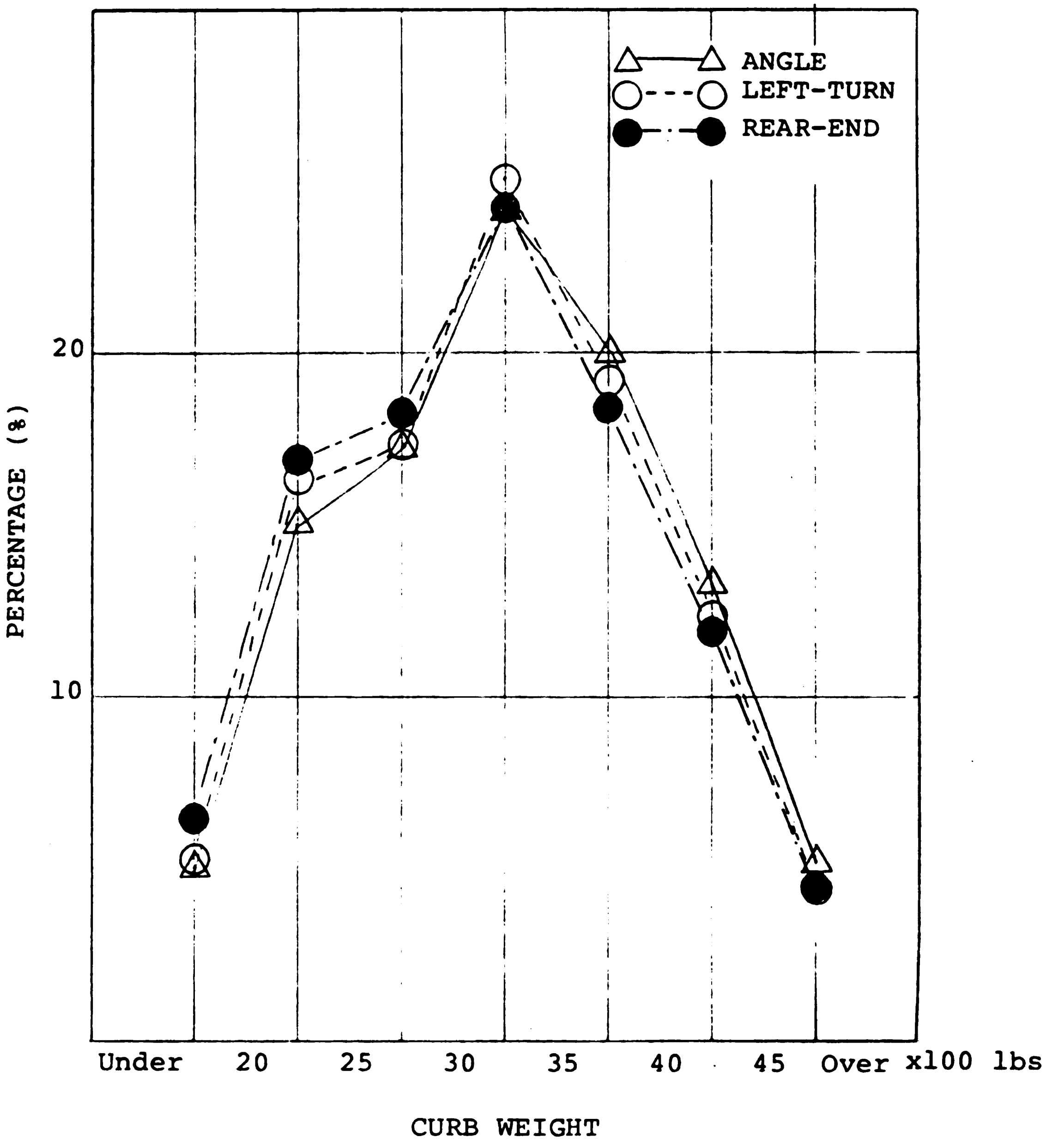


Figure 6.5. Population Distribution #1

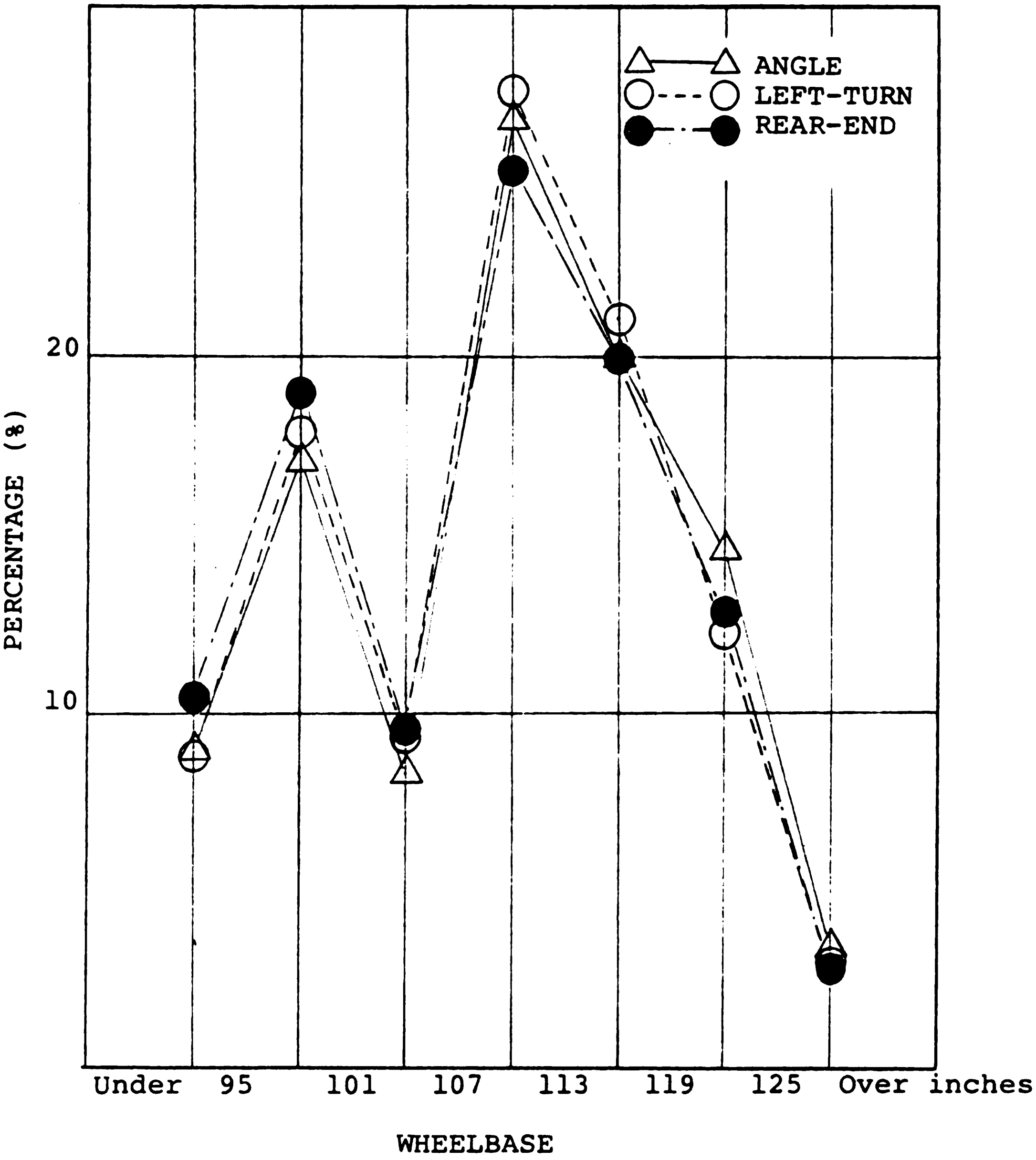


Figure 6.6. Population Distribution #2

Table 6.3. Statistical Test for Population Distributions of VEH #2 Accidents by Weight for Accident Type.

Weight Class	1	2	3	4	5	6	7	Total
Observed (Angle)	5.1	15.1	17.3	24.1	19.9	13.2	5.3	100%
Expected (Rear-End)	6.4	17.0	18.3	24.1	18.2	11.7	4.3	100%
$\frac{(O-E)^2}{E}$	.26	.21	.05	0	.16	.19	.23	1.10

$x^2 = 1.10$

Wheelbase Class

Wheelbase Class	1	2	3	4	5	6	7	Total
Observed (Angle)	8.9	17.1	8.4	26.7	20.7	14.6	3.5	100%
Expected (Rear-end)	10.5	19.1	9.6	25.3	20.0	12.8	2.7	100%
$\frac{(O-E)^2}{E}$	.24	.21	.15	.08	.02	.25	.24	1.19

$x^2 = 1.19$

7.0 RESULTS

The ratios of the actual to the expected number of accidents for seven groups of vehicle curb weights are obtained in this study using the new exposure approach. As described in the methodology, this study uses the number of VEH #2 accidents as a measure of exposure. This measure enables one to obtain relative exposures for any size of automobile, location, and duration. For example, a relative exposure of the smallest size of automobiles on Sundays is obtained by identifying accidents in which VEH #2 is of the smallest vehicle class on Sundays out of the total VEH #2 accidents on Sundays. This procedure is utilized throughout this study except for those accidents which do not include VEH #2 accidents. VEH #2 accidents on a state-wide basis for each category of automobile size are used to obtain the relative exposure for those accidents which do not include a VEH #2, such as single-vehicle-accidents, turnover vehicle accidents, accidents with a pedestrian, or driver injury accidents.

The three stages used in analyzing the accident data are shown in Figure 7.1. The total accident data set was initially used to determine statewide A/E ratios. For example, all accidents occurring at intersections were first analyzed to study intersection accident involvements for the seven groups of automobile size. Similarly, the A/E ratio for the following conditions were determined

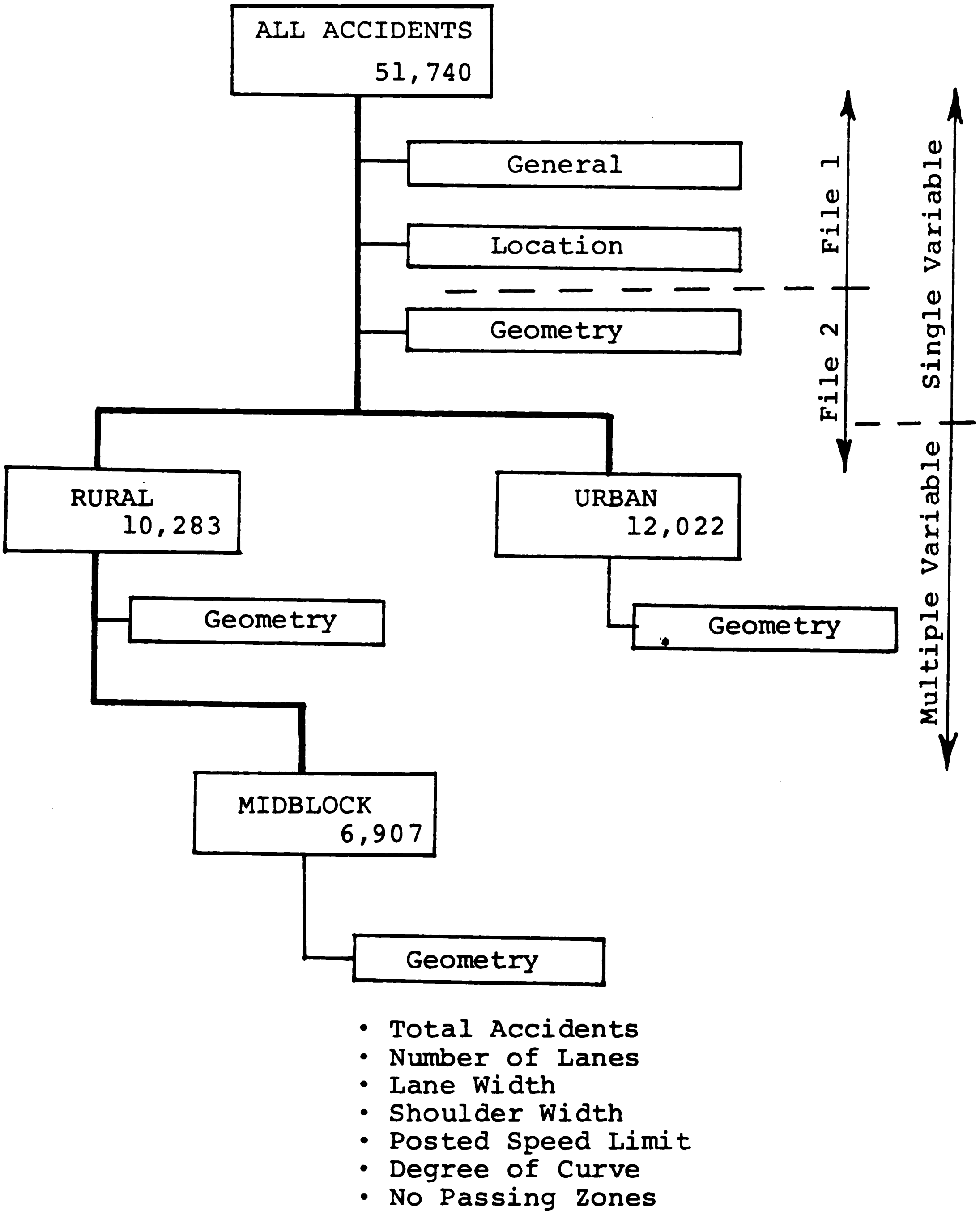


Figure 7.1. Research Procedure

using the state-wide accident data base:

General

- Total accidents
- Driver characteristics (age, sex, alcohol related)
- Accident type
- Time of day, day of week
- Roadway conditions

Location

- Rural or urban
- Michigan Department of Transportation districts

Geometry

- Number of lanes
- Lane width
- Shoulder width
- Posted speed limit
- Degree of curve
- No passing zones

The data set used for general and location analyses consisted of 51,740 accidents that occurred on the Interstate system and the Michigan Trunkline system in 1982. The data set used for analyzing the geometric features consisted of 38,828 accidents that occurred only on the Michigan Trunkline system.

The accident data was then divided into two subsets, rural and urban, and another analysis of the geometric features was conducted. The rural data set consists of 10,283 accidents, and the urban data set consists of 12,022 accidents. The 16,518 accidents which occurred in strip-fringe areas were excluded from these analyses.

Lastly, 6,907 accidents which occurred at midblock locations in rural areas were used to study geometric conditions, and the relative accident involvement for the seven automobile size groups at rural midblock locations were determined. For example, accidents occurring at midblock locations in rural areas where no passing restrictions apply were analyzed to compare the accident involvements for the seven groups of automobiles. The results obtained by the second and third stage analyses are discussed later.

7.1 Statewide Results

Results obtained by examining A/E ratios with a single independent factor were that small automobiles have a higher ratio in the following conditions:

- single vehicle accidents
- overturned vehicle accidents
- late at night
- on weekends
- in darkness
- on icy or snowy highway surfaces
- at midblocks
- in rural areas
- on 2 lane-2 way highways
- in no-passing zones

On the other hand, large automobiles were found to have a higher ratio in the following conditions:

- accidents with pedestrians
- accidents with parked vehicles
- accidents with other vehicles
- at intersections
- in urban areas

The statistical procedure used in this study consists of the -square test utilizing the observed number of VEH #1 accidents and the expected number of VEH #1 accidents. The expected number of VEH #1 accidents is obtained by equation 3 (page 39). The relationship is determined to be statistically significant if the level of confidence of the test is greater than 0.95.

Appendix A includes the number of VEH #1 accidents, the number of VEH #2 accidents, and the ratio of actual to expected number of accidents by curb weight for each study parameter.

Appendix B includes the number of VEH #1 accidents, the number of VEH #2 accidents, and the ratio of actual to expected number of accidents by wheelbase for each study parameter.

Appendix C includes the number of VEH #1 accidents, the number of VEH #2 accidents, and the ratio of actual to expected number of accidents by model-year for each study parameter.

Using curb weight categories, the equations for the best fitting curves are obtained by testing seven types of curves: linear, exponential, power, logarithmic functions and three kinds of hyperbolic functions. A curve type is selected by comparing the coefficient of determination R^2.

The ratios of the actual to the expected number of accidents are also obtained for wheelbase groups and by model-year. The curb weight and the wheelbase categories provide very similar results, however the curb weight categories show more consistent results, and are discussed in this study.

The automobile model-year is used to examine other possible factors in accident involvement. It was found that newer models have lower accident involvement rate than earlier model automobiles. Newer model-year automobiles have lower A/E ratios regardless of the age of driver, the sex of driver, and the type of accident, except for certain types of accidents for which small automobiles are found to be overrepresented. The average curb weight of the newer model-year automobiles is much smaller than that of the older model-years. Because of this fact, the effect of model-year is sometimes offset by the effect of automobile size.

The A/E ratio for total accidents shows a slightly higher value for large automobiles, with the ratio varying from 0.96 to 1.04 (Figure 7.2). Only the two smallest groups (less than 2000 pounds and 2000-2500 pounds) are found to have an A/E ratio lower than one. This is not unexpected because this analysis includes all accidents at

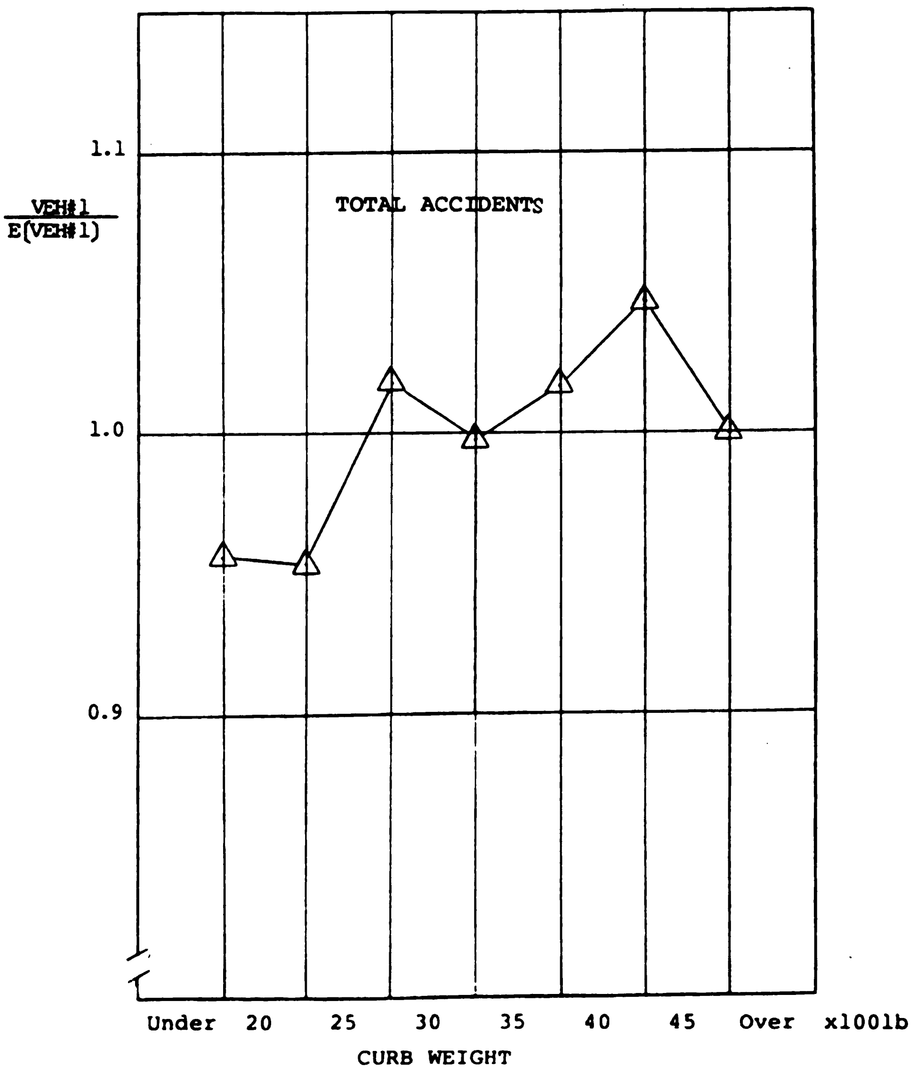


Figure 7.2. Total Accidents by Curb Weight

all locations on the Interstate and Trunkline system. The data points are based on relatively large numbers of accidents, with the actual and expected accidents for the seven vehicle classifications ranging from 2362 for the largest size vehicle class to 12,617 for the 3000-3499 pound vehicle class.

The same general trend is true regardless of the sex of the driver, as shown in Figure 7.3. Contrary to some reports, there is no evidence that females are "safer" drivers than males. These results indicate that any difference in the number of accidents involving males or females is explained by their relative exposure more than their sex.

The results of an analysis of accidents in which the driver was suspected to be under the influence of alcohol or drugs were interesting. There was a clear trend toward a higher percentage of drivers of large vehicles being under the influence of alcohol or drugs. This may be explained by the fact that younger drivers tend to drive older automobiles which are generally larger than new vehicles. Since there was no reliable data on the number of VEH #2 drivers that might have been driving while under the influence of alcohol or drugs, it was not possible to obtain a value for the expected number of involvements by VEH #1 drivers. Thus, Figure 7.4 simply portrays the involvement as a percent of all VEH #1 drivers, and not the A/E ratio.

When the type of accident was analyzed, some much

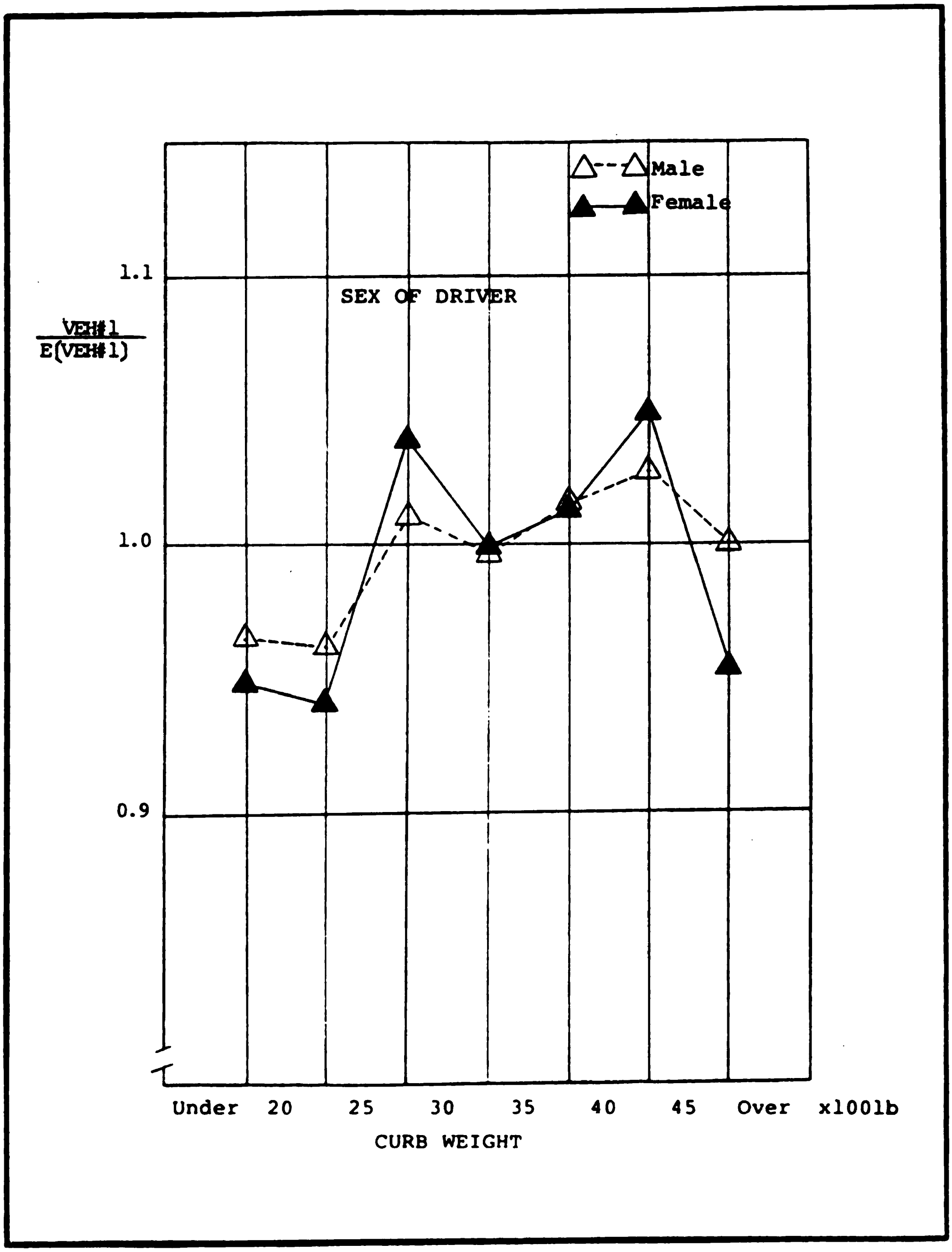


Figure 7.3. Accidents by Sex of Driver

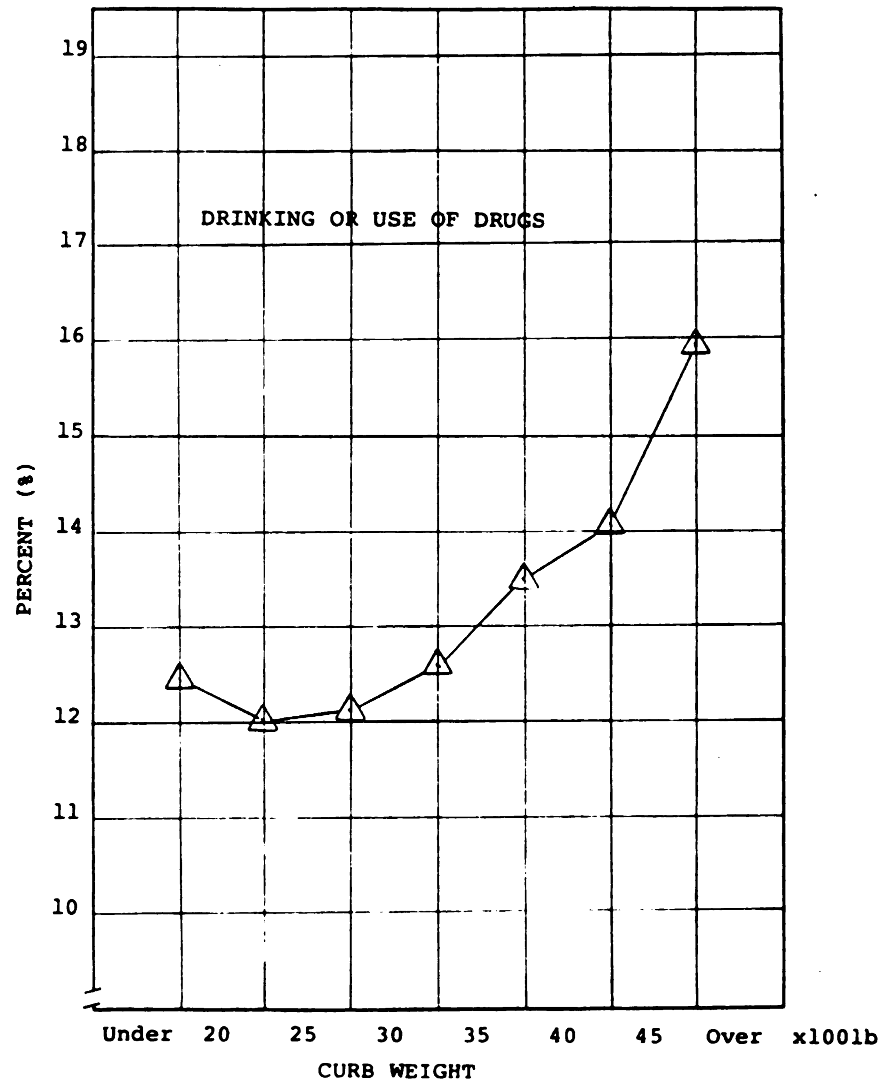


Figure 7.4. Drinking/Drugs

stronger relationships were found between accident involvement and automobile size. Small cars are much more likely to be involved in single car accidents than their exposure would indicate, with an A/E ratio of 1.11 for those automobiles which weigh less than 2000 pounds. The ratio decreases consistently with vehicle size with each of the two large vehicle classes having an A/E ratio of approximately 0.9 as shown in Figure 7.5. Due to the analytic procedure being used, a result above the 1.0 axis for a small curb weight has a nearly equal and opposite result for a large curb weight. This dependency is prevalent. Since different types of accidents tend to occur in urban and rural areas, it is not clear whether this observation is related only to vehicle size or also to location.

As might be expected, the same phenomenon is exhibited when overturned vehicle accidents are analyzed. In this case, however, the ratio varies even more as a function of vehicle size, with the smallest automobiles having an A/E ratio of 2.4, while vehicles over 3000 pounds have a ratio of less than 0.5 (Figure 7.6). This indicates that the probability of overturning in a small vehicle is 4.8 times as likely for the same level of exposure. This may indicate a need to carefully review highway design standards as the vehicle fleet continues to get smaller.

The probability of being involved in a two car accident appears to be independent of vehicle size (Figure 7.7). When the A/E ratio is plotted against vehicle size,

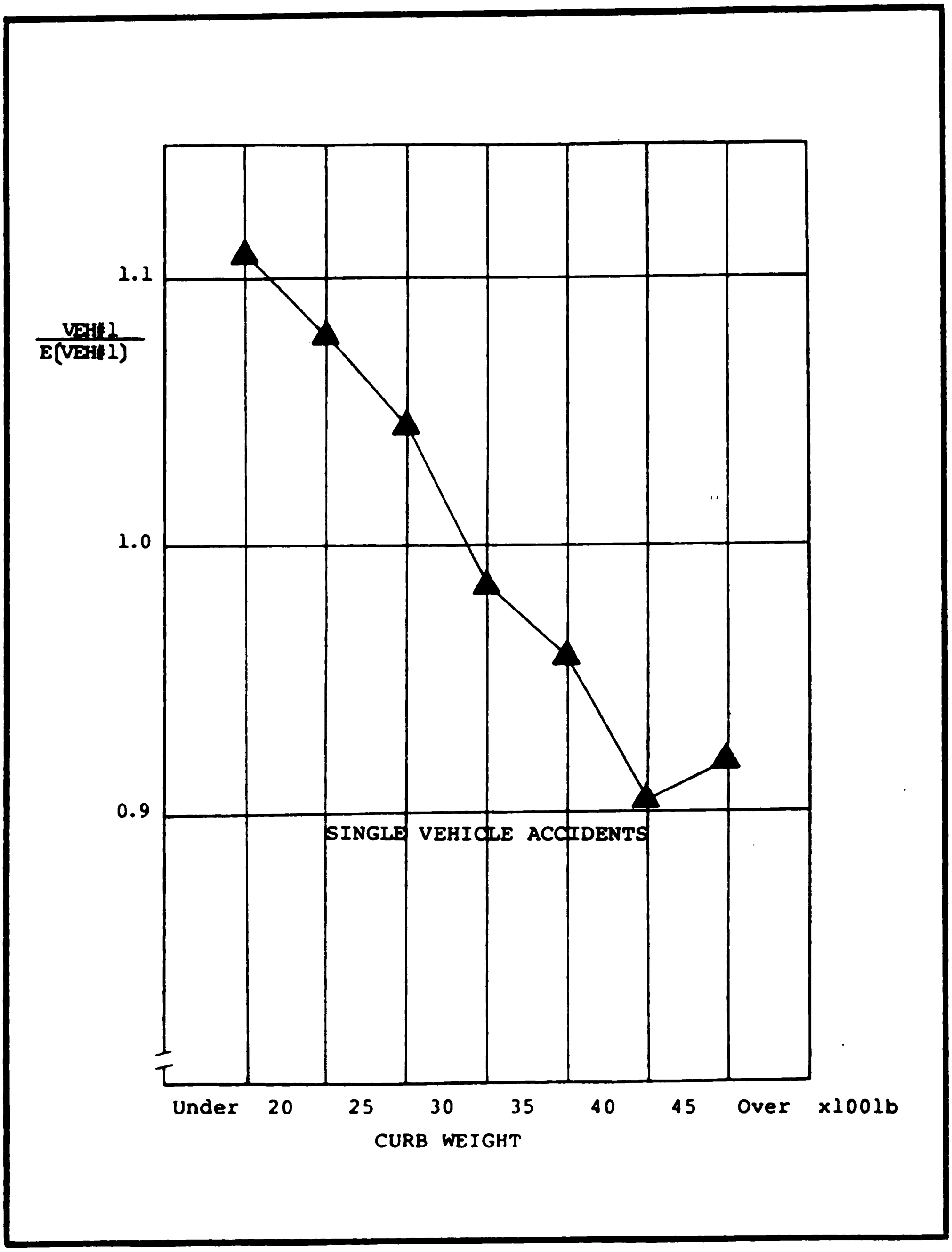


Figure 7.5. Single Vehicle Accidents

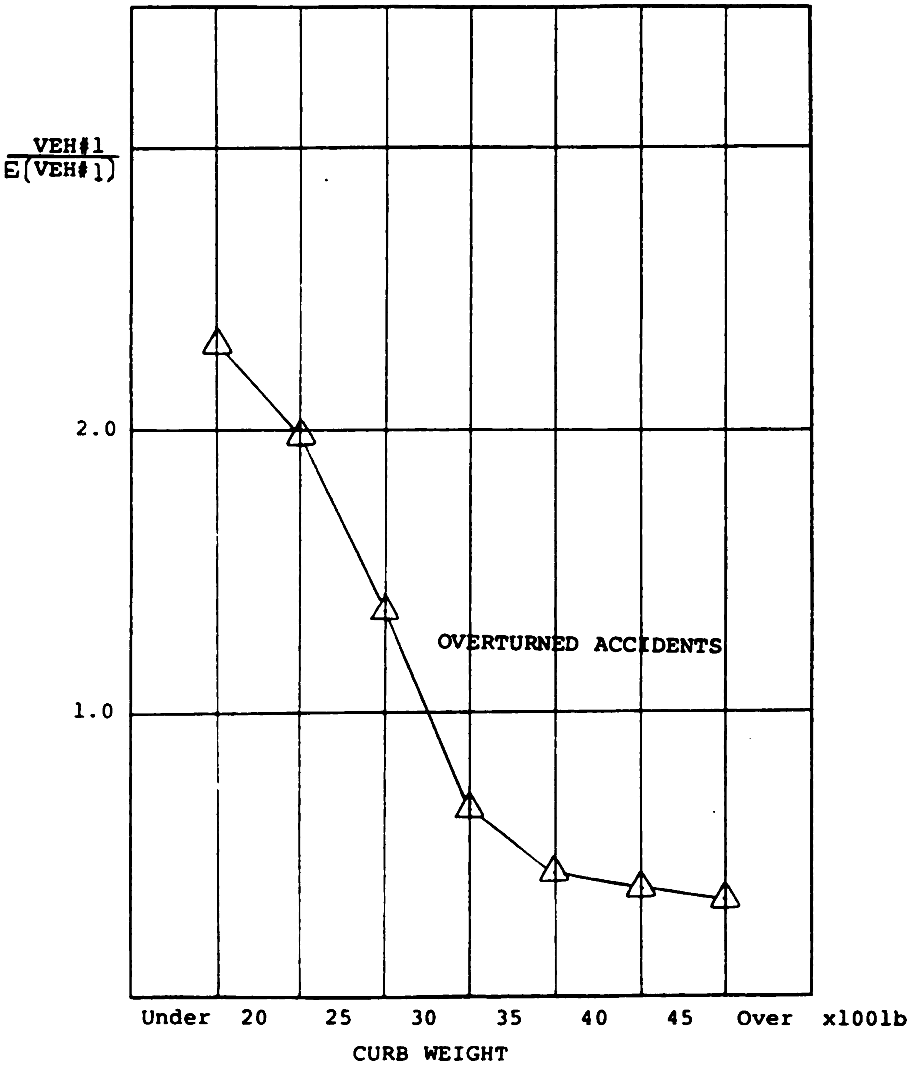


Figure 7.6. Overturned Accidents

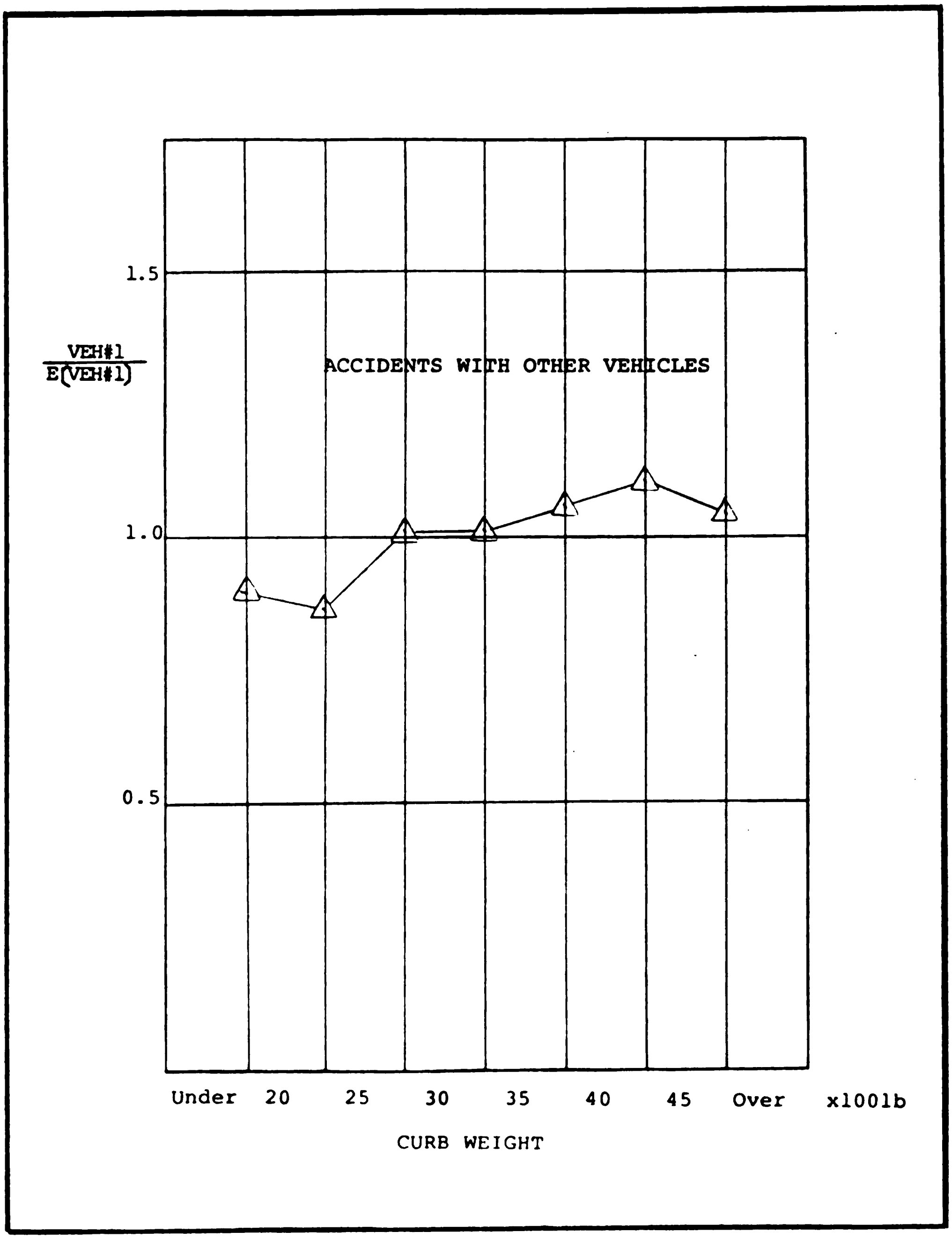


Figure 7.7. Other Vehicles

the result is nearly a horizontal line at an A/E ratio of 1.0.

Large vehicles exhibit an A/E ratio higher than one for accidents with parked vehicles, bicycles and pedestrians (Figures 7.8, 7.9 and 7.10). It is not known whether this is related to the size of the automobile or the location in which most of these accidents occur (urban areas). We will gain some additional information on this when the urban and rural areas are separated for further study.

When the accident data was stratified by road condition, two interesting trends were noted. There is a relatively large difference between the A/E ratio for small and large cars on icy roads, with the large cars having the lower ratio as shown in Figure 7.11. The reverse is true on both dry and wet roads, where small cars have the lower ratio. The differences in both cases are roughly 20 percent.

The findings discussed above are all statistically significant.

7.1.1 Findings for Locations

The relationship between accidents and highway area types (intersection or midblock), road classes (Interstate, U.S. routes, and Michigan routes), and state highway districts were also investigated. Small automobiles are found to have an A/E ratio greater than 1.0 at midblock locations and lower than 1.0 at intersections on all

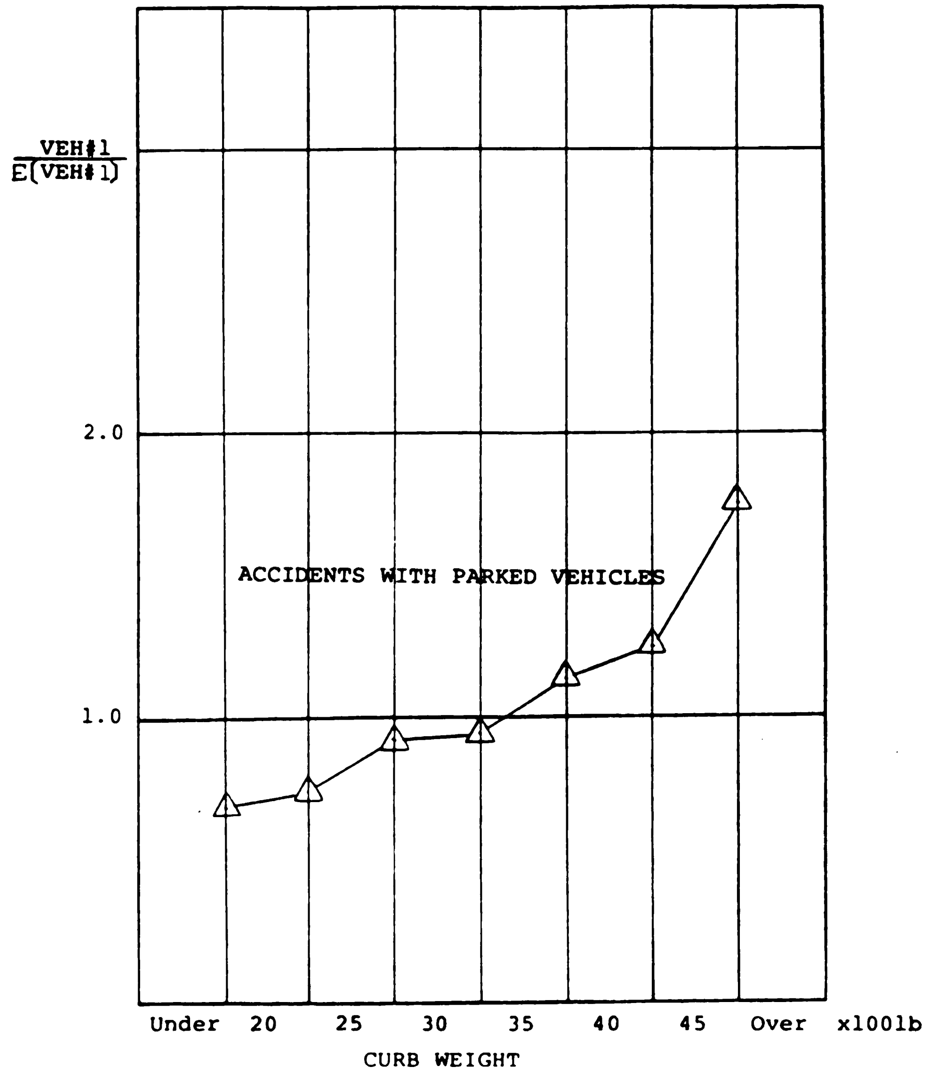


Figure 7.8. Parked Vehicles

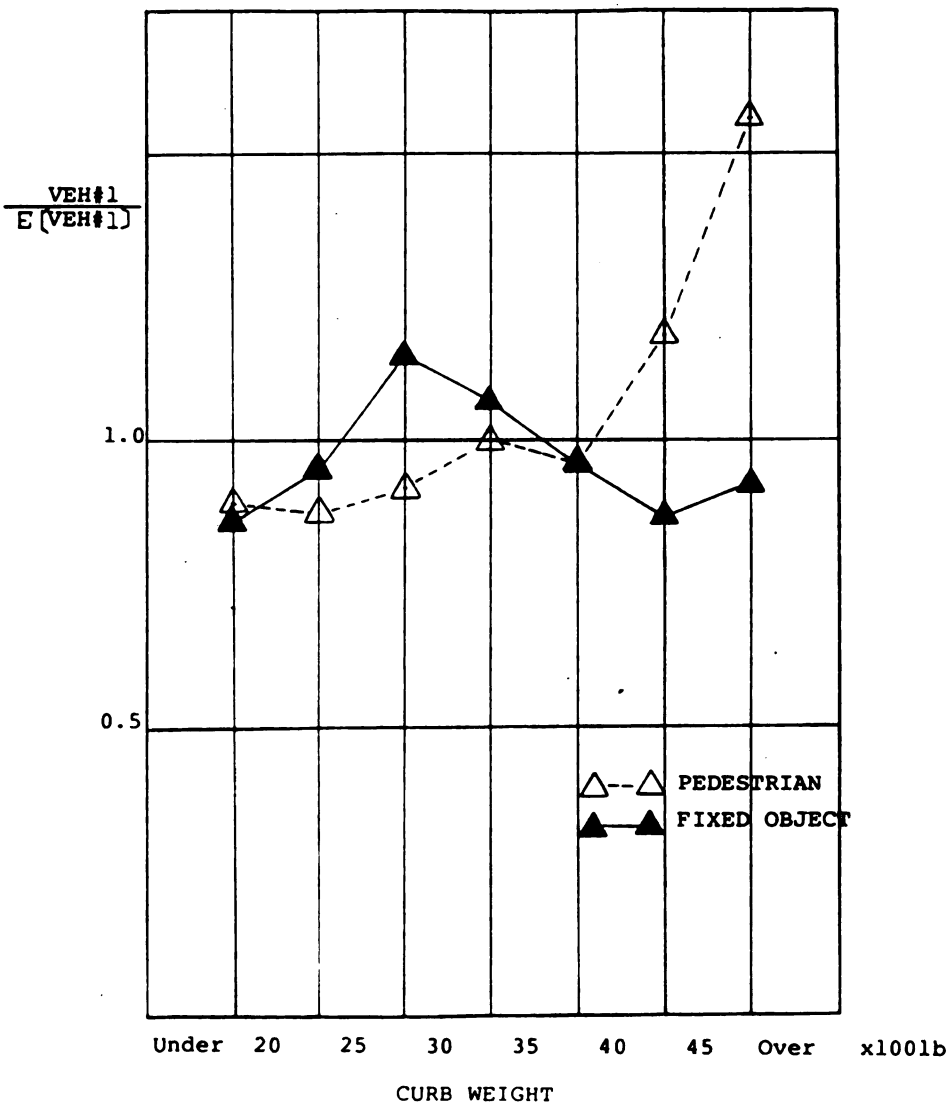


Figure 7.9. Pedestrian/Fixed Object

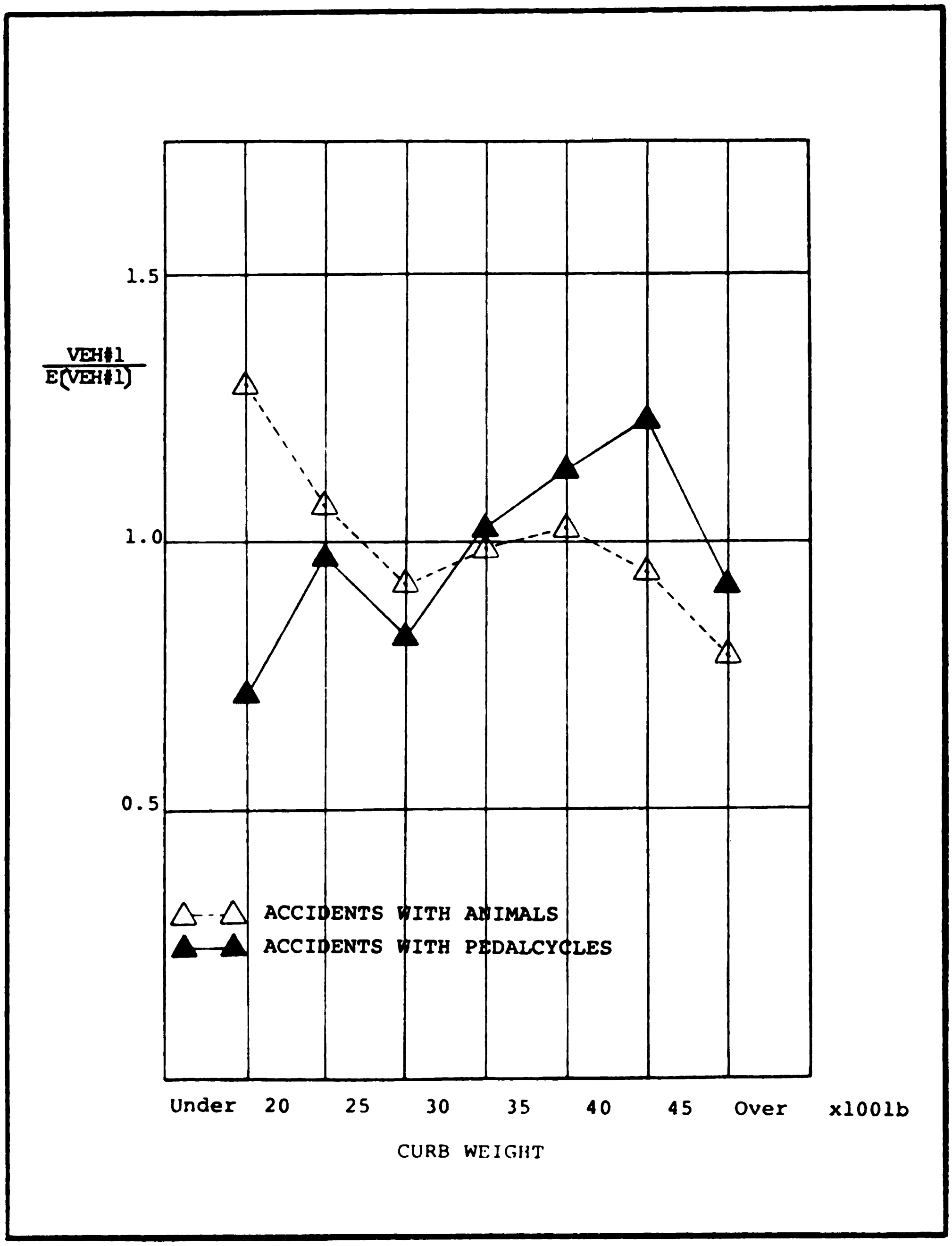


Figure 7.10. Animals/Bicycles

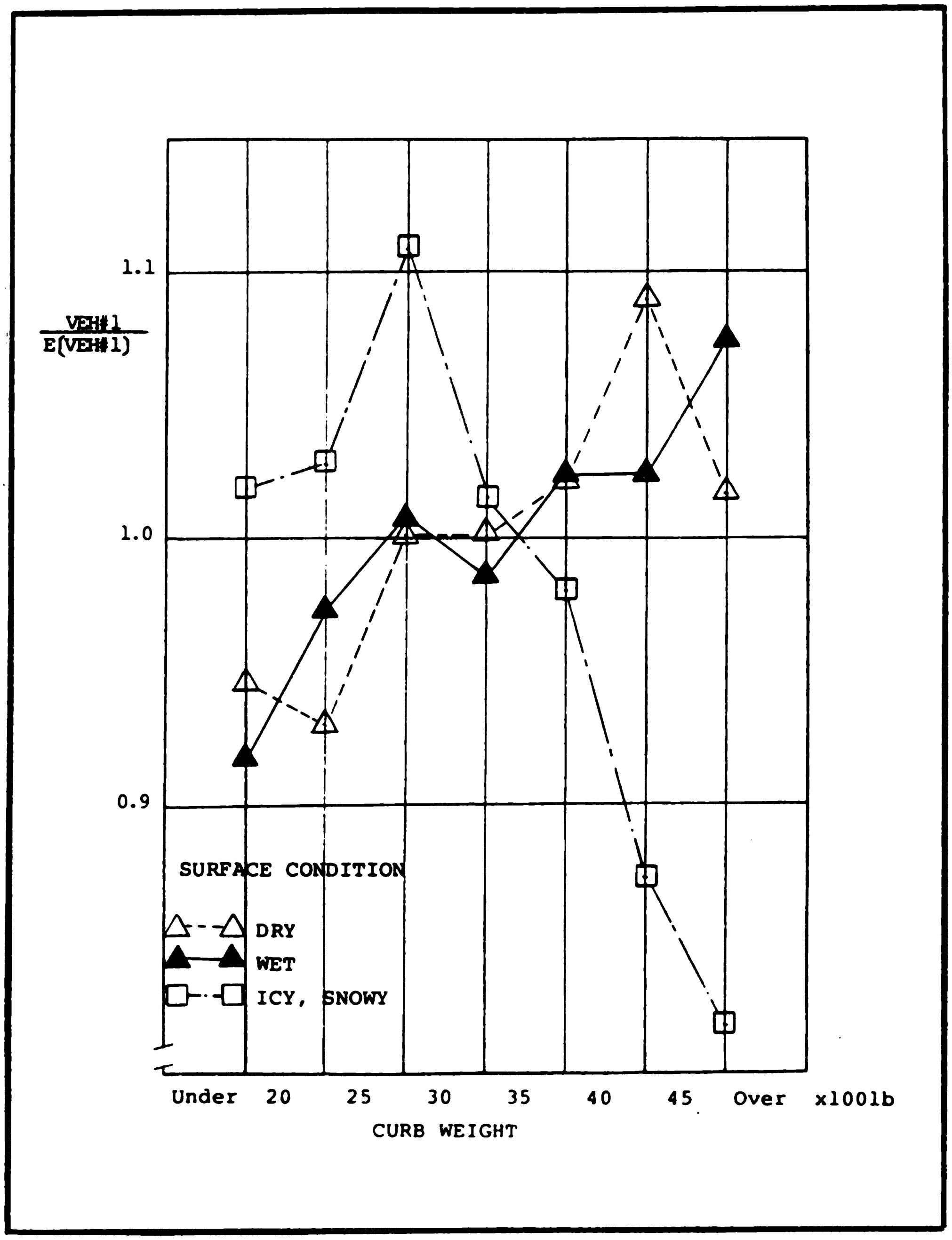


Figure 7.11. Surface Condition

classes of road. The ratio for the group of smallest automobiles is 21 percent higher than that for the group of largest automobiles at midblock locations for all roadway types combined. At intersections, the largest automobiles have about a 25 percent higher ratio than the group of smallest automobiles. These results are illustrated in Figure 7.12.

These results are consistent with the observations for single and multiple vehicle accidents. Small automobiles appear to be involved in a disproportionate number of single vehicle accidents at midblock locations, while large automobiles are involved in a disproportionate number of accidents at intersections. This may explain the urban-rural differences noted previously, since intersection accidents tend to dominate the urban accident experience.

The A/E ratios for U.S. routes and Michigan routes follow the same trend when plotted against vehice size as shown in Figure 7.13. Thus, data from both groups were combined for the analysis.

Figure 7.14 shows the results for three of the 9 state highway districts. These results are consistent with previous findings. For example, in District 4, large automobiles have a lower ratio than small automobiles, while District 8 and District 9 have the reverse trend, with the higher ratio associated with large automobiles. This is probably due to the differences in the traffic environment, as District 9 (metro area) and District 8 are

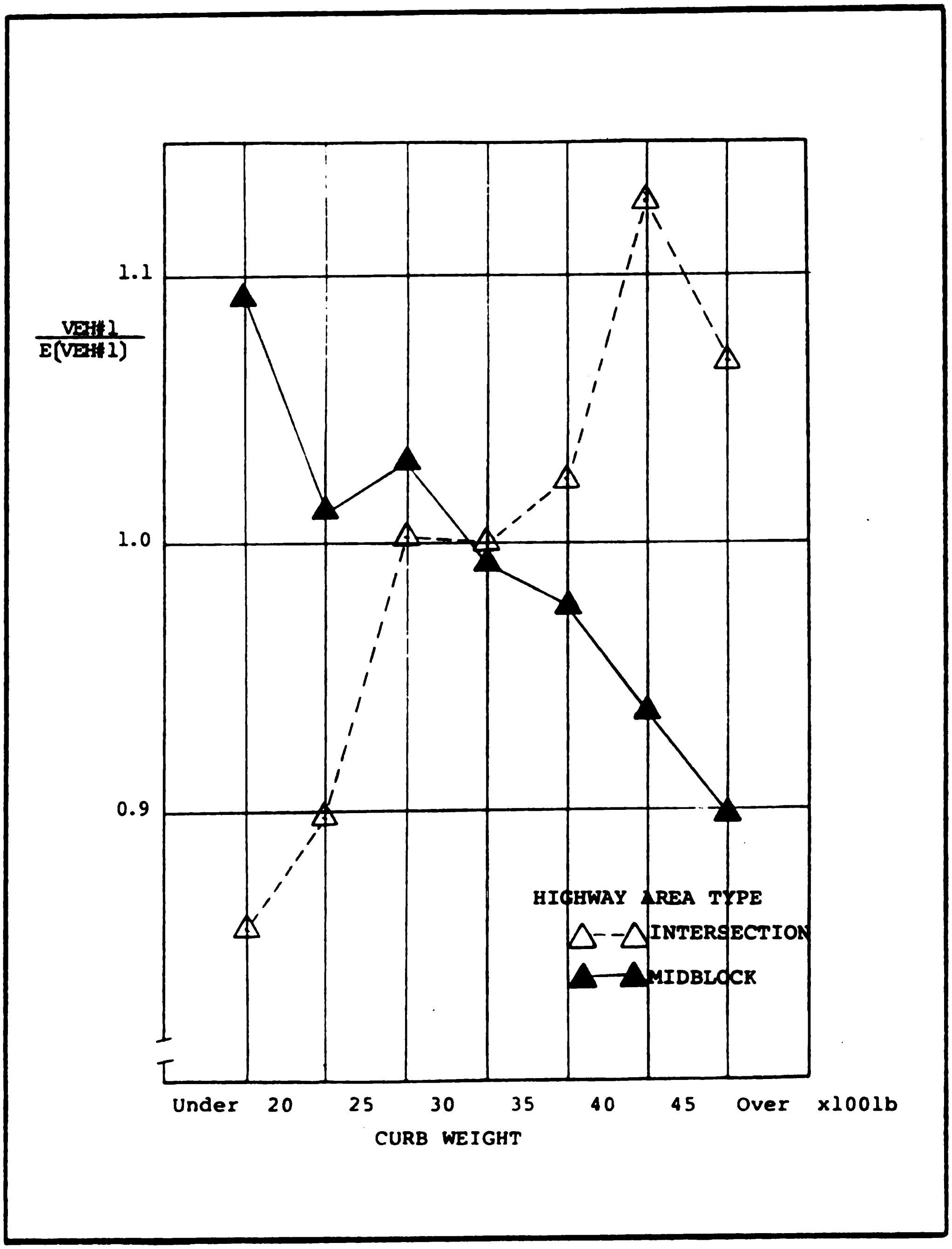


Figure 7.12. Area Type

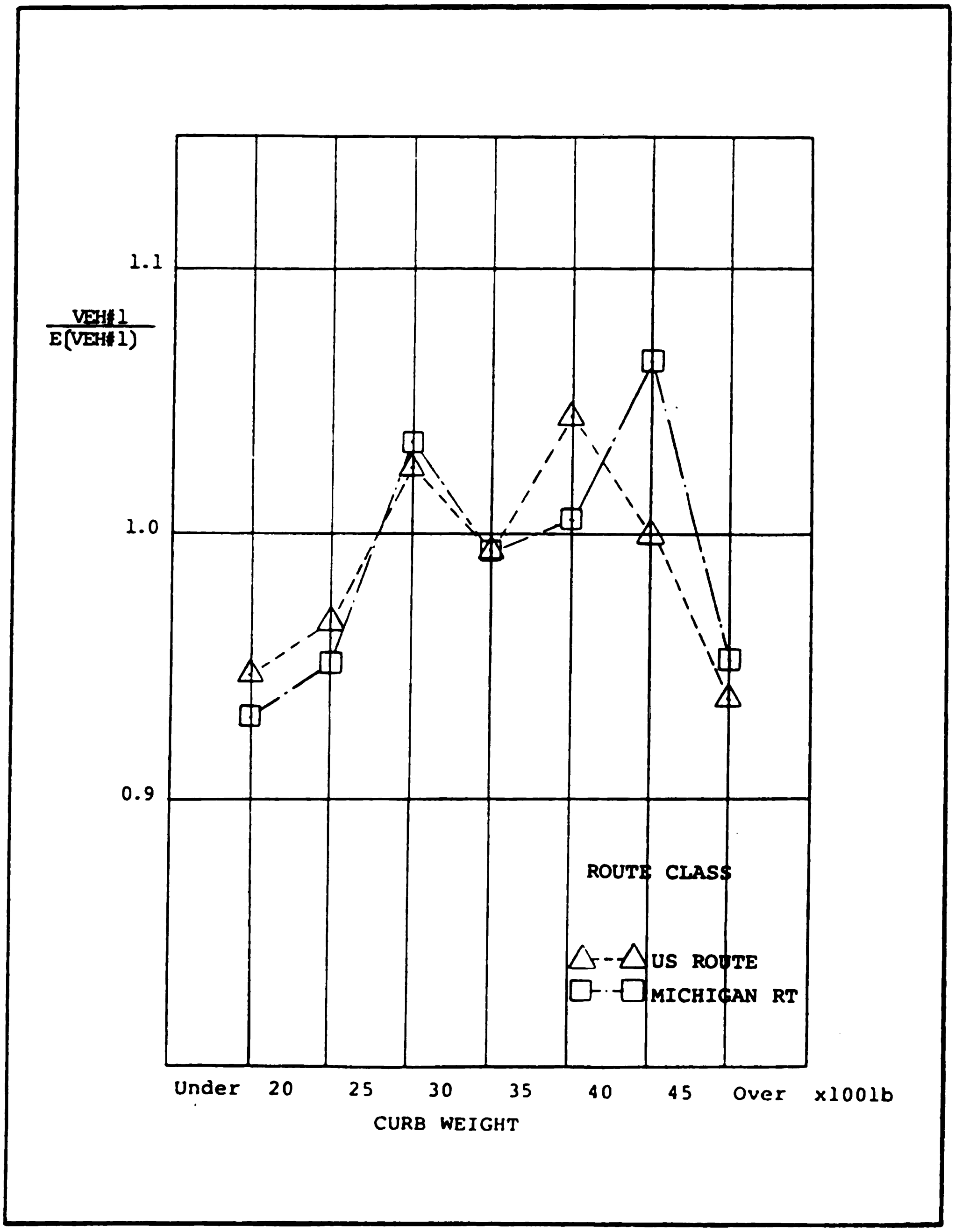


Figure 7.13. Route Class

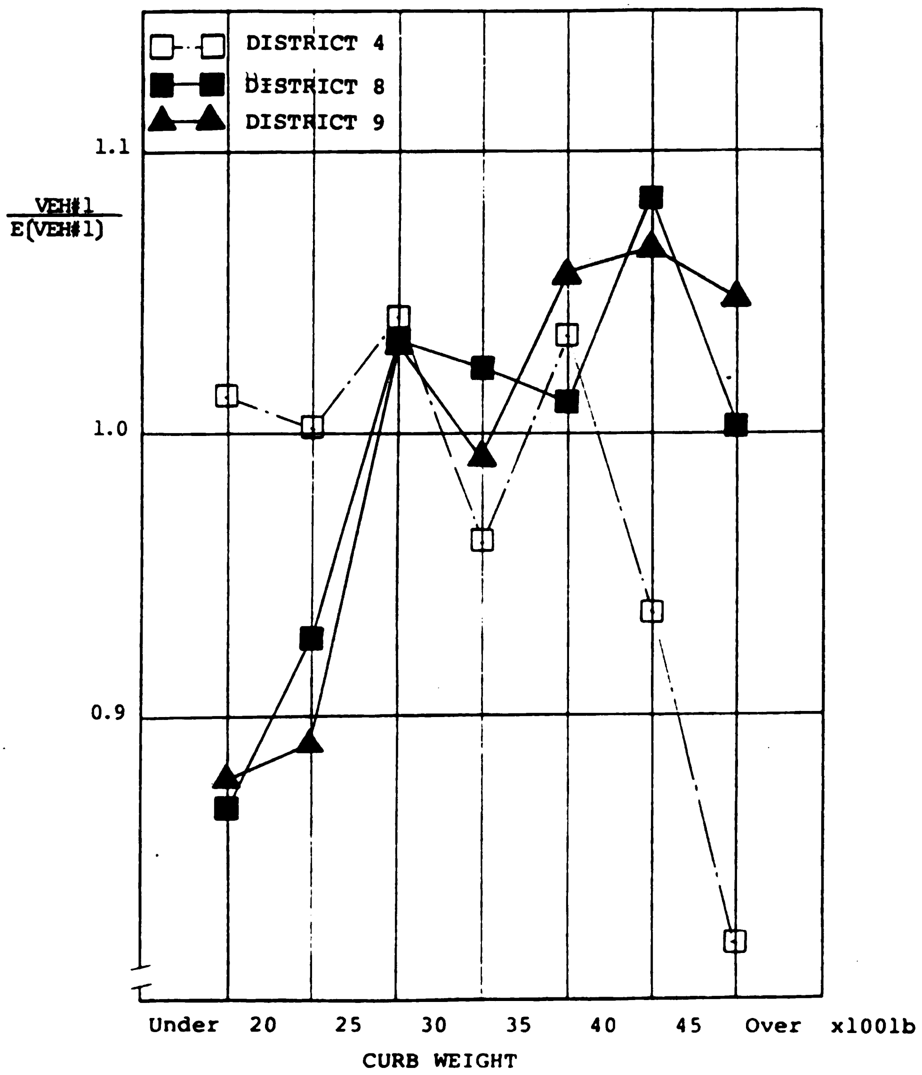


Figure 7.14. District

primarily urban, and District 4 is basically a rural district.

7.1.2 Findings for Geometric Features

File 2 (the file consisting of information on geometric features and accidents) was used to determine the relationship between vehicle size, accidents and selected geometric features. This data file consists of the 38,828 accidents which occurred on the Michigan Trunkline system. The A/E at any location is calculated by Equation 6 (page 46).

The geometric features investigated in this phase of the study were:

- number of lanes
- lane width
- shoulder width
- posted speed limit
- roadside development
- no-passing zones
- degree of curve
- number of intersection legs (intersection, midblock)

Figures 7.15 through 7.17 show the results obtained for some of the features listed above. The common denominator for the results of these analyses is that small automobiles have a ratio greater than one for features associated with rural areas, and a ratio less than one for features common to urban areas. Small automobiles are found to be over-represented in accidents at the following

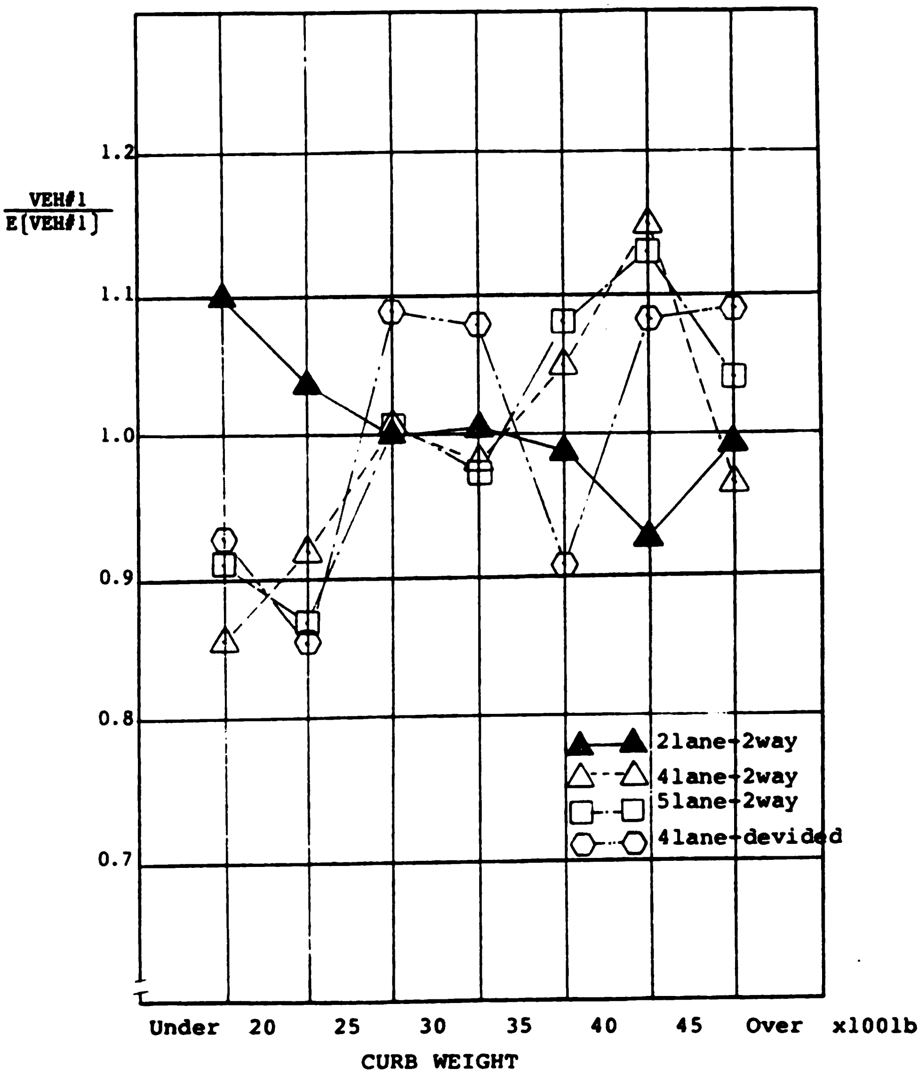


Figure 7.15. Number of Lanes

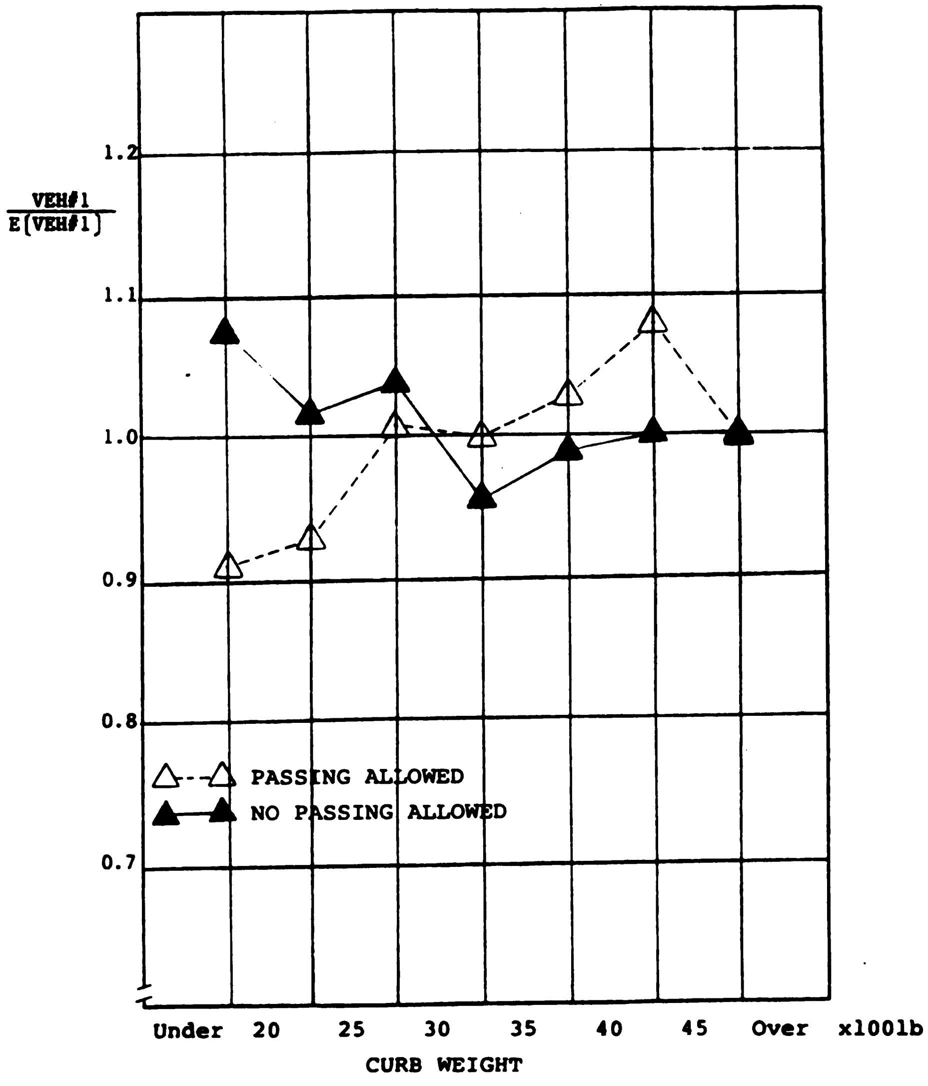


Figure 7.16. No Passing

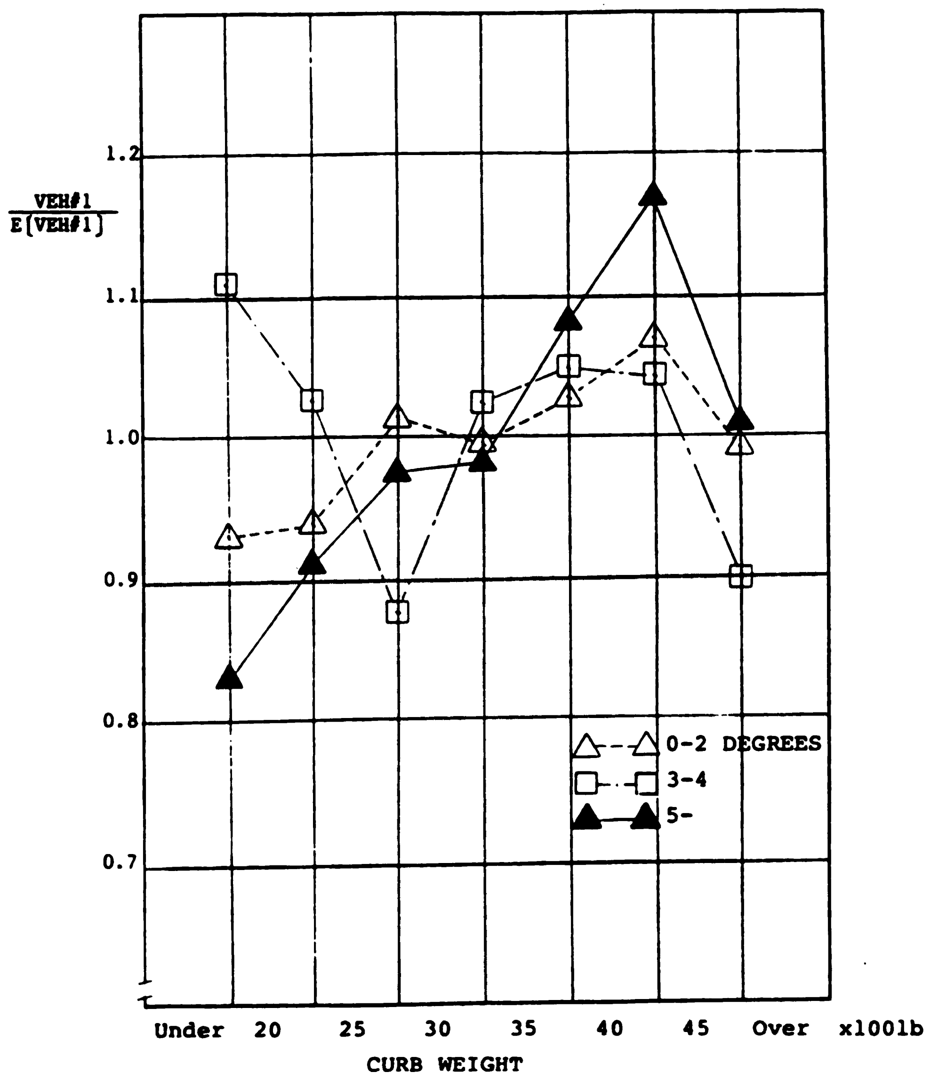


Figure 7.17. Degree of Curvature

features:

- 2 lane-2 way roads
- 55 mph posted speed limit
- no-passing zones
- midblocks

These features are characteristic of rural areas, and the results confirm that small automobiles are more likely to be involved in an accident in rural areas. This could be because small automobiles are less stable when driven at the high speeds than are large automobiles.

Consistent with the urban-rural dichotomy, small automobiles are found to have a ratio of less than one for the following features:

- multiple lanes
- cross sections with curbs
- low posted speed limits
- curves with a degree of curve of 5 degrees or more
- intersections
- zones in which passing is allowed

These features are characteristic of urban areas. Small automobiles may be able to maneuver better than large automobiles in urban areas, and there are more vehicles, pedestrians and bicycles in urban areas.

As described earlier, curves were fit to the data points shown in the preceding figures, and an equation of the line of best fit determined for each relationship. Table 7.1 contains the equations for the relationships between the A/E ratio and vehicle size using the entire

Table 7.1. The Best Fitting Curves for Geometric Features

Condition	Equation	R^2
2 lane-2 way	$Y = .875 + 387 /X$	.759
Curb	$Y = X/(907 + .708 X)$	.879
25 MPH	$Y = X/(727 + .786 X)$	.536
55 MPH	$Y = 1.16 - .0000545 X$	.768
Rural	$Y = 1.25 - .0000780 X$	.954
Urban	$Y = X/(807 + .742 X)$	.877
Passing Allowed	$Y = X/(429 + .865 X)$	.738
No Passing	$Y = .932 + 230 /X$	.524
5-Degree	$Y = X/(850 + .728 X)$	.796
Intersection	$Y = X/(766 + .752 X)$	.940

where Y = The ratio of the actual to the expected number of accidents

X = Curb weight

R^2 = Coefficient of determination

accident data base.

It is reasonably clear from the preceding analyses that one of the major variables in explaining the over- or under-representation of different size vehicles in accidents is the urban-rural split. In almost all cases, those locations and geometric features related to urban areas exhibit a small automobile A/E ratio lower than 1.0, and those features related to rural areas have an A/E ratio greater than 1.0.

Because there is also a significant difference between accident involvement ratio at intersections and non-intersections, it is probable that there is some interaction between this factor and the urban-rural factor. To separate these two factors, the accident data set was divided into urban, fringe area and rural subsets. The accidents occuring in fringe areas were then set aside, and separate analyses conducted on the urban and rural subsets. The data sets are still relatively large, with the urban subset containing 12,022 accidents and the rural subset containing 10,283 accidents.

7.2 Relationships for Urban-Rural Subsets

The A/E ratios were obtained for several location factors and geometric features in rural and urban areas separately. The relationships among automobile design, geometric features and accidents were expected to become more clear when the accident data were separated, since the relative value of these ratios seemed to be opposite each other for urban and rural areas.

Once again, the distribution of accidents by type were plotted for both rural and urban areas to verify the use of VEH #2 accidents as an unbiased estimator of exposure. Figure 7.2.1 shows the distribution of VEH #2 accidents by weight class for "angle," "left-turn," and "rear-end" accidents in rural areas. Figure 7.2.2 shows population distributions of VEH #2 accidents by weight class for "angle," "left-turn," and "rear-end" accidents in urban areas. Statistical tests were conducted and the null hypothesis "population distributions of VEH #2 are the same" is accepted at α = .975 for both cases (Table 7.2.1). Thus, the use of the new exposure approach is supported for both rural and urban areas.

The accident file consisting of information on geometric features and accidents (File 2) is used in the following studies. The data base consists of 10,283 accidents for rural areas, and 12,022 accidents for urban areas. The accidents occurred on the Michigan Trunkline system.

The expected number of accidents is calculated by Equation 6 on page 46 for the following categories:

- total accidents (rural, urban)
- highway area type (intersection or midblock)
- number of lanes
- lane width

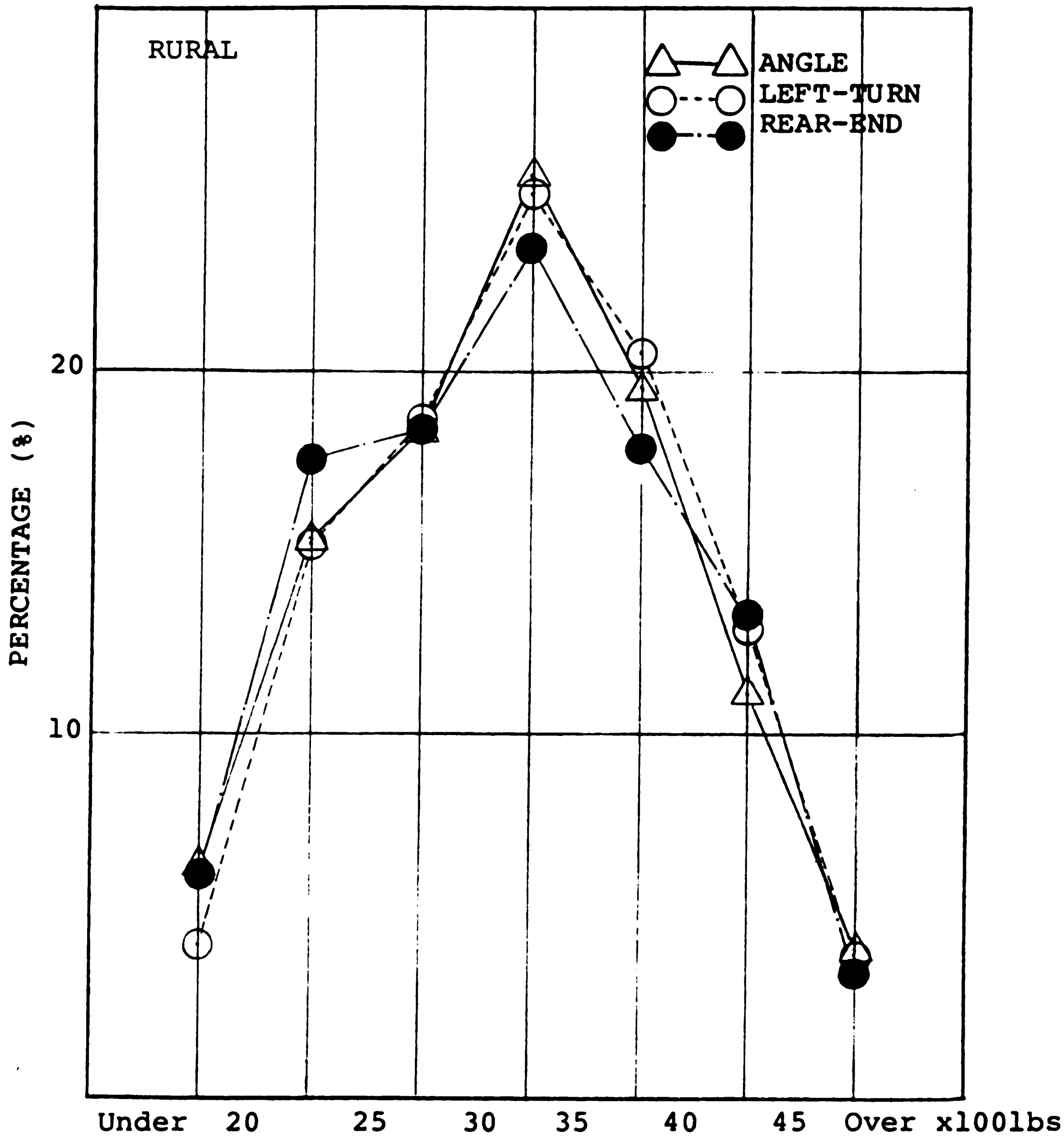


Figure 7.2.1. Distribution #3

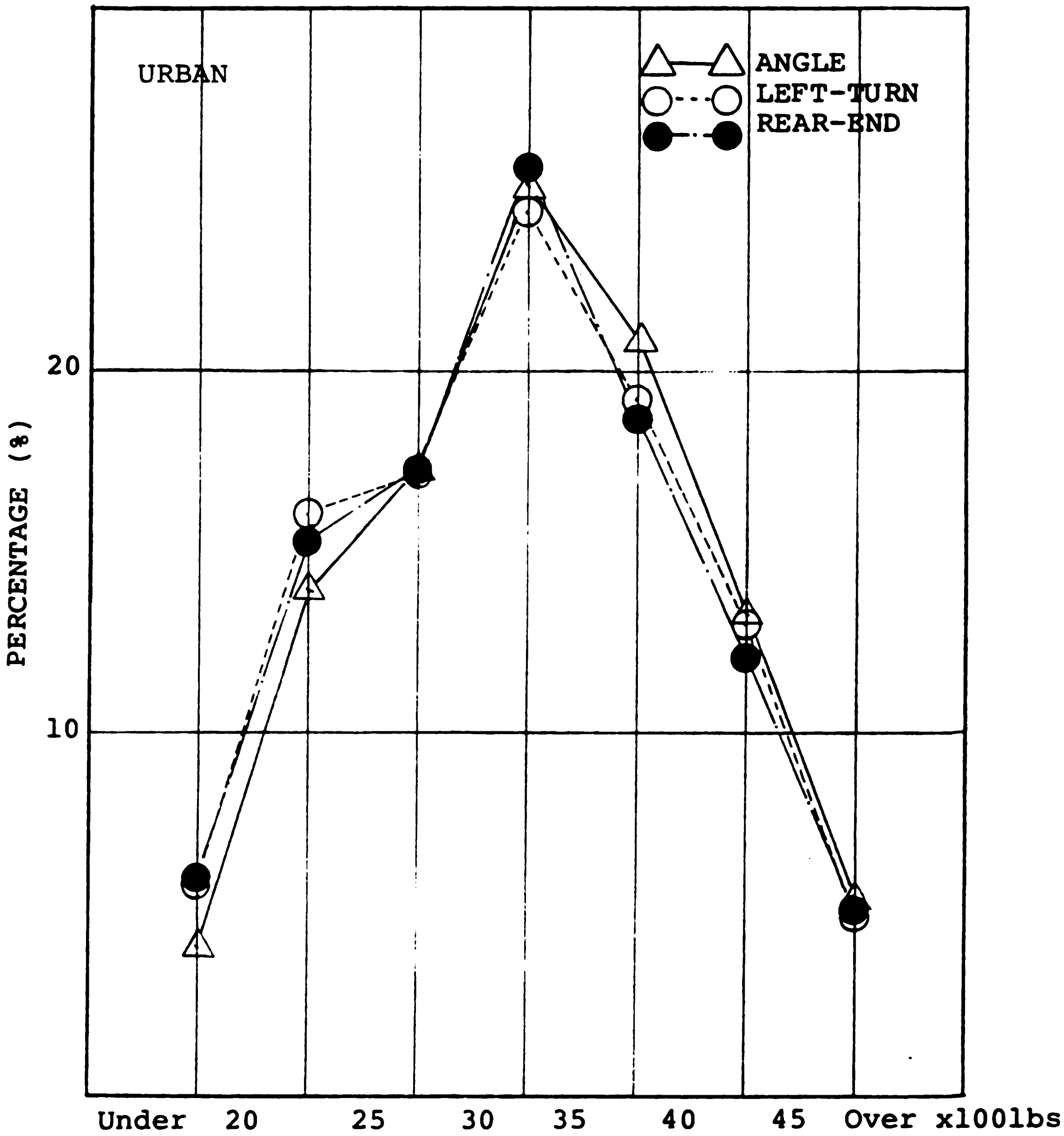


Figure 7.2.2. Distribution #4

Table 7.2.1. Statistical Test for Population Distributions of VEH #2 Accidents for Rural and Urban Areas.

RURAL

Weight Class	1	2	3	4	5	6	7	Total
Observed (Angle)	6.39	15.28	18.32	25.35	19.50	11.05	4.01	100.00
Expected (Rear-End)	6.14	17.53	18.34	23.30	17.75	13.39	3.55	100.00
$\frac{(O-E)^2}{E}$	.01	.26	.00	.18	.17	.41	.06	1.09

$X^2 = 1.09$

URBAN

Weight Class	1	2	3	4	5	6	7	Total
Observed (Angle)	4.17	13.97	17.34	25.10	20.70	13.31	5.41	100.00
Expected (Rear-end)	6.03	15.31	17.24	25.71	18.59	12.06	5.06	100.00
$\frac{(O-E)^2}{E}$	.57	.12	.00	.01	.24	.13	.02	1.09

$X^2 = 1.09$

- shoulder width
- posted speed limit
- degree of curve
- no passing zones

As expected, the results are more consistent than the results obtained when all accident data were combined. There were 8,559 accidents on rural 2 lane-2 way highways and 878 accidents on urban 2 lane-2 way highways. When the accident data were separated, the coefficient of determination (R^2) for total accidents on rural 2 lane-2 way highways is .993. This value is considerably greater than .759 which was obtained for 2 lane-2 way highways for all highways combined.

7.2.1 Findings for Rural Areas

The relationship between accidents and geometric features in rural areas shows remarkable consistency for these geometric features typically found in rural areas. The following geometric features were analyzed:

- total accidents
- midblock accidents
- 2 lane-2 way highways
- no-passing zones
- 10 ft., 12 ft. lane width
- highways with shoulders
- 0-2 degrees of curve

Figure 7.2.3 shows the results for total accidents on rural Michigan trunklines. Small automobiles are found to

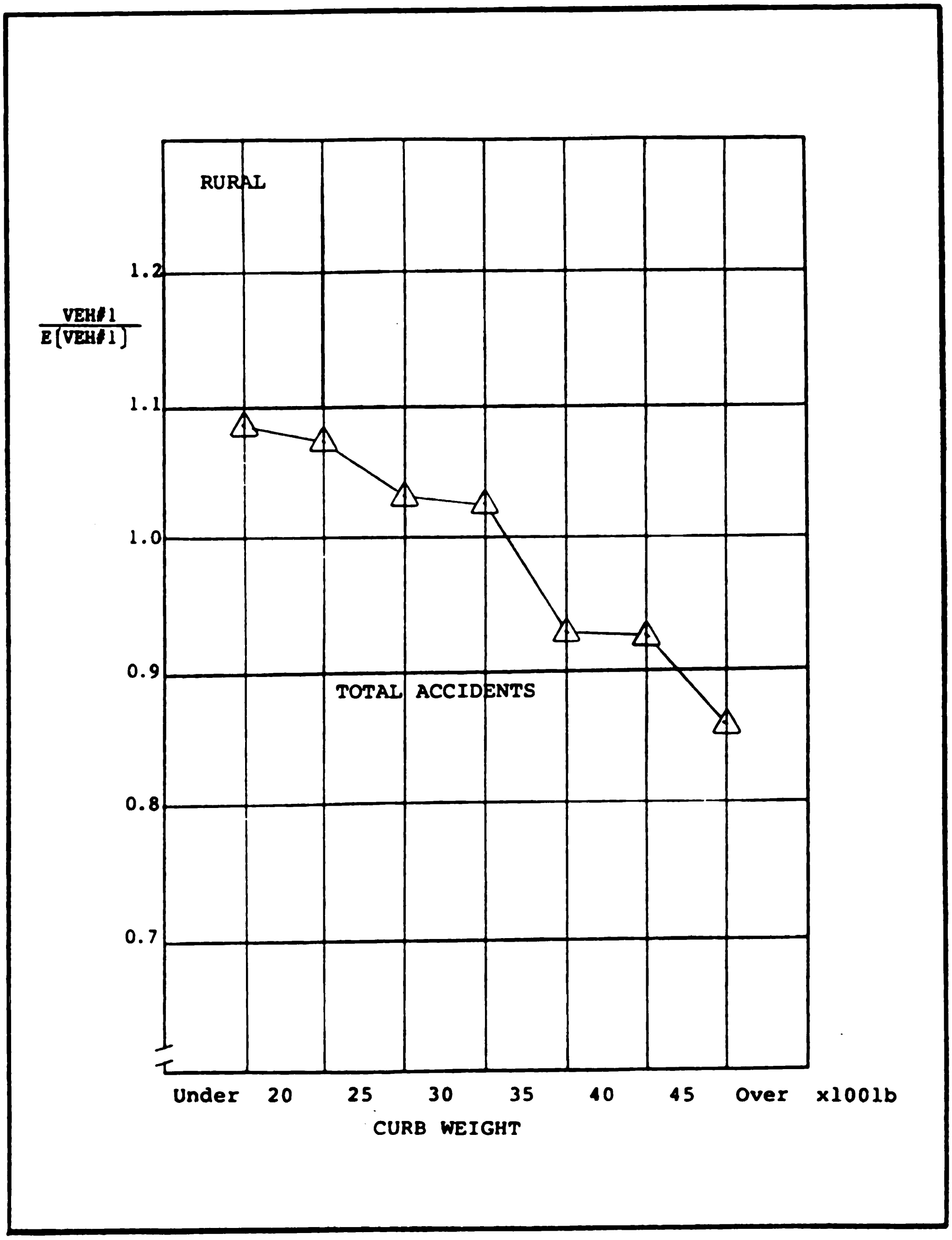


Figure 7.2.3. Total Accidents

have a higher A/E ratio than large automobiles with the difference being about 26 percent.

Figure 7.2.4 shows the results for highway area types, with the accident data stratified into intersection and midblock locations. The number of accidents at midblock locataions is dominant in rural areas, with 3,194 accidents at intersections and 7,094 accidents at midblock locations. The group of the smallest automobiles is found to have an A/E ratio 48 percent higher than the group of the largest automobiles at mid-block locations. This stratification helps explain the accident phenomena, as the intersection accidents A/E ratio is not related to vehicle size on rural highways.

Figure 7.2.5 shows the results by number of lanes. There were 8,559 accidents on 2 lane-2 way highways and 874 accidents on 4 lane-divided highways. The sample size was inadequate for any other lane configuration in rural areas. On 2 lane-2 way highways, small automobiles are found to have a high A/E ratio. The ratio for the group of the smallest automobiles is about 36 percent higher than the group of the largest automobiles. No trend is apparent for the 4-lane divided highways, as the accident data appears to be randomly distributed over automobile size.

The results for lane width in rural areas are shown in Figure 7.2.6. There were 1,730 accidents on 10 foot lanes, and 5,494 accidents on 12 foot lanes. Small automobiles are found to have a higher ratio than large automobiles regardless of lane width. However, small automobiles seem

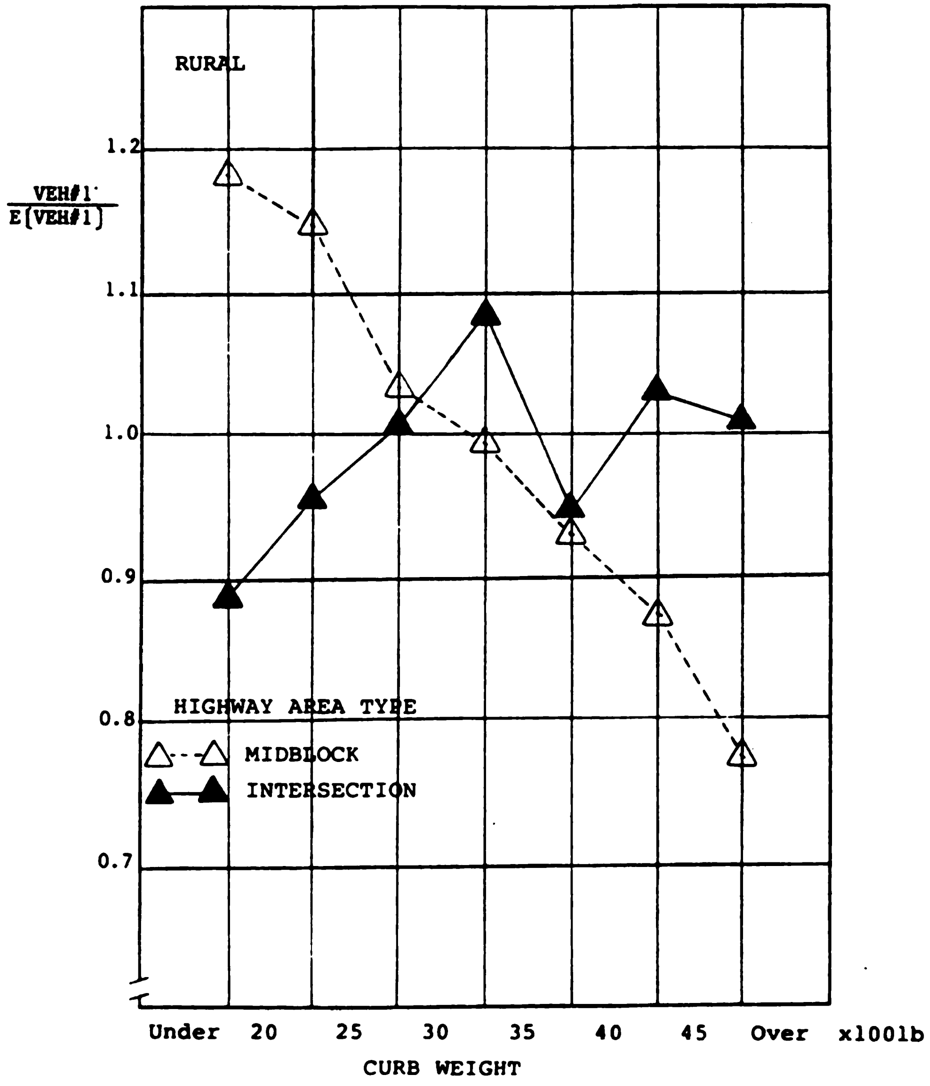


Figure 7.2.4. Area Type

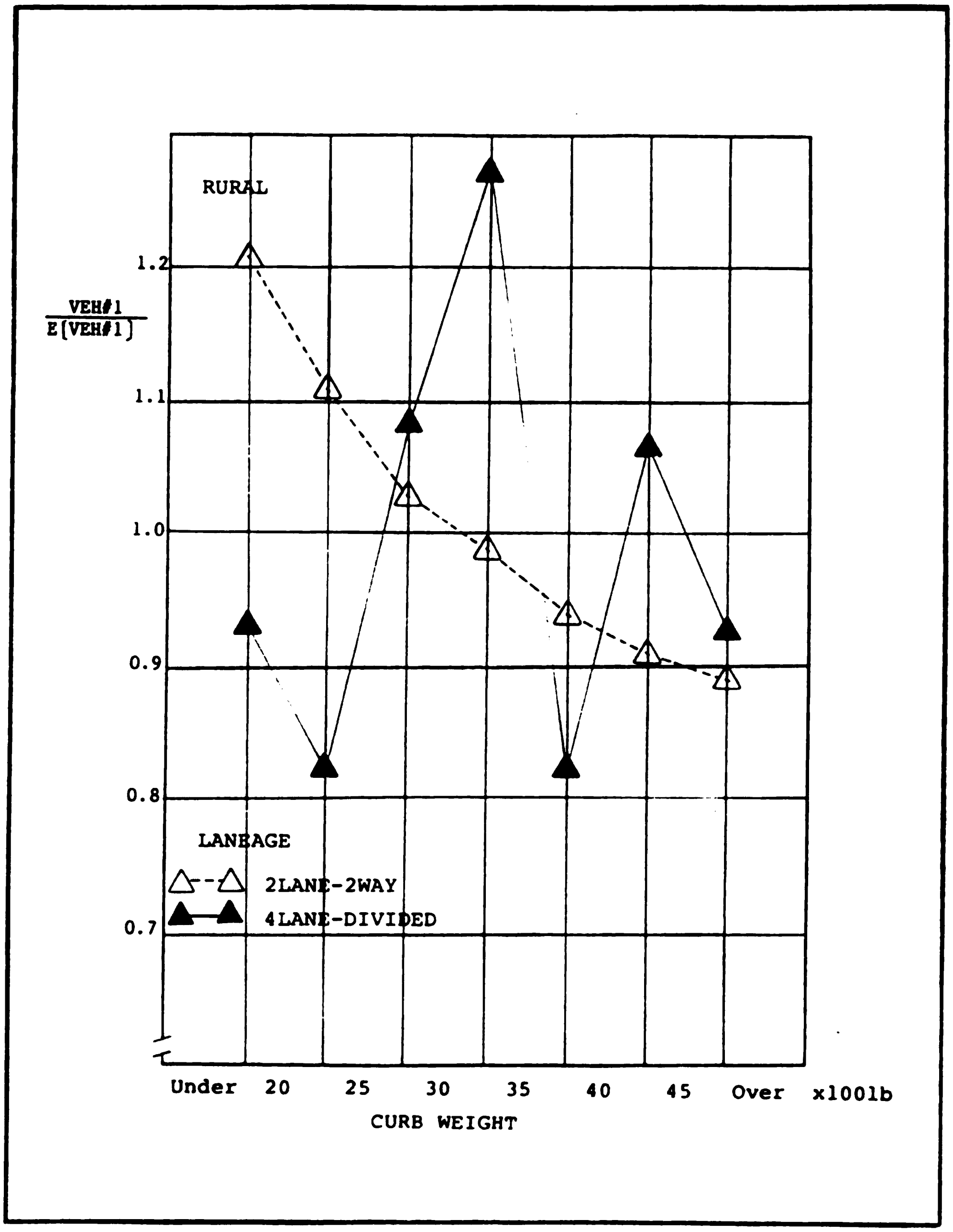


Figure 7.2.5. Number of Lanes

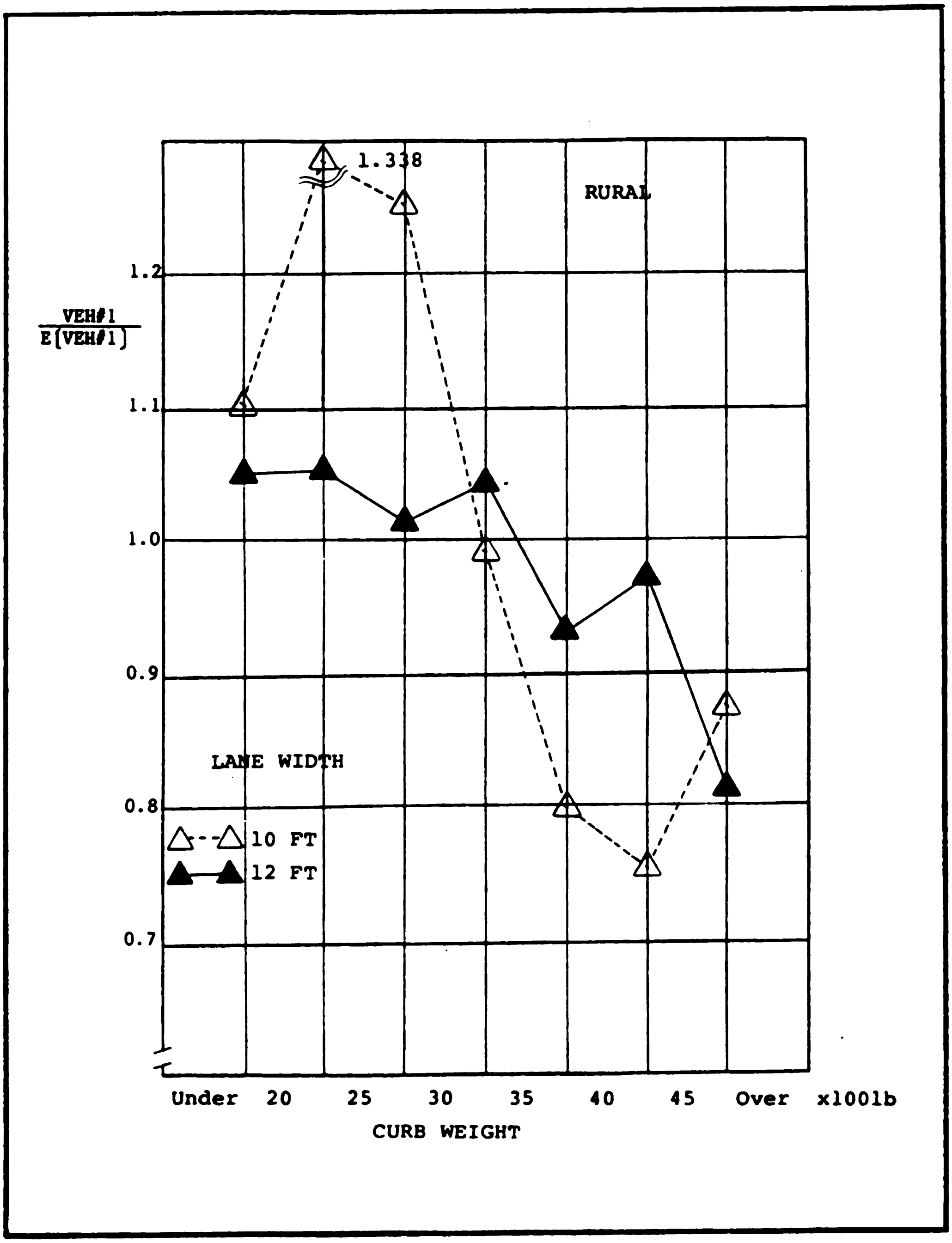


Figure 7.2.6. Lane Width

to be more sensitive to narrow lane width than are large automobiles. The trend toward a lower A/E ratio as vehicle size increases on 12 foot lanes is less than that for total accidents, and probably reflects this general trend rather than a relationship to lane width.

The variation in the A/E ratio on 10 foot lanes is more erratic than for the wider lanes, and the relationship appears to be more pronounced. With the exception of the smallest automobile groups and the largest automobile groups (which are based on an expected value of 36 and 24 respectively) the trend is fairly consistent. More data will be required to determine whether the extreme points are as shown in the figure, or whether these variations are due to small samples.

The results for the shoulder width in rural areas are shown in Figure 7.2.7. There were 3,461 accidents on highways with 4-8 foot shoulder width, 5,797 accidents on highways with 8-10 foot shoulder width, and 432 accidents on highways with curbs. Small automobiles are found to have a higher A/E ratio on highways with shoulders and a lower ratio on highways with curbs. The best fitting curves show that the ratio for the group of the smallest automobiles is about 32 percent higher on highways with 4-8 foot shoulder, and about 24 percent higher than the group of the largest automobiles where the shoulder width is 8-10 feet.

These results are difficult to interpret, and may be complicated by other factors. The curbed sections are

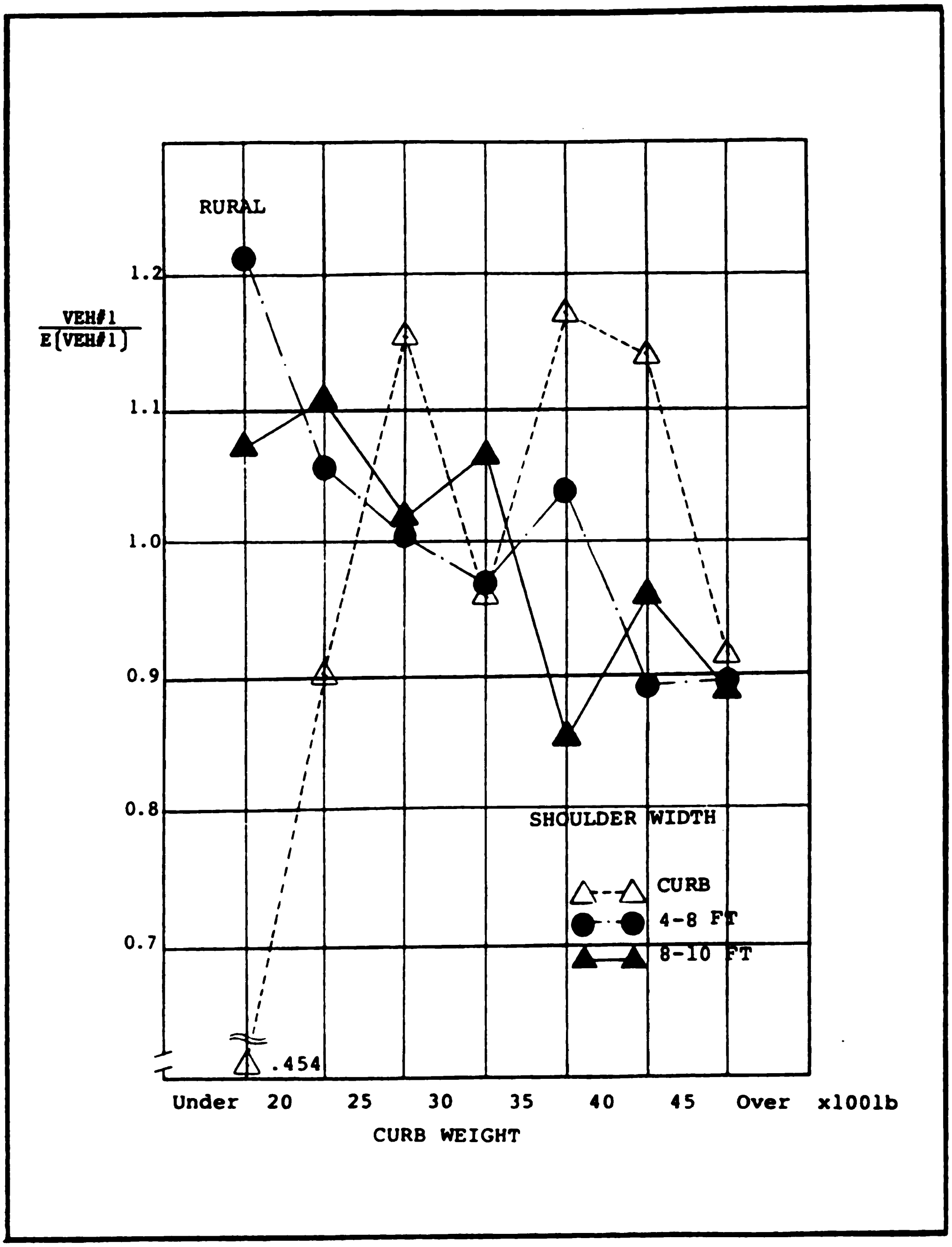


Figure 7.2.7. Shoulder Width

probably in more developed areas with a higher density of intersections, and thus may simply be reflecting accident type. The sections with shoulders appear to reflect the general trend in rural accidents, and thus the A/E ratio may be independent of the shoulder width. An explanation of the relationship between shoulder width and accidents is probably only possible if the data are further stratified by accident type, and single vehicle run-off-road type accidents are analyzed.

The results for the degree of curve in rural areas are shown in Figure 7.2.8. There were 9,693 accidents (94 percent of the accidents in rural areas) on highways with 0-2 degrees of curve and 323 (6 percent) accidents on highways with 5 or greater degrees of curve. Small automobiles are found to have a higher A/E ratio than large automobiles regardless of the degree of curve. However, small automobiles seem to be more sensitive to the degree of curve. The best fitting curves show that the group of the smallest automobiles has about a 35 percent higher ratio than the group of the largest automobiles for 5 or greater degrees of curve and about a 25 percent higher ratio for 0-2 degrees of curve.

In this analysis, the expected number of accidents was based on all rural accidents, not just those on curves. This is a different concept than is used for the other figures, and thus the results should be interpreted accordingly.

The results for no-passing zones in rural areas are

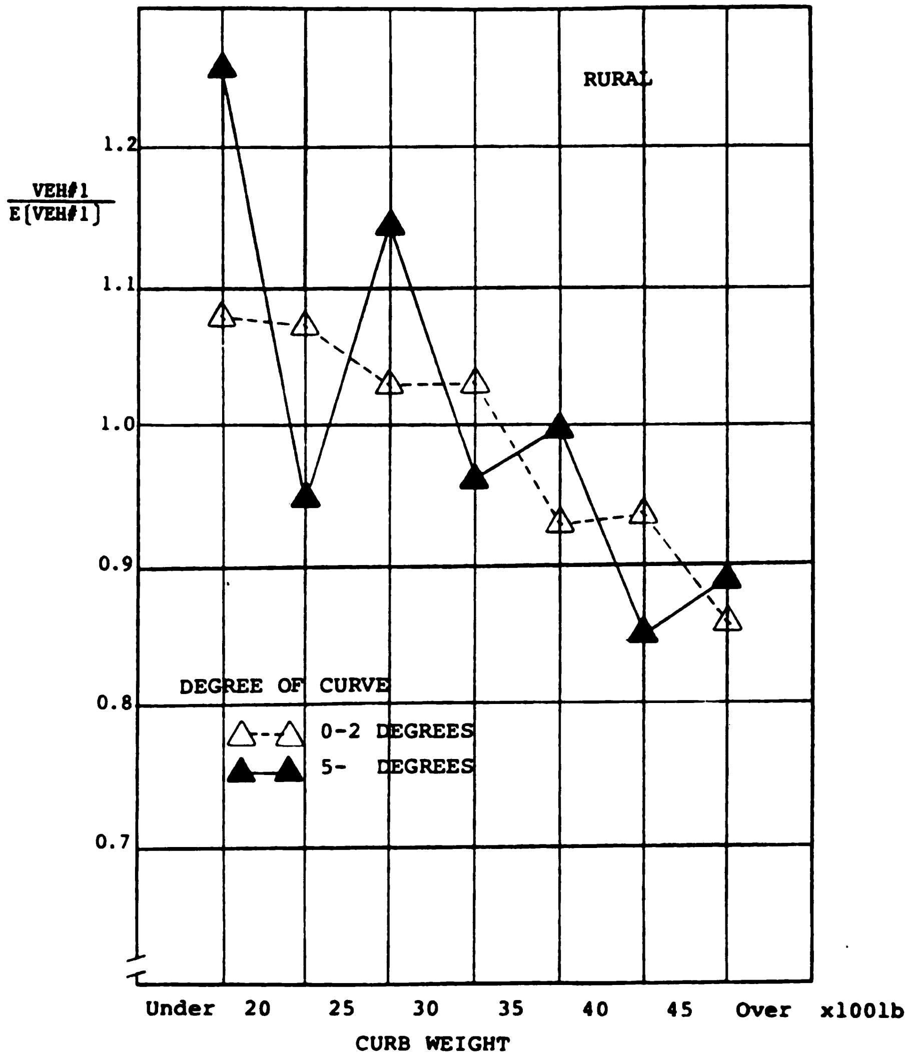


Figure 7.2.8. Degree of Curvature

shown in Figure 7.2.9. There were 7,372 accidents on highways where passing is allowed and 2,911 accidents on highways where no passing is allowed. All VEH #2 accidents in rural areas were used for the exposure in this analysis as well. Small automobiles have a higher ratio regardless of whether passing is allowed. However, the ratio for the group of the smallest automobiles is about 37 percent higher than the group of the largest automobiles in no passing zones, while it is only about 22 percent higher where passing is allowed. This result may be related to the geometry of no passing zones, the difference in eye height of drivers in small automobiles, or some combination of these factors. Additional stratification will be required to make this determination.

Table 7.2.2 shows the best fitting curves for the geometric features shown in the preceding figures.

7.3 Findings for Midblock Locations in Rural Areas

In an attempt to better understand the relationship among automobile design, geometric features, and accidents, all intersection accidents occuring in rural areas were removed from the file and only those accidents occurring at midblock locations were analyzed. Many of the geometric features being studied are more likely to be related with safety at midblock locations than at intersections.

The relationships obtained by examining this data set are better defined than when using combined intersection and non-intersection accident data. Small automobiles are

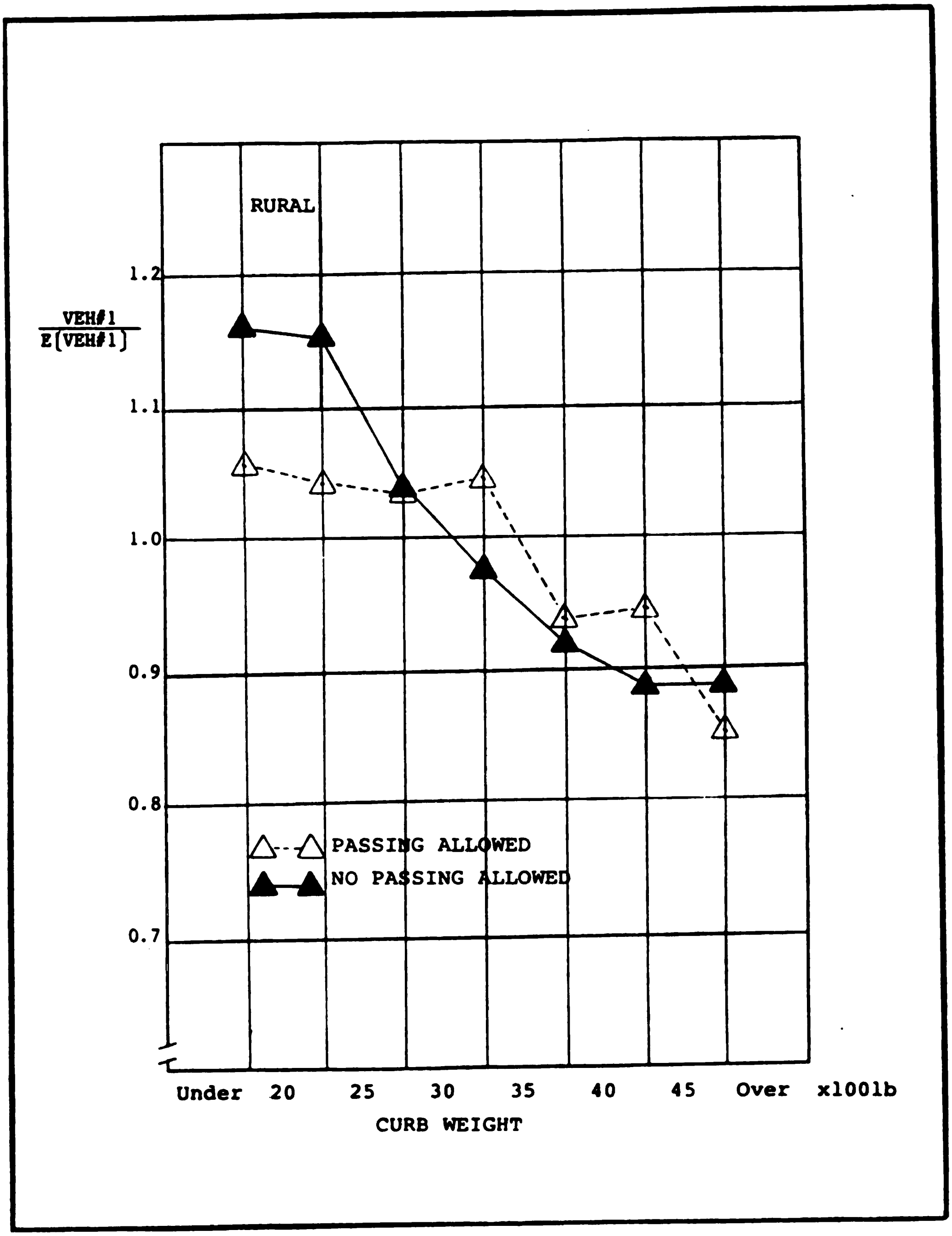


Figure 7.2.9. No Passing

Table 7.2.2. Best Fitting Curves for Geometric Features in Rural Areas

Geometric Features	Equation	R^2
Total Accidents	$Y = 1.25 - .0000780\ X$	.954
Midblock	$Y = 1.36 - .000112$	.990
2 Lane-2 Way	$Y = X/(-910 + 1.31\ X)$	.993
10 Ft. Lane Width	$Y = 1/(.478 + .000168\ X)$	.650
12 Ft. Lane Width	$Y = 1.21 - .0000708\ X$	.750
4-8 Ft. Shoulder	$Y = .713 - .871\ /X$	.814
8-10 Ft. Shoulder	$Y = 1.24 - .0000735\ X$	.652
0-2 Degrees	$Y = 1.23 - .0000758\ X$	.928
5-Degrees	$Y = .683 + 958\ /X$	.620
Passing Allowed	$Y = 1.20 - .0000670\ X$	.836
No Passing	$Y = 3.70 - .335 \log X$	.951

where Y = The ratio of the actual to the expected number of accidents

X = Curb weight

R^2 = Coefficient of determination

found to have a higher A/E ratio at midblock locations in rural areas for all geometric features studied. In particular, the relationship between accidents and lane width and shoulder width are more pronounced than in the previous analysis. All VEH #2 accident in rural areas are used in determining the exposures.

The A/E ratio for total accidents occuring in mid-block locations in rural areas is shown in Figure 7.3.1. The elimination of intersection accidents helps to illustrate the relationship between this type of accident and vehicle size. The difference in the A/E ratio between the smallest and largest automobiles is about 1.2 versus 0.8.

There were 6,224 mid-block accidents on 2 lane-2 way highways. The number of accidents for other laneage are too small to obtain results which are statistically significant. The results shown in Figure 7.3.2 show less of an effect than the results obtained for all rural accidents. This would suggest that the laneage is related with accidents not only at midblock locations but also at intersections.

There were 1,265 accidents on 10 foot lanes and 3,523 accidents on 12 foot lanes. As shown in Figure 7.3.3, small automobiles seem to be more sensitive to narrow lane width than are large automobiles. The best fitting curves show that the A/E ratio for the group of the smallest automobiles is about 59 percent higher on 10 foot lanes, and about 33 percent higher on 12 foot lanes at midblock

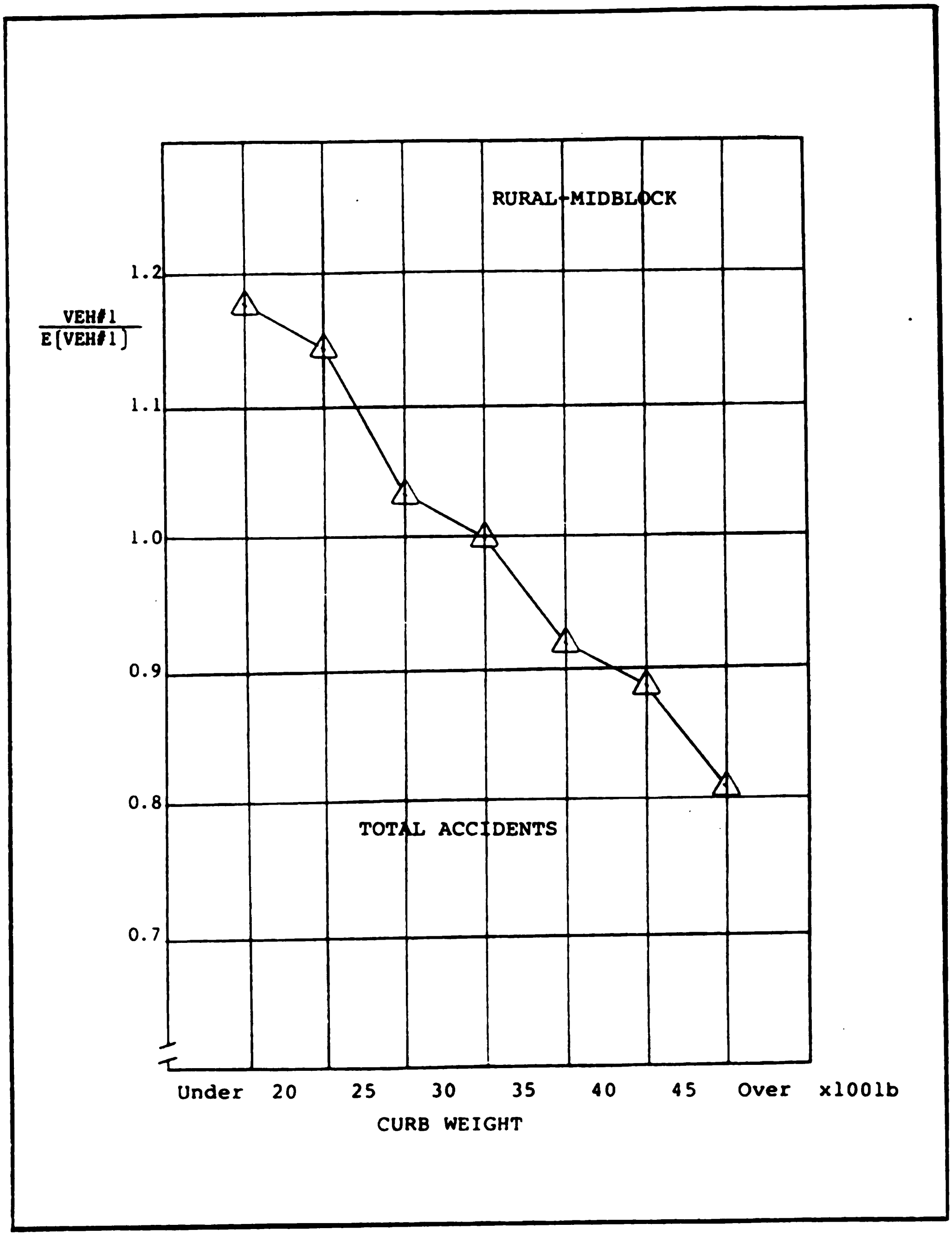


Figure 7.3.1. Total Accidents

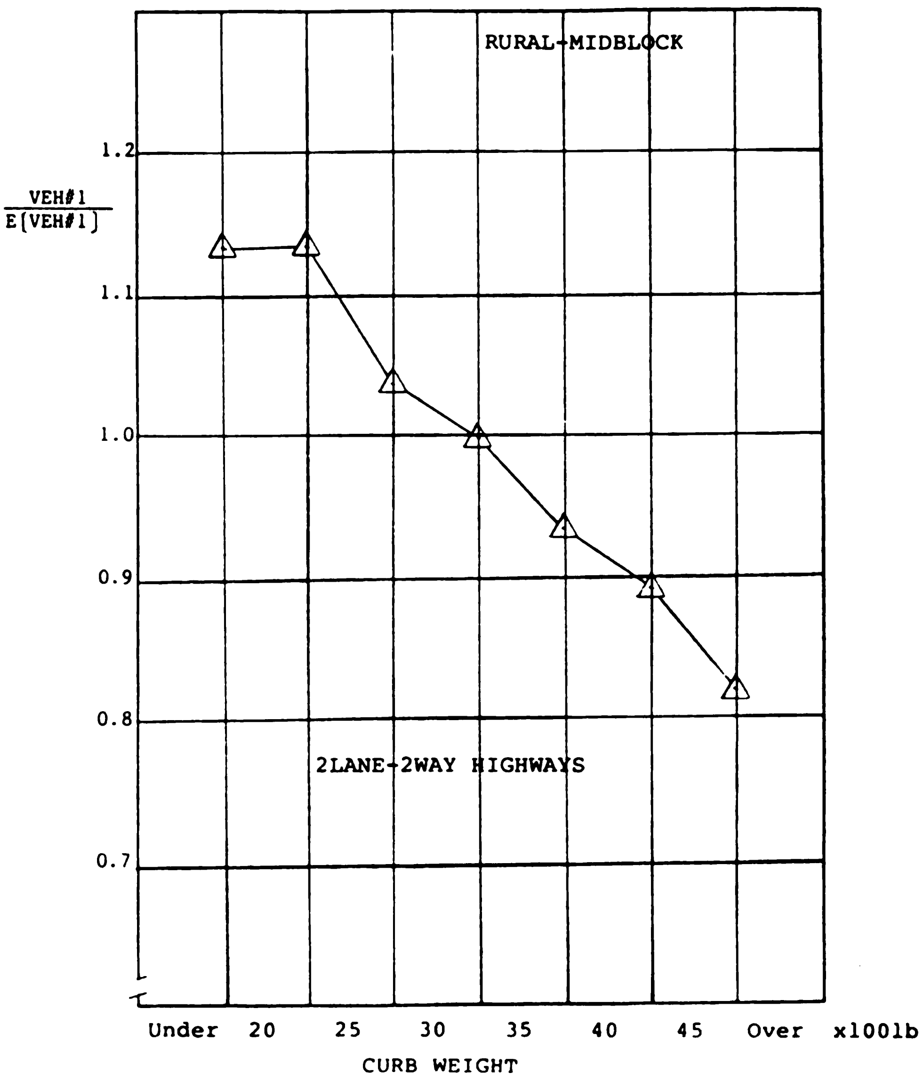


Figure 7.3.2. Midblock Accidents

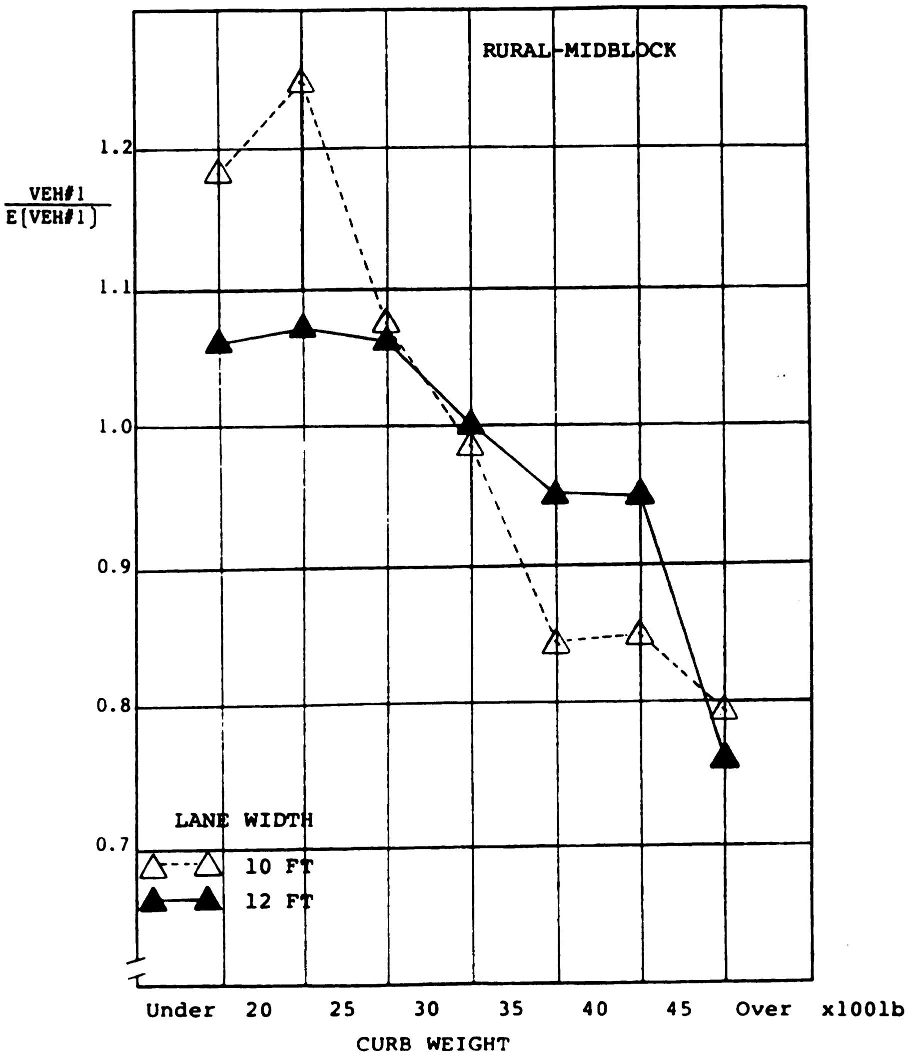


Figure 7.3.3. Lane Width

locations. This compares to 35 and 25 percent respectively when all rural accidents were used in the analysis.

There were 2,373 accidents at midblock locations with 4-8 foot shoulder width, 4,006 accidents where there are 8-10 foot shoulders, and 287 accidents where there are 10-12 foot shoulders. The results shown in Figure 7.3.4 are consistent with the results obtained for total accidents in rural areas. Small automobiles have a higher A/E ratio than large automobiles regardless of the shoulder width. The results for 4-8 foot and 8-10 foot shoulder widths are statistically significant, but the sample size for 10-12 foot shoulder width is too small to obtain statistical significnce.

There were 4,896 accidents at midblock locations where passing is allowed and 2,011 accidents at midblock locations where no passing is allowed. Once again, the greatest difference in the A/E ratio as a function of automobile size is in the areas with no passing allowed (Figure 7.3.5). The best fitting curve for no passing zones shows that the ratio for the group of the smallest automobiles is about 56 percent higher than that for large automobile ratio compared to about 33 percent higher for midblock locations where passing is allowed.

Figure 7.3.6 shows the results for overturned accidents at midblock locations in rural areas. The results show a very similar tendency to the results obtained for overturned accidents for statewide data. Small automobiles are found to be more involved in

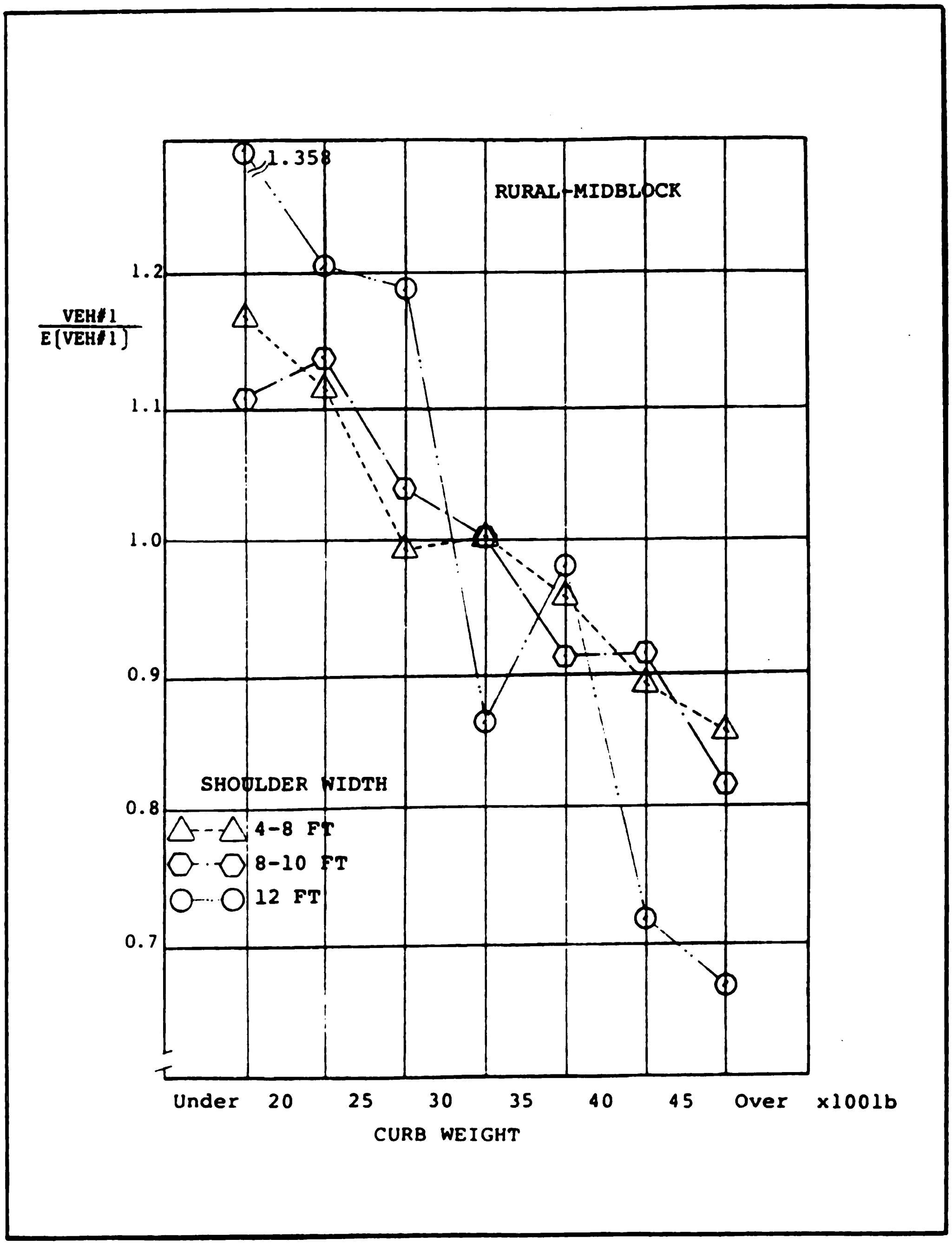


Figure 7.3.4. Shoulder Width

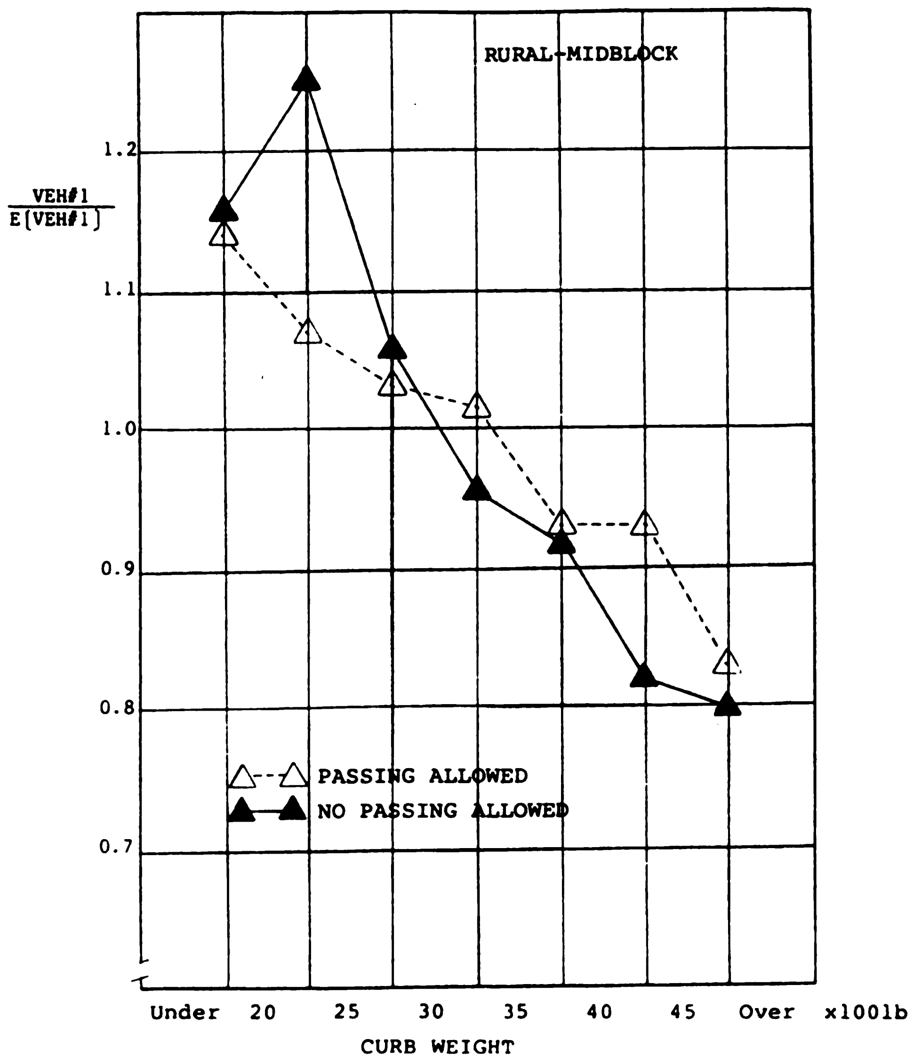


Figure 7.3.5. No Passing

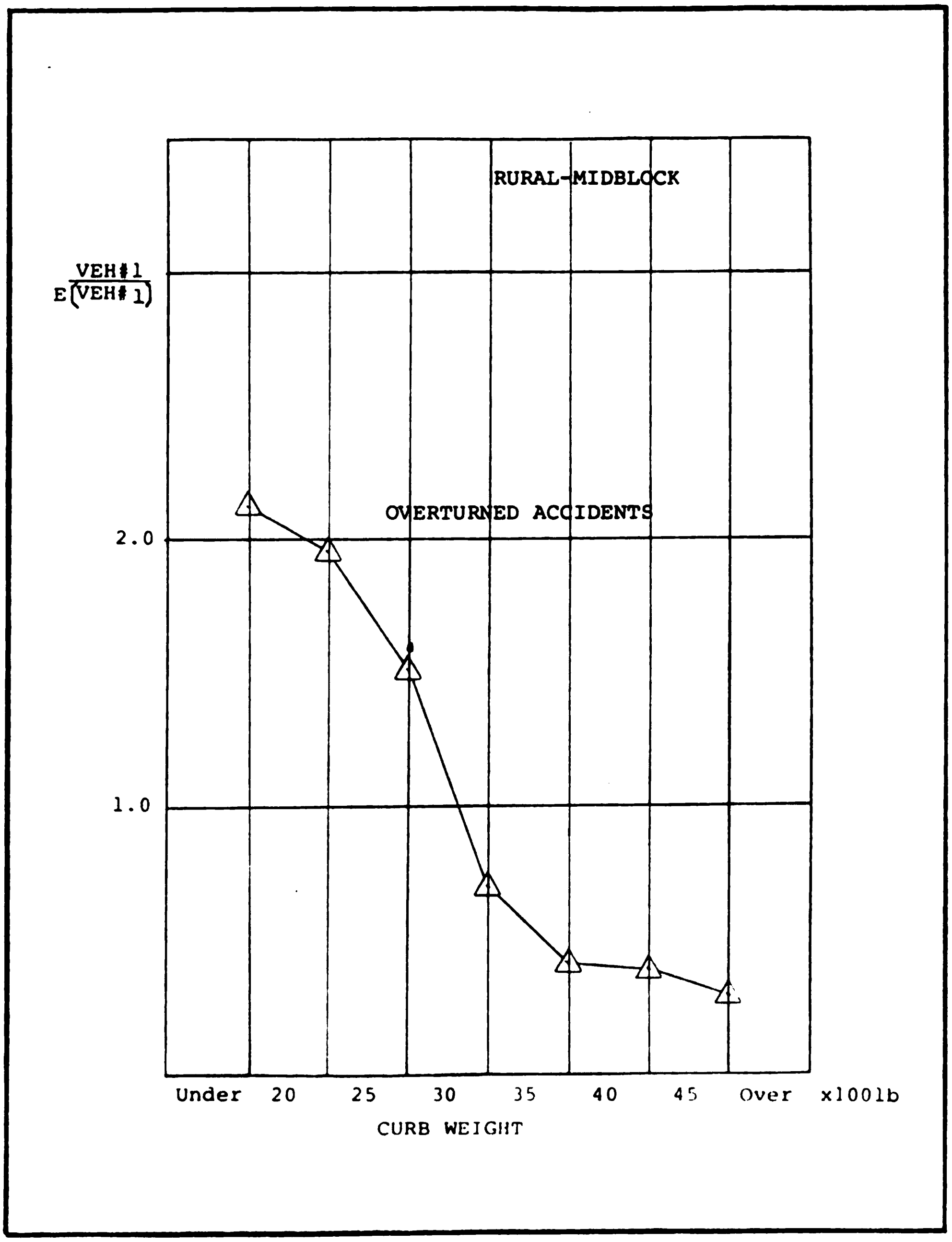


Figure 7.3.6. Overturned

overturned accidents than large automobiles at midblock locations in rural areas, with the ratio being about 4:1 for the extremes.

Table 7.3.1 shows the equation of the best fitting curves for geometric features at midblock locations in rural areas.

7.4 Findings for Urban Areas

Small automobiles are found to have a lower A/E ratio than large automobiles for all geometric features in urban areas. The results for the following geometric features in urban areas are discussed:

- total accidents
- intersections
- multi-lane facilities

The results for total accidents in urban areas are shown in Figure 7.4.1. Small automobiles have a lower A/E ratio than large automobiles, with the group of the smallest automobiles about 26 percent lower than the group of the largest automobiles.

The results for intersections and midblock locations in urban areas are shown in Figure 7.4.2. There were 9,715 accidents at intersections and 2,307 accidents at midblocks in the sample. Intersection accidents appear to have a consistent relationship with vehicle size, with the small automobiles having the lower A/E ratio. The group of the smallest automobiles is about 29 percent lower than the group of the largest automobiles. Conversely, the

Table 7.3.1. Best Fitting Curves for Geometric Features at Midblock Locations in Rural Areas

Geometric Features	Equation	R^2
Total Accidents	Y = 1.36 - .000112	.990
2 Lane-2 Way	Y = 1.43 exp (-.000113 X)	.984
10 Ft. Lane Width	Y = 1/(.501 + .000163 X)	.934
12 Ft. Lane Width	Y = 1.28 - .0000929 X	.817
4-8 Ft. Shoulder	Y = 3.54 - .316 log X	.956
8-10 Ft. Shoulder	Y = 1.40 exp(-.000108 X)	.945
12 Ft. Shoulder	Y = 6.89 - .733 log X	.909
Passing Allowed	Y = 1.31 - .0000961 X	.961
No Passing	Y = 1/(.522 + .000157 X)	.940

where Y = The ratio of the actual to the expected number of accidents

X = Curb weight

R^2 = Coefficient of determination

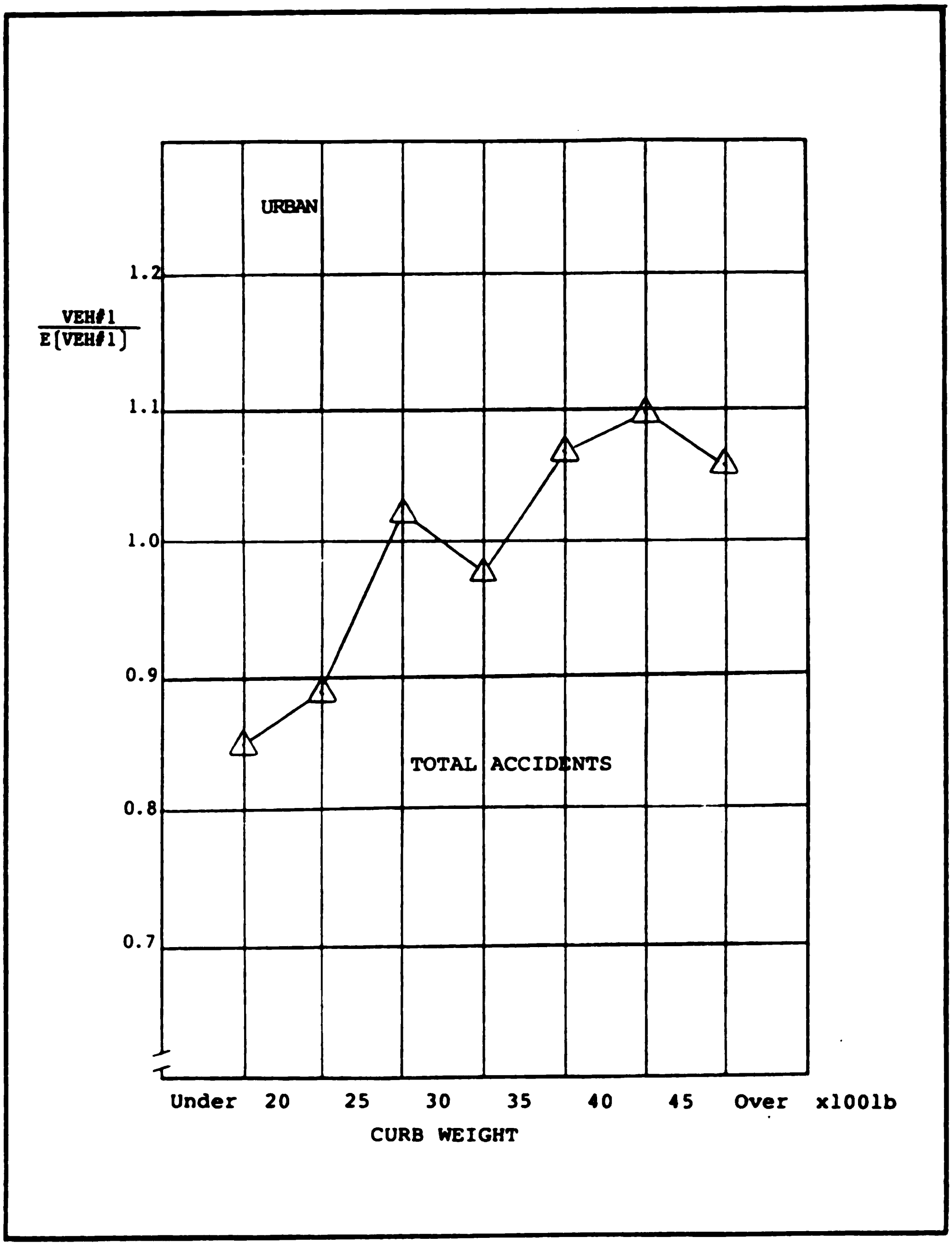


Figure 7.4.1. Total Accidents

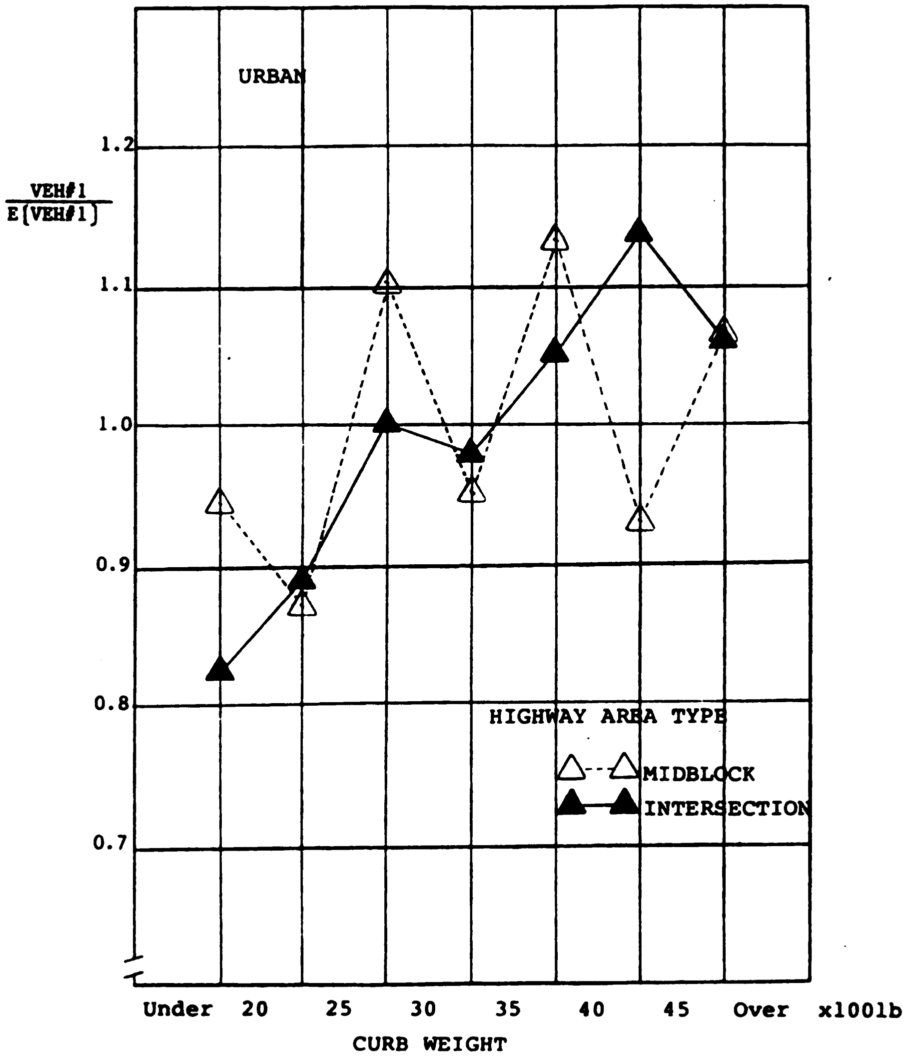


Figure 7.4.2. Area Type

mid-block accidents appear to be randomly distributed over vehicle size.

The relationship between accidents and the number of lanes in urban areas are shown in Figure 7.4.3. There were 878 accidents on 2 lane-2 way highways, 1,820 accidents on 5 lane-2 way highways, and 1,481 accidents on 6 lane-divided highways. All of the laneage combinations show the same trend as all urban accidents. It does not appear that there is a significant difference in results as a function of laneage. The group of the smallest automobiles is found to have about a 50 percent lower ratio than the group of the largest automobiles for all lane combinations.

The equations for the relationships discussed above are given in Table 7.4.1.

7.5 Results for Driver Injuries

To eliminate any bias due to a difference in the number of occupants by different automobile designs, only injuries sustained by the drivers are used in the analyses. Fatal (F-injury), incapacitating (A-injury), non-incapicitating (B-injury), and possible injury (C-injury) of drivers are considered as the injury classifications. Driver injuries in VEH #1 and driver injuries in VEH #2 are analyzed separately. The number of driver injuries in VEH #1 and VEH #2 by curb weight are displayed in Table 7.5.1.

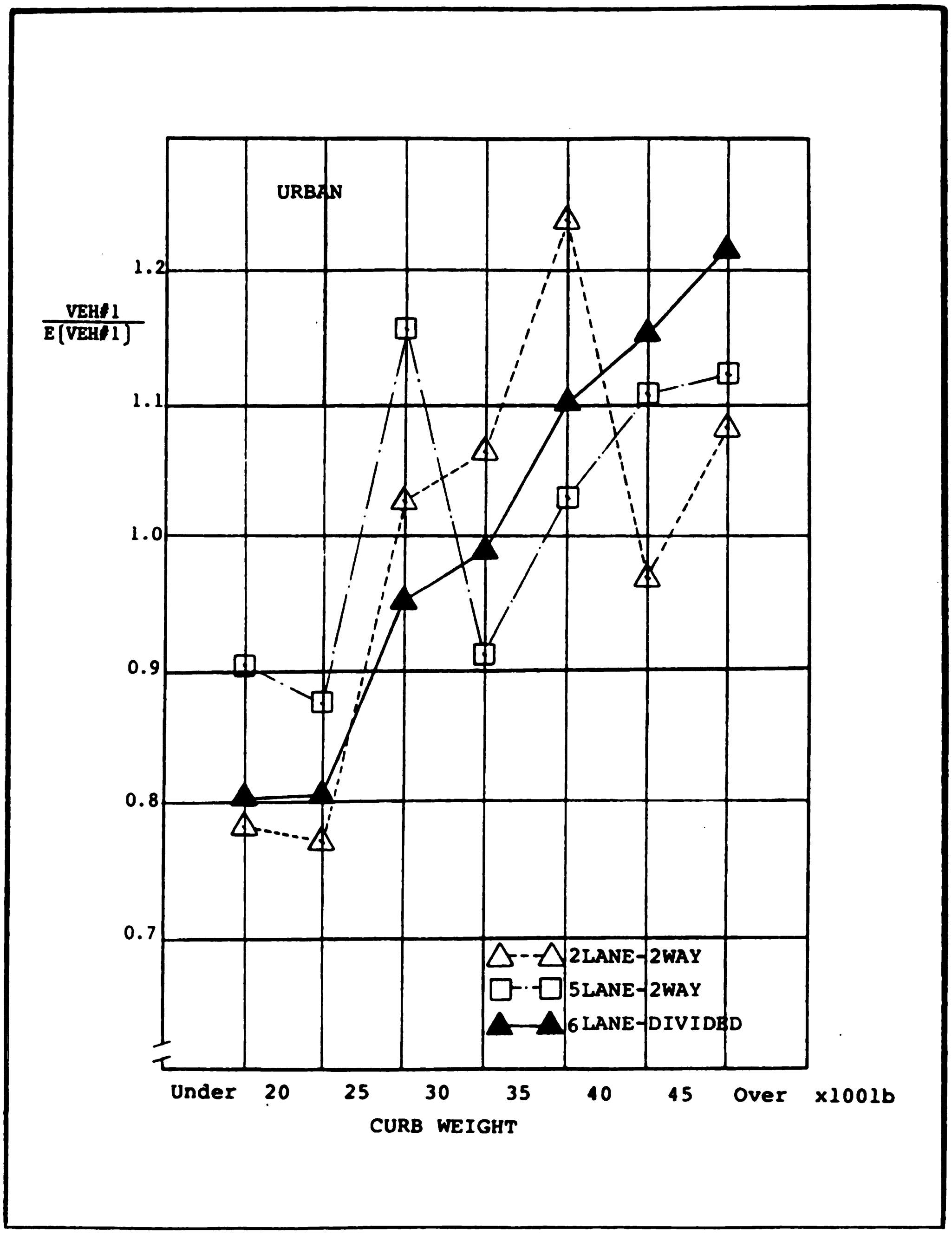


Figure 7.4.3. Number of Lanes

Table 7.4.1. Best Fitting Curves for Geometric Features in Urban Areas

Geometric Features	Equation	R^2
Total Accidents	$Y = X/(807 + .742\ X)$	.877
Intersection	$Y = X/(918 + .706\ X)$	.905
6 Lane-Divided	$Y = .511 + .000151\ X$	.972
10 Ft. Lane Width	$Y = X/(1190 + .626\ X)$	.847
12 Ft. Lane Width	$Y = X/(905 + .711\ X)$	.843

where Y = The ratio of actual to the expected number of accidents

X = Curb weight

R^2 = Coefficient of determination

Table 7.5.1. Number of Driver Injuries in VEH #1 and VEH #2 by Curb Weight (1982)

	Less Than 2000 lbs	2000- 2499 lbs	2500- 2999 lbs	3000- 3499 lbs	3500- 3999 lbs	4000- 4499 lbs	4500 lbs or more	Total
(VEH #1)								
Injury	571	1761	1889	2116	1547	923	318	9225
F + A	128	278	348	350	243	142	48	1530
(VEH #2)								
Injury	554	1517	1469	1762	1352	818	288	7760
F + A	67	194	176	195	112	60	23	827

The A/E ratio for automobiles of any class (D1) is calculated using Equation 4 (page 40).

Drivers in small automobiles were found to have a greater risk of being injured. Driver injuries in VEH #1 and driver injuries in VEH #2 are analyzed separately, with the drivers of vehicle number 1 in the group of smallest automobiles found to have a 72 percent higher risk of being injured, and a 108 percent higher risk of being seriously injured than drivers in the group of largest automobiles for the same exposure.

Similarly, drivers of vehicle number 2 in the group of smallest automobiles have a 56 percent higher risk of being injured, and a 178 percent higher risk of being seriously injured than drivers of the largest automobiles.

The results for VEH #1 are shown in Figure 7.5.1. This shows that drivers of small automobiles are more likely to be injured (and more likely to sustain a serious injury) given that an accident occurs, than are drivers of larger automobiles. The method of least squares indicates

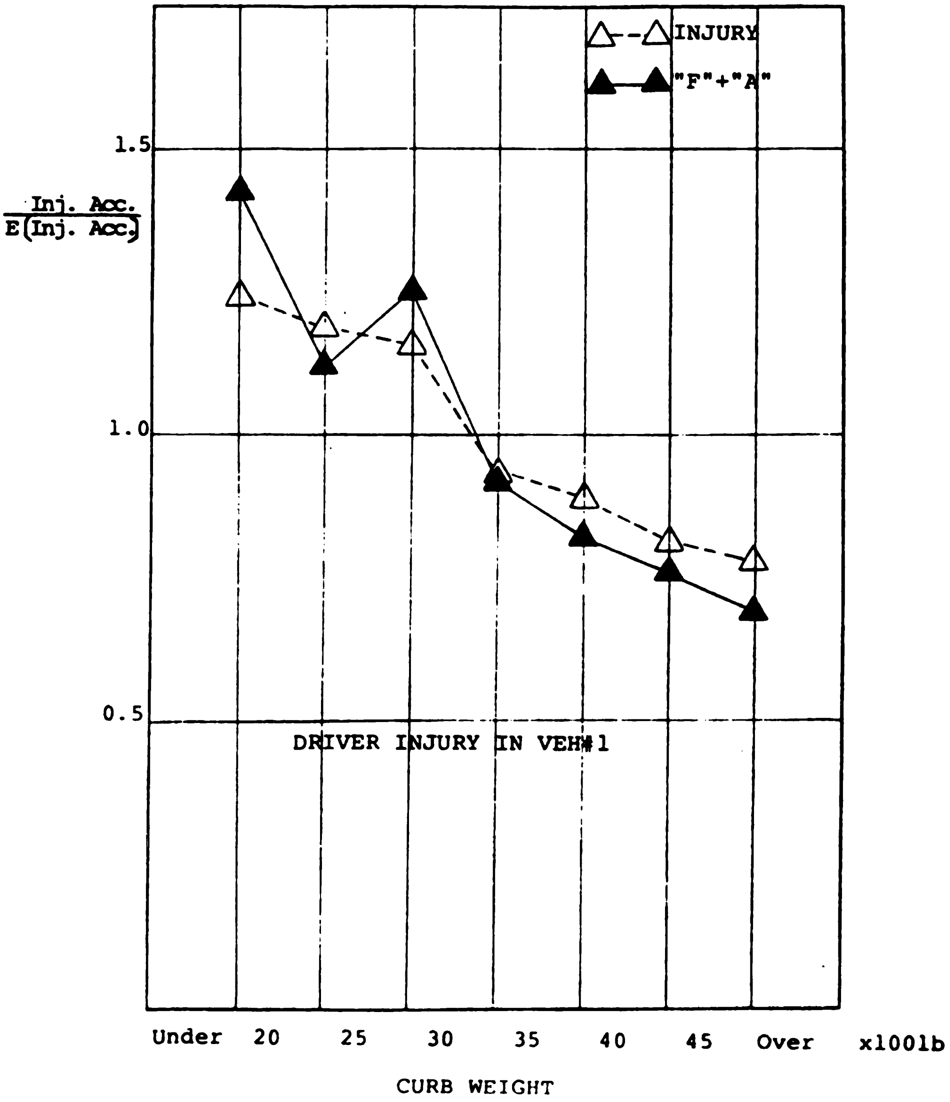


Figure 7.5.1. Driver Injury VEH #1

that a hyperbolic function $Y = 1/(.422 + .000189 X)$, is the curve of best fit. In this equation: Y is the ratio of the actual to the expected number of injury accidents, and X is the curb weight. The coefficient of determination $R^2 = .971$.

The best fitting curve for the F + A injuries is a hyperbolic function: $Y = 1/(.222 - .000258 X)$ with $R^2 = .949$. Using these curves the drivers in automobiles weighing less than 2000 lbs. would be estimated to have a 72 percent higher risk of being injured and a 108 percent higher risk of being seriously injured than drivers in automobiles weighing 4,500 lbs. or more for the same exposure.

The results for VEH #2 are shown in Figure 7.5.2. The results are similar to those for drivers of VEH #1. The best fitting curve is a power function: $Y = 1.39 \times X^{-0.413}$ with $R^2 = .963$ for all injuries, and an exponential function: $Y = 2.88 \exp (.000348 X)$ with $R^2 = .932$ for serious injuries. These curves provide estimates that the drivers in automobiles weighing less than 2000 lbs. have a 56 percent higher risk of being an injured driver of VEH #2, and a 178 percent higher risk of being a seriously injured driver of VEH #2 than drivers in automobiles weighing 4,500 lbs. or more for the same exposure. This suggests that the likelihood of being seriously injured in VEH #2 would be greatly affected by the size of the vehicle. The results of a least square fit of the linear transform of these equations are shown for

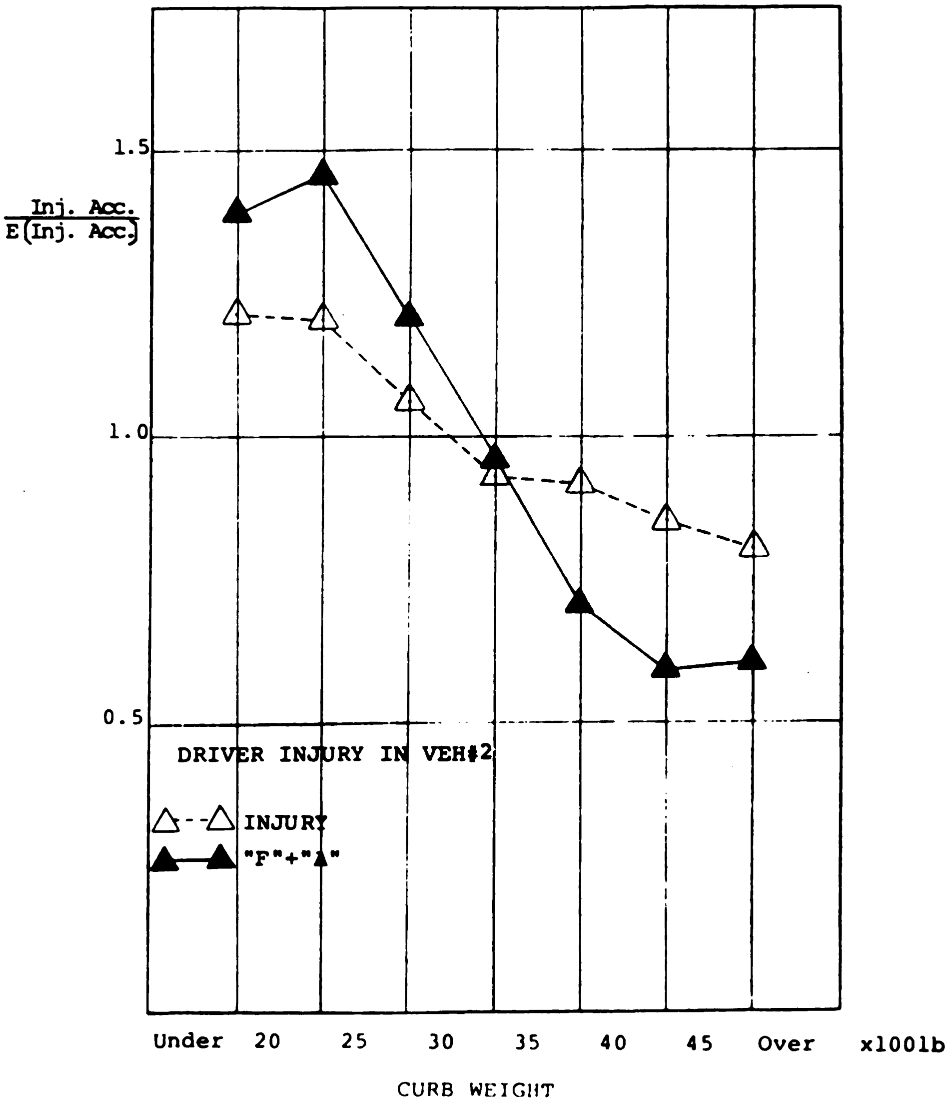


Figure 7.5.2. Driver Injury VEH #2

VEH #1 and VEH #2 in Tables 7.5.1 and 7.5.2 respectively.

Although small automobiles have a lower A/E ratio for certain geometric and locational parameters, once a small automobile _is_ involved in an accident the driver has a higher risk of being injured than drivers of larger automobiles.

The likelihood of being injured when a driver is involved in an accident with automobiles of various sizes was also examined. The number of injured drivers in automobiles of design D1 in collision with automobiles of design D2 were obtained for the seven groups of curb weight. Table 7.5.4 shows the number of injured drivers in VEH #1 as the result of accidents involving two passenger automobiles. The table entries are recorded as the driver in an automobile of design D1, listed in the row, in collision with an automobile of design D2, listed in the column. For example, only four drivers in automobiles weighing 4,500 lbs. or more were injured when their automobiles hit automobiles weighing less than 2000 lbs.

Table 7.5.5 shows the number of injured drivers in VEH #2 as the result of accidents involving two passenger automobiles. For this table, the entries are for drivers in an automobile of design D1, listed in the row, in collision within an automobile of design D2, listed in the column, sustaining an injury. For example, nineteen drivers in the group of smallest automobile were injured when their automobiles were hit by an automobile from the group of largest automobiles. This corresponds to the four

Table 7.5.2. Results of a Least Square Fit of Its Linear Transform for Driver Injury in VEH #1

* Injury $Y = 1/(.422 + .000189\ X)$, $R^2 = .971$

X-ACTUAL	Y-ACTUAL	Y-CALC	PCT DIFFER
1867	1.239	1.28901	-3.8
2245	1.183	1.18017	.2
2701	1.159	1.07107	8.2
3223	.939	.968573	-3
3729	.884	.886352	- .2
4215	.811	.819533	-1
4802	.755	.751139	.5

* F+A $Y = 1/(.222 - .000258\ X)$, $R^2 = .949$

X-ACTUAL	Y-ACTUAL	Y-CALC	PCT DIFFER
1867	1.425	1.4214	.2
2245	1.126	1.24831	-9.7
2701	1.261	1.08842	15.8
3223	.936	.949236	-1.3
3729	.837	.844549	- .8
4215	.752	.763657	-1.5
4802	.687	.684473	.3

X = Curb weight (lbs.)

Y = The ratio of the actual to the expected number of accidents

Table 7.5.3. Results of a Least Square Fit of Its Linear Transform for Driver Injury in VEH #2

* Injury $Y = 1.39 \text{ x } X^{-.0413}$, $R^2 = .963$

X-ACTUAL	Y-ACTUAL	Y-CALC	PCT DIFFER
1867	1.216	1.25558	-3.1
2245	1.211	1.15171	5.1
2701	1.071	1.05616	1.4
3223	.929	.972279	-4.4
3729	.918	.908092	1
4215	.854	.857454	- .4
4802	.812	.806661	.6

* F+A $Y = 2.88 \exp(.000348 X)$, $R^2 = .932$

X-ACTUAL	Y-ACTUAL	Y-CALC	PCT DIFFER
1867	1.38	1.50506	- 8.3
2245	1.454	1.31959	10.1
2701	1.204	1.12601	6.9
3223	.965	.939007	2.7
3729	.714	.787435	- 9.3
4215	.588	.66494	-11.5
4802	.609	.542112	12.3

X = Curb weight (lbs.)

Y = The ratio of the actual to the expected number of accidents

Table 7.5.4. Crosstabulation 1

```
* * * * * * * * * * * * * * * * * *   C R O S S T A B U L A T I O N   O F  * * * * * * * * * * *
   VWEIT1    CAR WEIGHT VEH1 BY VIN                          BY  VWEIT2    CAR WEIGHT VEH2 BY VIN
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                     VWEIT2
             COUNT  I
                    ILESS THA 2000-249 2500-299 3000-349 3500-399 4000-449 4500 LBS   ROW
                    IN 2000 L 9 LBS    9 LBS    9 LBS    9 LBS    9 LBS     OR MORE  TOTAL
                    I      1.I      2.I      3.I      4.I      5.I      6.I      7.I
VWEIT1      --------I--------I--------I--------I--------I--------I--------I--------I
                 1. I    10  I    39  I    46  I    54  I    49  I    32  I    12  I   242
  LESS THAN 2000 L  I        I        I        I        I        I        I        I   6.9
                   -I--------I--------I--------I--------I--------I--------I--------I
                 2. I    27  I    86  I    93  I   176  I   138  I   101  I    39  I   660
  2000-2499 LBS     I        I        I        I        I        I        I        I  18.7
                   -I--------I--------I--------I--------I--------I--------I--------I
                 3. I    32  I    97  I   118  I   164  I   141  I   109  I    49  I   710
  2500-2999 LBS     I        I        I        I        I        I        I        I  20.1
                   -I--------I--------I--------I--------I--------I--------I--------I
                 4. I    29  I    98  I   142  I   196  I   191  I   121  I    50  I   827
  3000-3499 LBS     I        I        I        I        I        I        I        I  23.5
                   -I--------I--------I--------I--------I--------I--------I--------I
                 5. I    21  I    83  I    94  I   146  I   134  I    95  I    36  I   609
  3500-3999 LBS     I        I        I        I        I        I        I        I  17.3
                   -I--------I--------I--------I--------I--------I--------I--------I
                 6. I    12  I    37  I    56  I    89  I    87  I    51  I    26  I   358
  4000-4499 LBS     I        I        I        I        I        I        I        I  10.2
                   -I--------I--------I--------I--------I--------I--------I--------I
                 7. I     4  I    13  I    20  I    28  I    27  I    21  I     6  I   119
  4500 LBS OR MORE  I        I        I        I        I        I        I        I   3.4
                   -I--------I--------I--------I--------I--------I--------I--------I
            COLUMN      135      453      569      853      767      530      218     3525
             TOTAL      3.8     12.9     16:1     24.2     21.8     15.0      6.2    100.0

NUMBER OF MISSING OBSERVATIONS =    10392
```

Table 7.5.5. Crosstabulation 2

```
* * * * * * * * * * * * * * * * * * *  C R O S S T A B U L A T I O N   O F  * * * * * * * * * * *
  VWEIT1    CAR WEIGHT VEH1 BY VIN                     BY  VWEIT2    CAR WEIGHT VEH2 BY VIN
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                    VWEIT2
            COUNT  I
                   ILESS THA 2000-249 2500-299 3000-349 3500-399 4000-449 4500 LBS   ROW
                   IN 2000 L 9 LBS    9 LBS    9 LBS    9 LBS    9 LBS     OR MORE  TOTAL
                   I      1.I      2.I      3.I      4.I      5.I      6.I      7.I
VWEIT1     --------I--------I--------I--------I--------I--------I--------I--------I
                1. I   13   I   43   I   39   I   28   I   22   I   21   I    4   I   170
  LESS THAN 2000 L I        I        I        I        I        I        I        I   3.8
                  -I--------I--------I--------I--------I--------I--------I--------I
                2. I   37   I  108   I   84   I  124   I   78   I   65   I   19   I   515
  2000-2499 LBS    I        I        I        I        I        I        I        I  11.6
                  -I--------I--------I--------I--------I--------I--------I--------I
                3. I   51   I  141   I  134   I  163   I  121   I   71   I   29   I   710
  2500-2999 LBS    I        I        I        I        I        I        I        I  16.0
                  -I--------I--------I--------I--------I--------I--------I--------I
                4. I   66   I  223   I  225   I  287   I  206   I  105   I   34   I  1146
  3000-3499 LBS    I        I        I        I        I        I        I        I  25.8
                  -I--------I--------I--------I--------I--------I--------I--------I
                5. I   70   I  200   I  201   I  218   I  174   I  107   I   34   I  1004
  3500-3999 LBS    I        I        I        I        I        I        I        I  22.6
                  -I--------I--------I--------I--------I--------I--------I--------I
                6. I   45   I  117   I  133   I  143   I  129   I   60   I   29   I   656
  4000-4499 LBS    I        I        I        I        I        I        I        I  14.7
                  -I--------I--------I--------I--------I--------I--------I--------I
                7. I   19   I   43   I   38   I   58   I   57   I   25   I    9   I   249
  4500 LBS OR MORE I        I        I        I        I        I        I        I   5.6
                  -I--------I--------I--------I--------I--------I--------I--------I
            COLUMN     301      875      854     1021      787      454      158     4450
             TOTAL     6.8     19.7     19.2     22.9     17.7     10.2      3.6    100.0

NUMBER OF MISSING OBSERVATIONS =     7707
```

drivers of the large automobiles who were injured when they hit the small automobiles.

Table 7.5.6 shows the number of two passenger automobile accidents with VEH #1, listed in the row, and VEH #2, listed in the column. For example, there were 58 accidents that involved the group of largest automobiles as VEH #1 and the group of smallest automobiles as VEH #2. The numbers from Table 7.5.4 and Table 7.5.5 are divided by the numbers from Table 7.5.6, and the ratios are shown in Table 7.5.7 and Table 7.5.8 respectively. The numbers in these tables are the average number of injured drivers in VEH #1 and VEH #2 per accident. For example, there were .069 injured drivers of the group of largest automobiles per accident in which the group of largest automobiles hit the group of smallest automobiles. On the other hand, there were .286 injured drivers of the group of smallest automobiles per accident in which the group of smallest automobiles hit one of the largest automobiles. The ratio (.286/.069 = 4.1) provides a relative likelihood of the drivers of VEH #1 being injured.

The numbers shown in Table 7.5.8 illustrate a relative likelihood of being injured for the drivers of VEH #2. For example, the ratio (.328/.255 = 1.3) shows the likelihood of being injured is 30 percent greater for the drivers in automobiles weighing less than 2000 lbs. being hit by an automobile weighing 4,500 lbs. or more than when hit by an automobile of their same weight group. The ratio (.214/.095 = 2.3) shows the likelihood of being injured is

Table 7.5.6. Crosstabulation 3

```
* * * * * * * * * * * * * * * * *   C R O S S T A B U L A T I O N   O F   * * * * * * * * * * *
   VWEIT1    CAR WEIGHT VEH1 BY VIN                             BY  VWEIT2    CAR WEIGHT VEH2 BY VIN
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                     VWEIT2
            COUNT  I
                   ILESS THA 2000-249 2500-299 3000-349 3500-399 4000-449 4500 LBS   ROW
                   IN 2000 L 9 LBS    9 LBS    9 LBS    9 LBS    9 LBS    OR MORE   TOTAL
                   I      1.I      2.I      3.I      4.I      5.I      6.I      7.I
VWEIT1     --------I--------I--------I--------I--------I--------I--------I--------I
                1. I   51   I  172   I  184   I  230   I  188   I  134   I   42   I  1001
  LESS THAN 2000 L I        I        I        I        I        I        I        I   5.0
                  -I--------I--------I--------I--------I--------I--------I--------I
                2. I  165   I  458   I  495   I  693   I  550   I  375   I  108   I  2844
  2000-2499 LBS    I        I        I        I        I        I        I        I  14.2
                  -I--------I--------I--------I--------I--------I--------I--------I
                3. I  196   I  535   I  618   I  874   I  659   I  433   I  167   I  3482
  2500-2999 LBS    I        I        I        I        I        I        I        I  17.4
                  -I--------I--------I--------I--------I--------I--------I--------I
                4. I  255   I  775   I  892   I 1257   I  982   I  623   I  217   I  5001
  3000-3499 LBS    I        I        I        I        I        I        I        I  25.0
                  -I--------I--------I--------I--------I--------I--------I--------I
                5. I  214   I  635   I  695   I  990   I  753   I  489   I  188   I  3964
  3500-3999 LBS    I        I        I        I        I        I        I        I  19.8
                  -I--------I--------I--------I--------I--------I--------I--------I
                6. I  148   I  400   I  466   I  681   I  536   I  350   I  129   I  2710
  4000-4499 LBS    I        I        I        I        I        I        I        I  13.6
                  -I--------I--------I--------I--------I--------I--------I--------I
                7. I   58   I  151   I  142   I  243   I  214   I  122   I   42   I   972
  4500 LBS OR MORE I        I        I        I        I        I        I        I   4.9
                  -I--------I--------I--------I--------I--------I--------I--------I
           COLUMN     1087     3126     3492     4968     3882     2526      893    19974
            TOTAL      5.4     15.7     17.5     24.9     19.4     12.6      4.5    100.0

NUMBER OF MISSING OBSERVATIONS =    31716
```

Table 7.5.7. Number of Drivers Injured VEH #1
(Per Two Passenger Car Accidents)

VEH #2 VEH #1	Less Than 2000 lbs.	2000-2499	2500-2999	3000-3499	3500-3999	4000-4499	4500 Lb. or More
1	.196	.227	.250	.235	.261	.239	.286
2	.164	.188	.188	.254	.251	.269	.361
3	.163	.181	.191	.188	.214	.252	.293
4	.114	.126	.159	.156	.195	.194	.230
5	.098	.131	.135	.147	.178	.194	.191
6	.081	.093	.120	.131	.162	.146	.202
7	.069	.086	.141	.115	.126	.172	.143

Table 7.5.8. Number of Drivers Injured VEH #2
(Per Two Passenger Car Accidents)

VEH #2 VEH #1	Less Than 2000 lbs.	2000-2499	2500-2999	3000-3499	3500-3999	4000-4499	4500 Lb. or More
1	.255	.250	.212	.122	.117	.157	.095
2	.224	.236	.170	.179	.142	.173	.176
3	.260	.264	.217	.186	.184	.164	.174
4	.259	.288	.252	.228	.210	.169	.157
5	.327	.315	.289	.220	.231	.219	.181
6	.304	.293	.285	.210	.241	.171	.225
7	.328	.285	.268	.239	.266	.205	.214

2.3 times greater for drivers in automobiles weighing 4,500 lbs. or more being hit by automobiles of the same weight group than when hit by automobiles weighing less than 2000 lbs. These results show that drivers of small automobiles have a greater risk of being injured when they are involved in accidents regardless of whether they are in VEH #1 or in VEH #2.

7.6 Comparison of Results by Curb Weight, Wheelbase, and Model Year

The ratios of the actual to the expected number of accidents as a function of automobile weight have been discussed in this report. Ratios were also obtained using automobile wheelbase groups and by automobile model-year. Passenger automobiles are classified into seven classes by their curb weights or by the wheelbase. Model-year is used to classify into 11 groups (1972-1982).

It is important to know the relationship between the curb weight, wheelbase, and model-year of automobiles to understand the results obtained by grouping those automobiles involved in accidents with these parameters. A scattergram of curb weight versus wheelbase of automobiles which were involved in accidents as VEH #1 in 1982 is shown in Figure 7.6.1. It is clear that the curb weight and wheelbase are related. The curb weight varies from 1,560 lbs. (Datsun 1200) to 5,180 lbs. (Cadillac Brougham) while the wheelbase varies from 80 inches (MG Midget, Fiat Spider) to 145 inches (Cadillac Chassis), and the average curb weight is 3,199 lbs. and the average wheelbase is

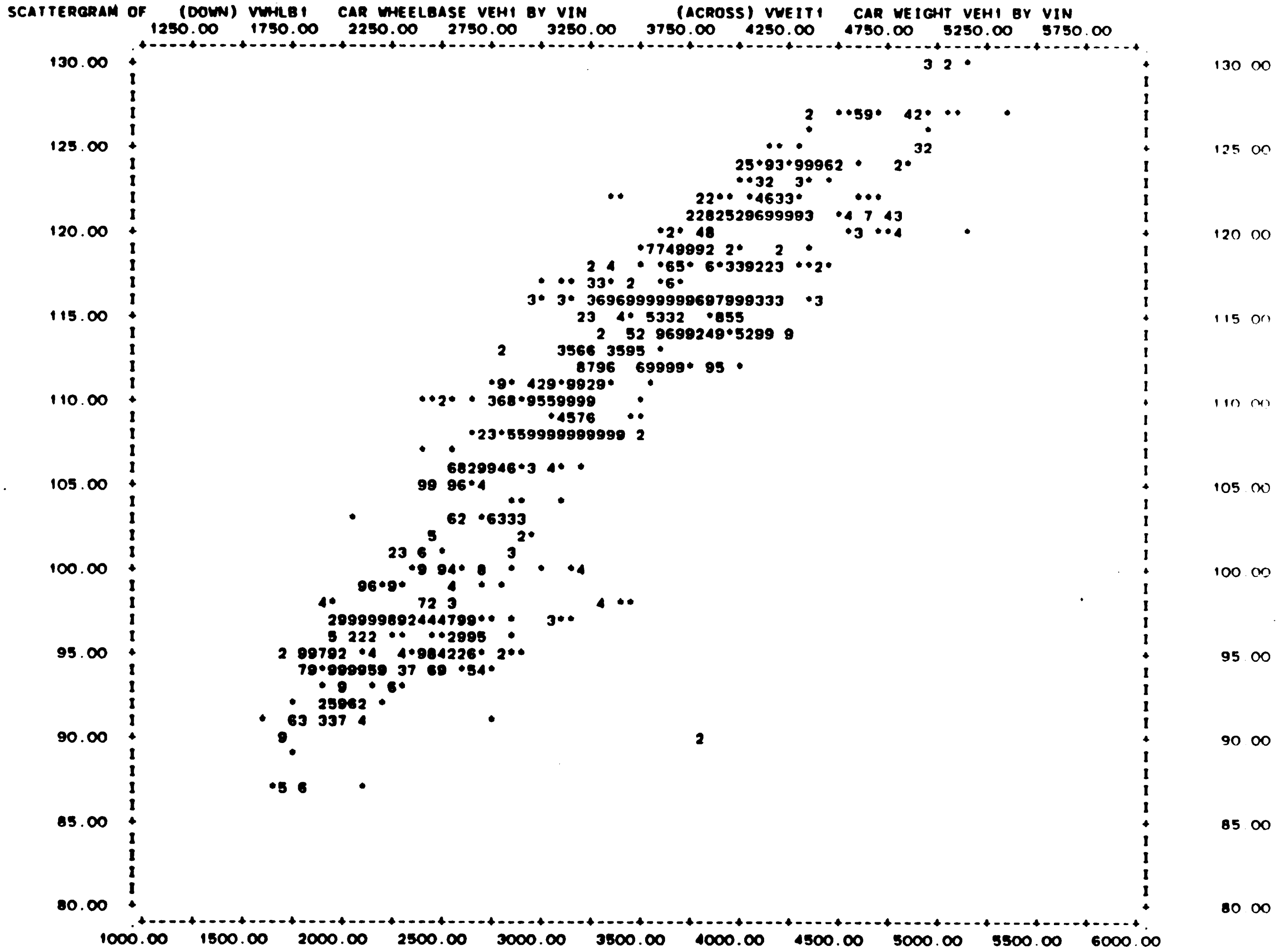


Figure 7.6.1. Scattergram 1

108.7 inches. the relationship between curb weight and wheelbase can be expressed by a simple regression equation: $Y = 71.9 + .0116 X$, where: Y = wheelbase, X = curb weight. The correlation coefficient is $R^2 = .903$.

The relationship between the curb weight and model-year of the automobiles involved in accidents as VEH #1 is shown in Figure 7.6.2. The variance of curb weight for new model-year automobiles is much smaller than that of older model-years. The average curb weight of new model-year automobiles is also much smaller than that of older model-years. Figure 7.6.3 shows the average curb weight of VEH #1 and VEH #2 for each model-year.

The average weight has decreased by about 1000 lbs. from 1973 (3,673 lbs.) to 1982 (2,674 lbs.). The description of the curb weight and wheelbase by model-year are shown in Figure 7.6.4 and in Figure 7.6.5. Figure 7.6.6 shows the relationship between the wheelbase and model-year of automobiles involved in accidents as VEH #1. The same tendency as in the curb weight can be seen. The average wheelbase is also getting shorter.

The curb weight, wheelbase, and model-year were all found to be important measures of accident potential. The curb weight and wheelbase categories show similar results. Newer model-year automobiles are found to have a lower A/E ratio than earlier model-year automobiles.

The conditions examined by wheelbase and model-year are as follows:

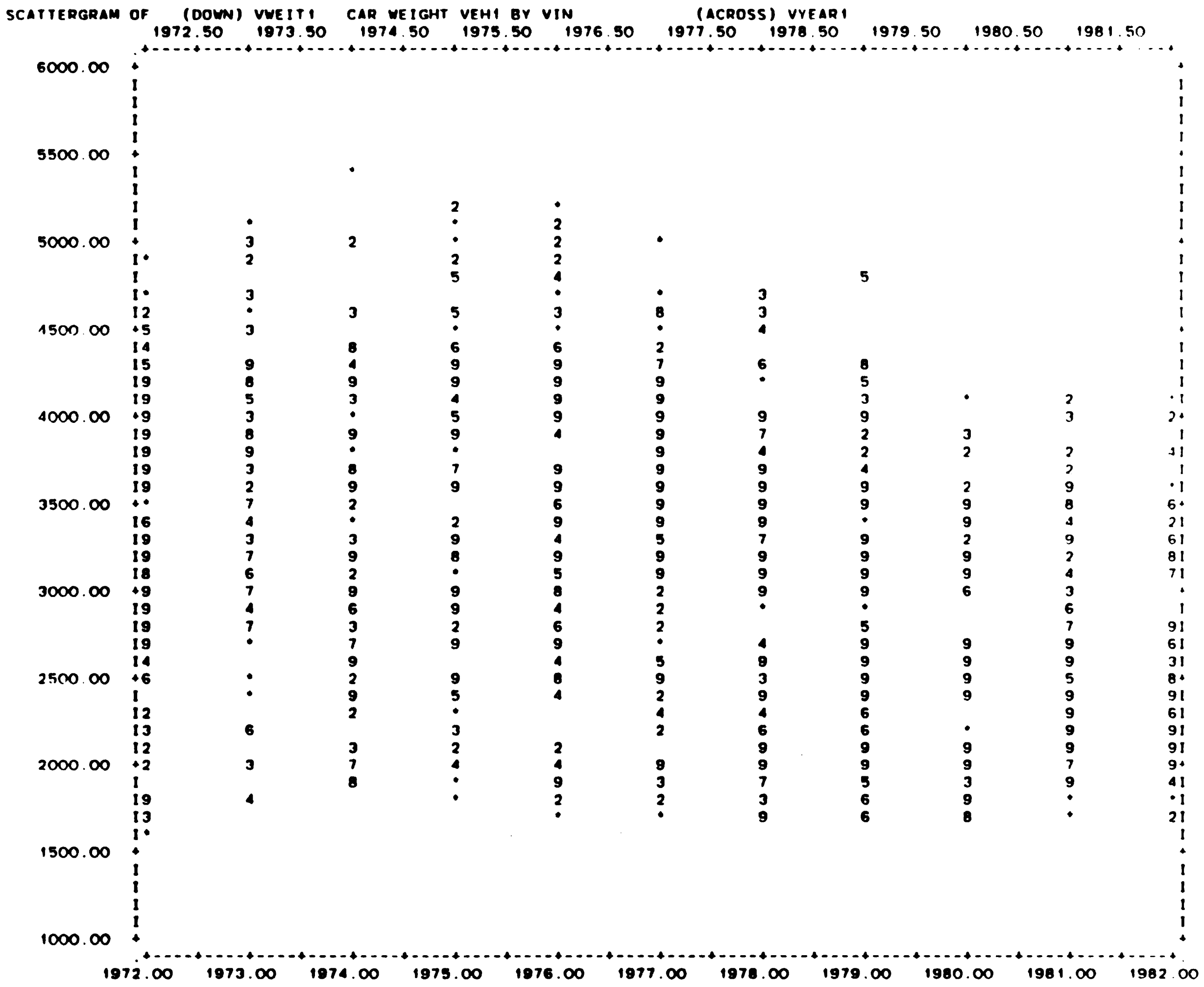


Figure 7.6.2. Scattergram 2

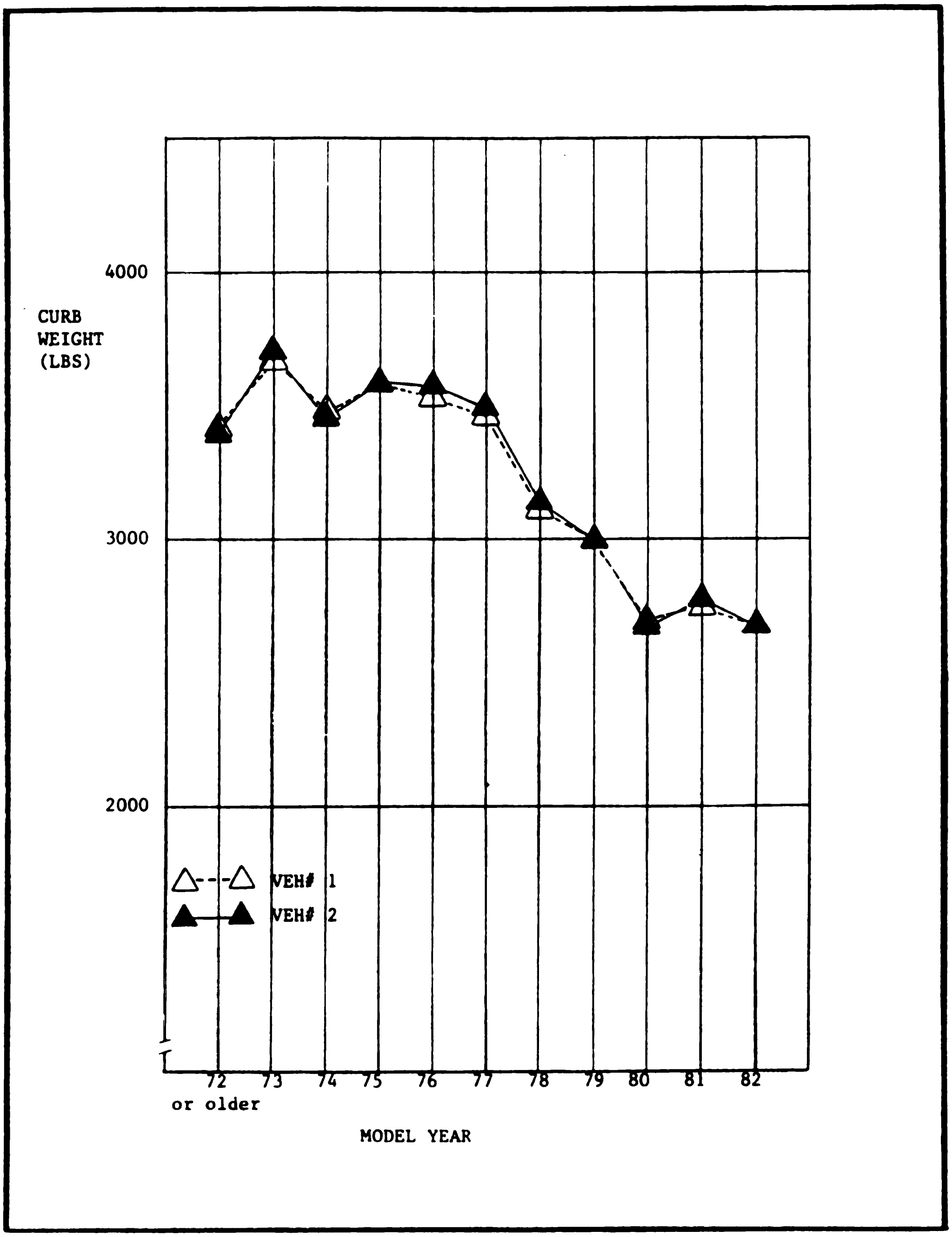


Figure 7.6.3. Model Year

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- - - - - - - - - - - - - - - - -  D E S C R I P T I O N   O F   S U B P O P U L A T I O N S  - - - - - - - - - - - - - - - - -
CRITERION VARIABLE   VWEIT1     CAR WEIGHT VEH1 BY VIN
   BROKEN DOWN BY    VYEAR1
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

VARIABLE                    CODE      VALUE LABEL                   SUM          MEAN       STD DEV       VARIANCE         N

FOR ENTIRE POPULATION                                     165536278.0000     3199.3869      779.6575    607865.7477     ( 51740)

VYEAR1                     1972.                           17852756.0000     3417.4495      710.7059    505102.8651     (    5224)
VYEAR1                     1973.                           12789845.0000     3673.1318      780.2979    608864.8321     (    3482)
VYEAR1                     1974.                           12868391.0000     3482.6498      821.9169    675547.4112     (    3695)
VYEAR1                     1975.                           12292312.0000     3580.6327      789.2580    622928.1316     (    3433)
VYEAR1                     1976.                           16836505.0000     3531.1462      793.3876    629463.8849     (    4768)
VYEAR1                     1977.                           19915886.0000     3464.8375      664.0589    440974.2795     (    5748)
VYEAR1                     1978.                           18638286.0000     3119.9006      702.9115    494084.6313     (    5974)
VYEAR1                     1979.                           18308112.0000     2998.8717      697.4600    486450.4228     (    6105)
VYEAR1                     1980.                           14670870.0000     2685.0055      537.7070    289128.8541     (    5464)
VYEAR1                     1981.                           12933950.0000     2748.9798      597.7992    357363.9207     (    4705)
VYEAR1                     1982.                            7991509.0000     2673.6397      577.7421    333785.9254     (    2989)
VYEAR1                     1983.                             437856.0000     2861.8039      648.4179    420445.7771     (     153)

  TOTAL CASES =    54896
MISSING CASES =     3156 OR    5.7 PCT.
```

Figure 7.6.4. Model Year by Curb Weight

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- - - - - - - - - - - - - - - - -   D E S C R I P T I O N   O F   S U B P O P U L A T I O N S   - - - - - - - - - - - - - - - - - -
CRITERION VARIABLE   VWHLB1     CAR WHEELBASE VEH1 BY VIN
   BROKEN DOWN BY    VYEAR1
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

VARIABLE                     CODE      VALUE LABEL                  SUM            MEAN          STD DEV       VARIANCE            N

FOR ENTIRE POPULATION                                      5633279.0000        108.7443           9.6964        94.0200      ( 51803)

VYEAR1                      1972.                           595407.0000        113.9535           8.7601        76.7388      (   5225)
VYEAR1                      1973.                           398648.0000        114.3897           9.1177        83.1317      (   3485)
VYEAR1                      1974.                           410829.0000        111.1851          10.1995       104.0307      (   3695)
VYEAR1                      1975.                           383839.0000        111.7761          10.1433       102.8863      (   3434)
VYEAR1                      1976.                           529672.0000        111.0889          10.0344       100.6898      (   4768)
VYEAR1                      1977.                           648145.0000        111.2313           8.7551        76.6523      (   5827)
VYEAR1                      1978.                           644427.0000        108.0709           9.0714        82.2897      (   5963)
VYEAR1                      1979.                           647084.0000        106.2535           8.7611        76.7572      (   6090)
VYEAR1                      1980.                           564975.0000        103.5511           7.5640        57.2146      (   5456)
VYEAR1                      1981.                           487920.0000        103.4606           7.4819        55.9787      (   4716)
VYEAR1                      1982.                           306287.0000        102.4029           7.3686        54.2962      (   2991)
VYEAR1                      1983.                            16046.0000        104.8758           7.6651        58.7542      (    153)

  TOTAL CASES =    54896
MISSING CASES =     3093 OR    5.6 PCT.
```

Figure 7.6.5. Model Year by Wheelbase

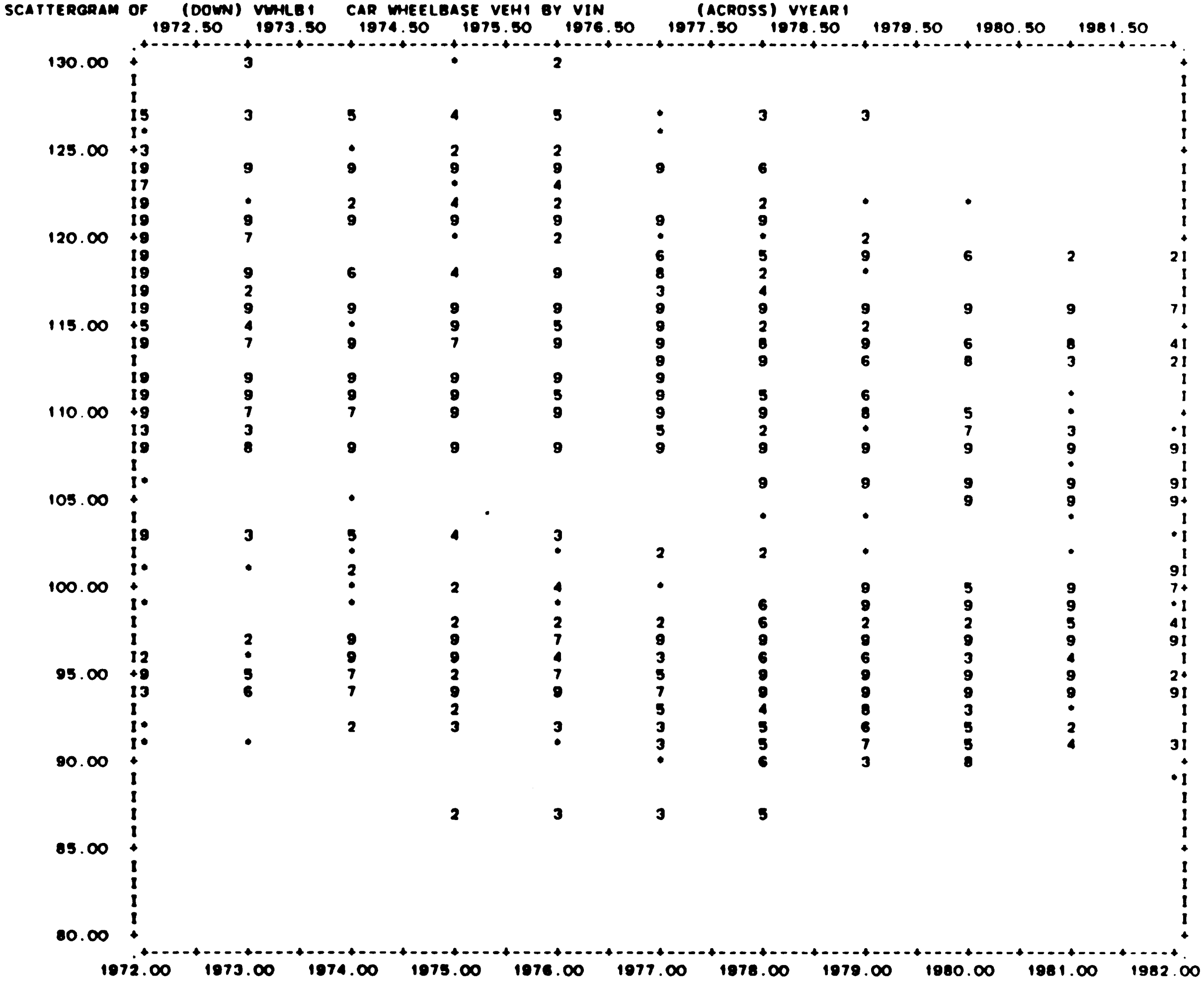

Figure 7.6.6. Scattergram 3

- total accidents
- driver injury (VEH #1, VEH #2)
- sex of driver
- age of driver
- single vehicle accidents
- overturned vehicle accidents
- accident with other vehicles
- accidents with pedestrians
- accidents with fixed objects
- highway area type
- highway surface condition

The results by wheelbase are shown in Figures 7.6.7 through 7.6.17. However, using wheelbase as a measure of vehicle size does not show as consistent results as do the curb weight categories. Table 7.6.1 shows equations and coefficients of determination for the best fitting curves. Only overturned vehicle accidents and serious injury in VEH #2 produce larger coefficients of determination than the curb weight categories.

The results by model-year are shown in Figures 7.6.18 through 7.6.23. It is apparent that newer model-year automobiles are less likely to be involved in an accident than earlier model-year automobiles (for the same exposure), regardless of the sex or age of the driver. While there seems to be a major effect of model-year on highway safety, the model-year is not the only significant factor in explaining relative accident involvement. As shown in the early part of this chapter, the size of automobile is also an important factor. For example, small

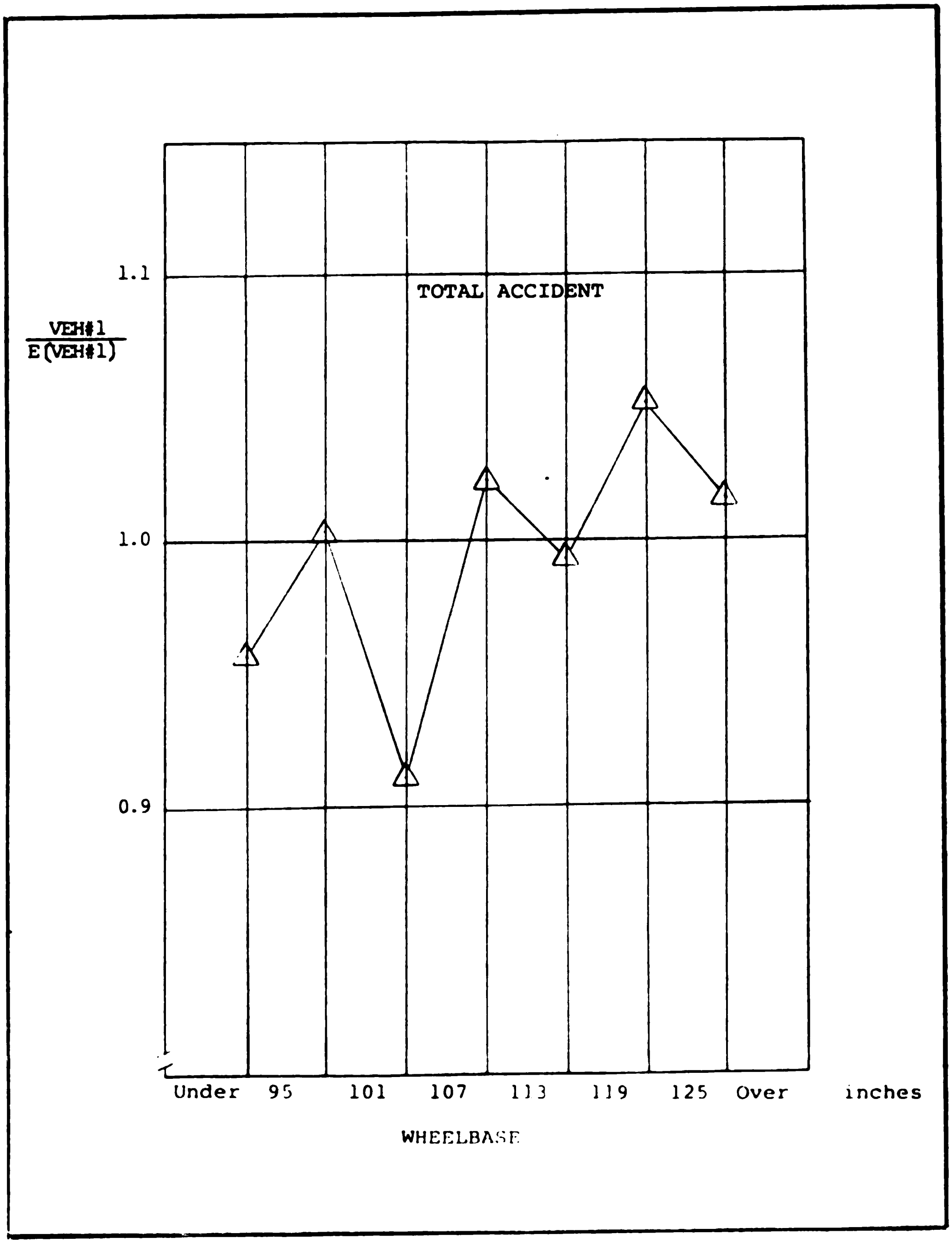

Figure 7.6.7. Total Accidents

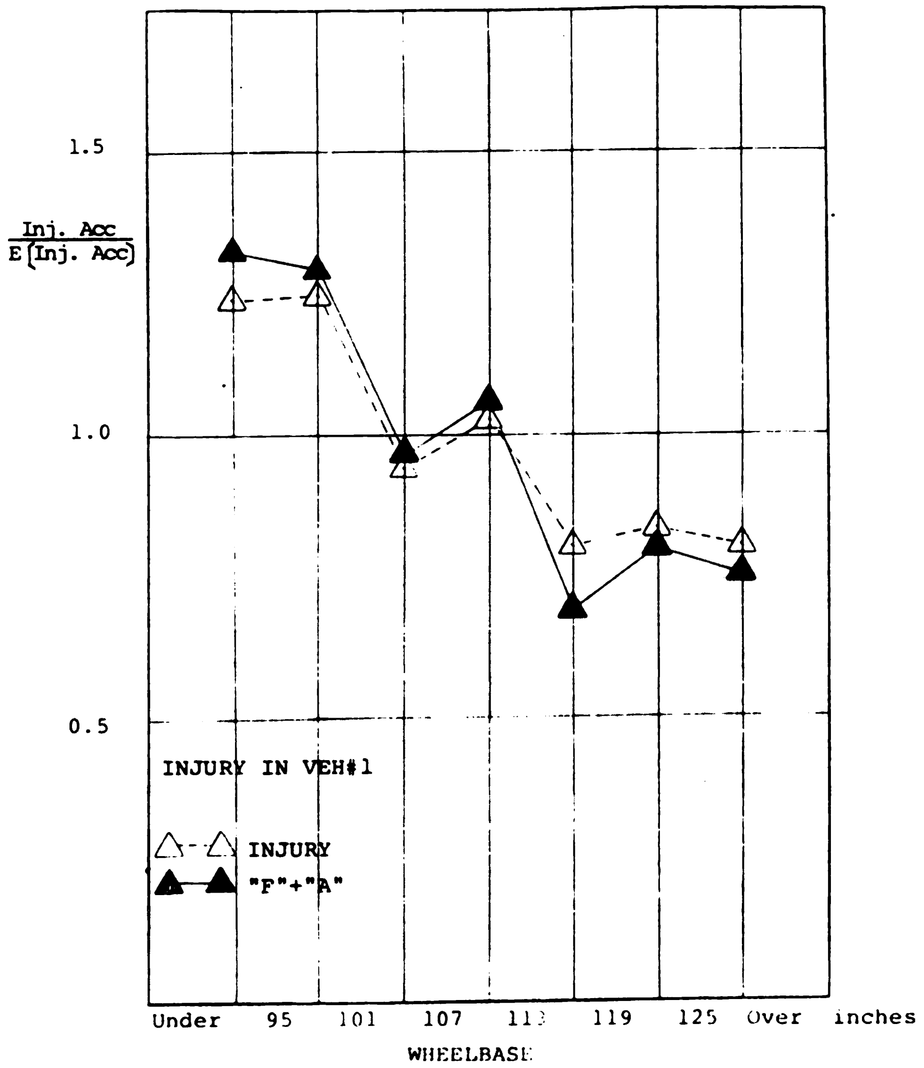

Figure 7.6.8. Driver Injury VEH #1

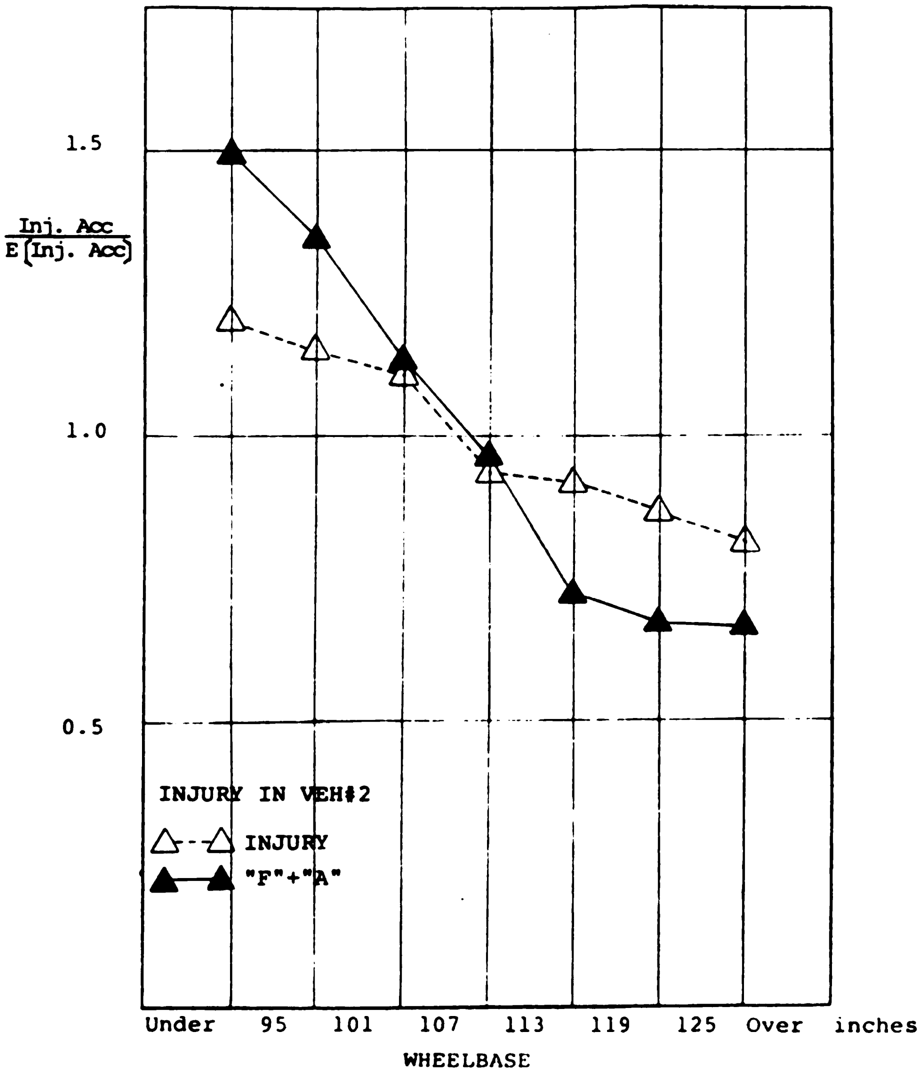

Figure 7.6.9. Driver Injury VEH #2

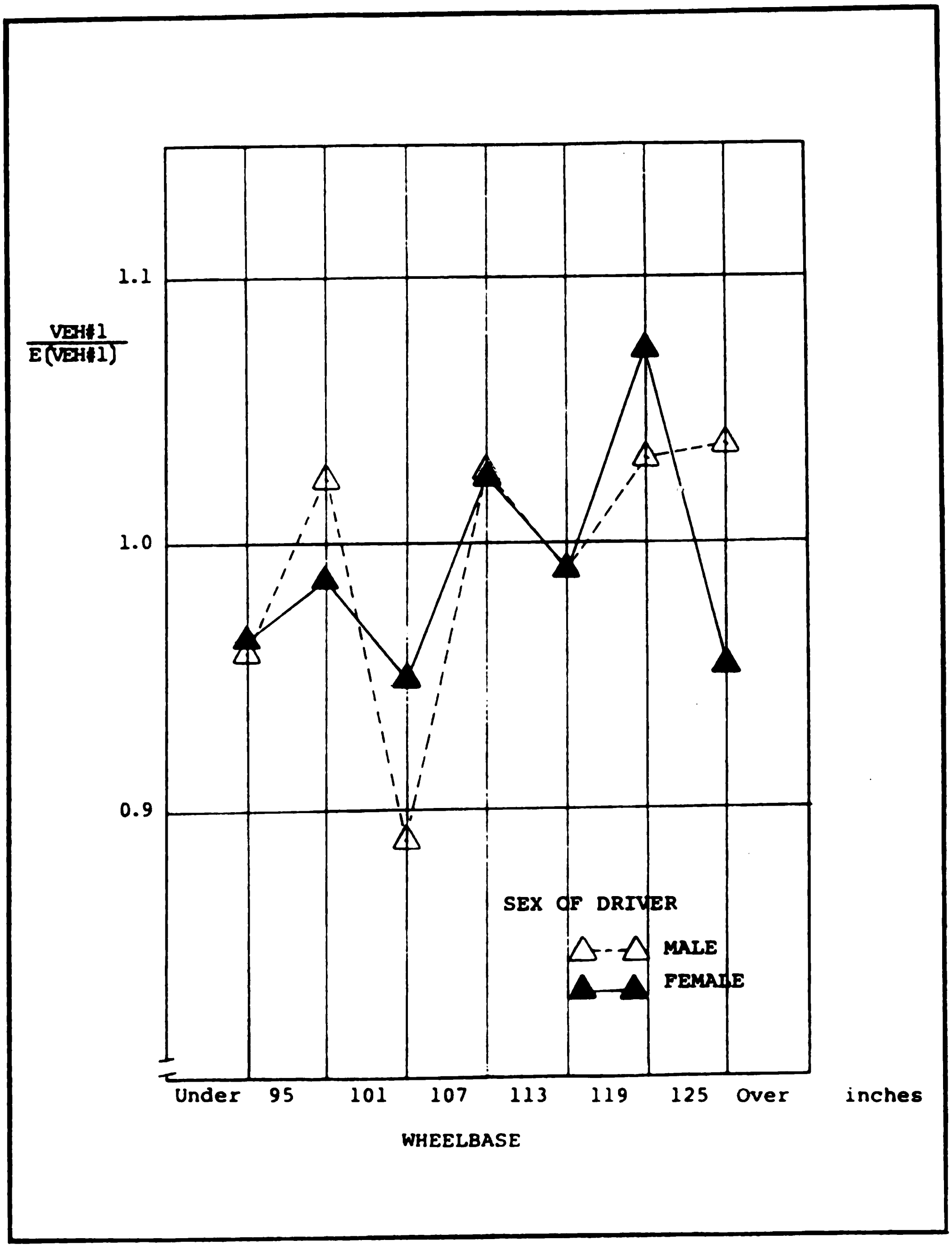

Figure 7.6.10. Sex of Driver

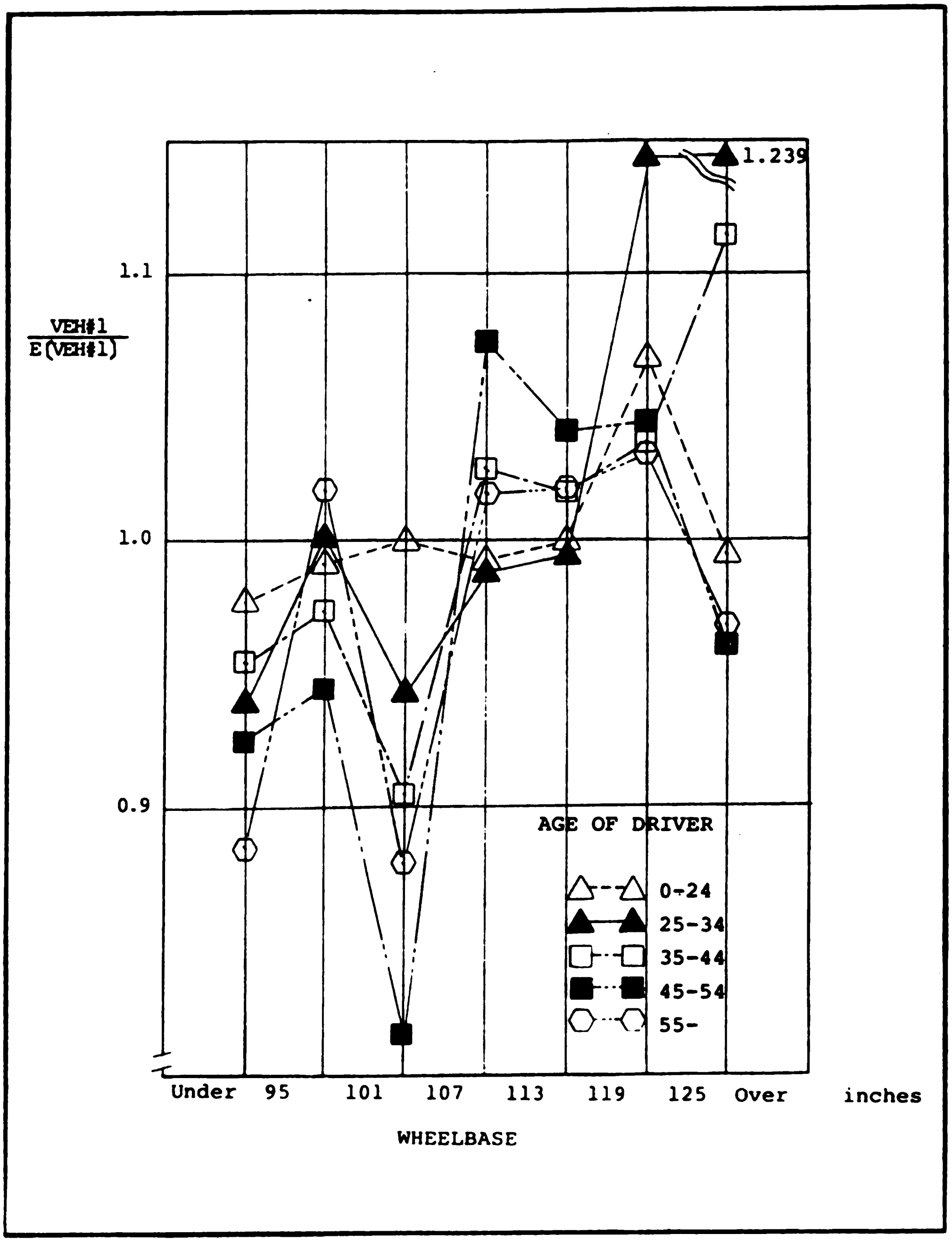

Figure 7.6.11. Age of Driver

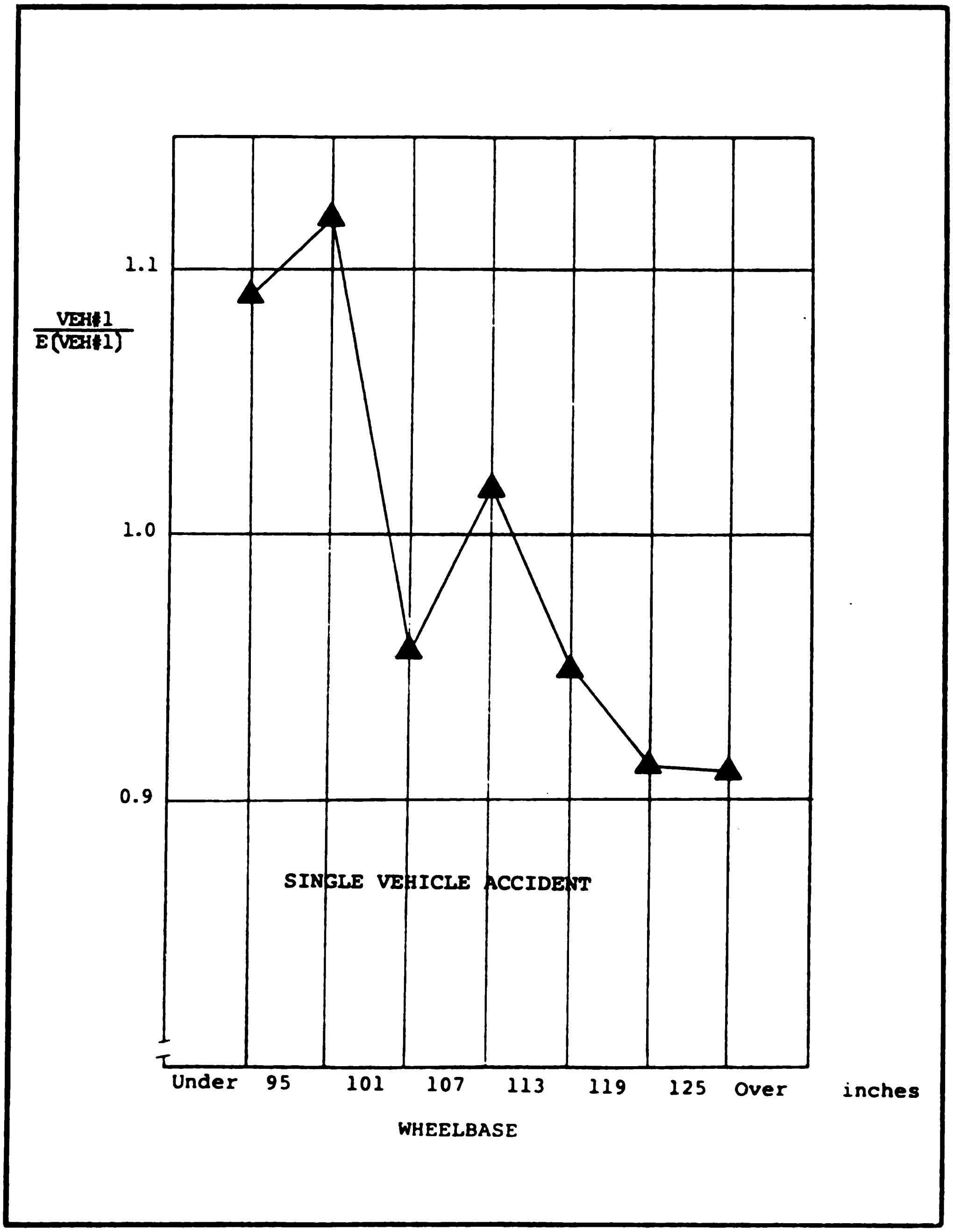

Figure 7.6.12. Single Vehicle

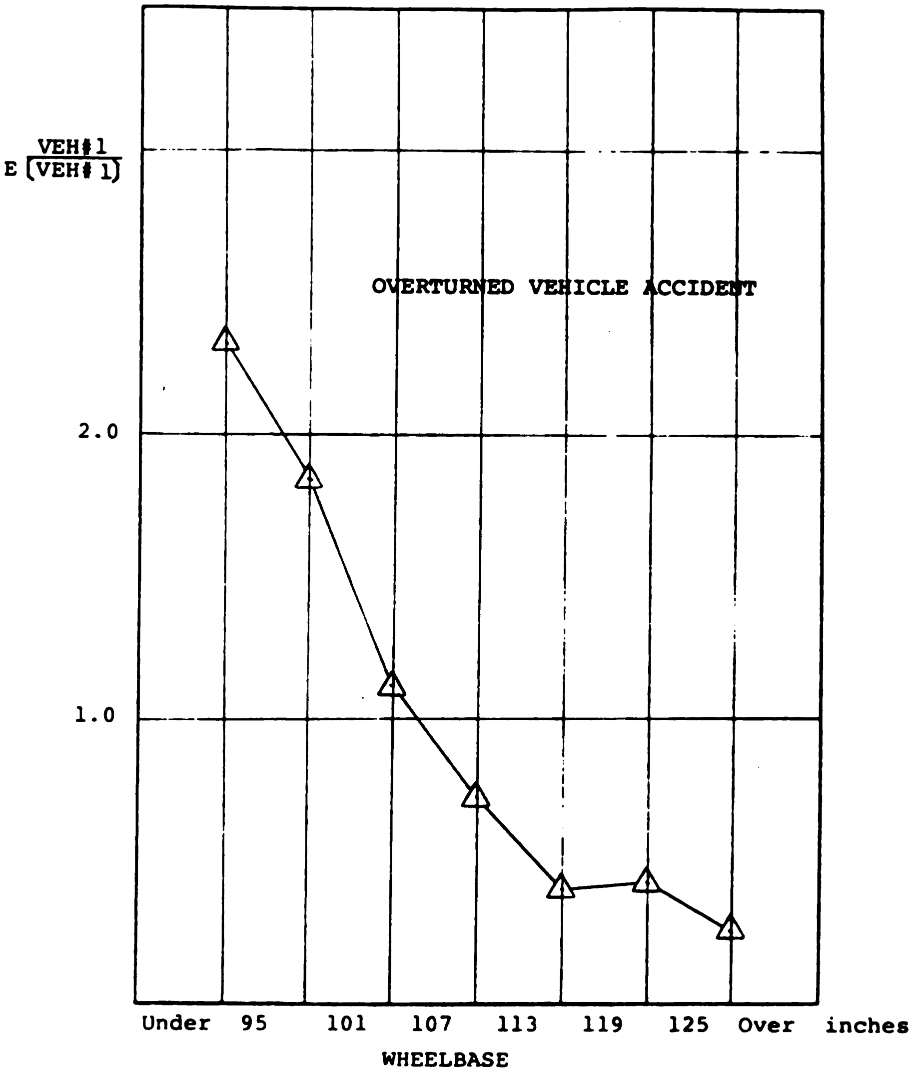

Figure 7.6.13. Overturned Vehicle

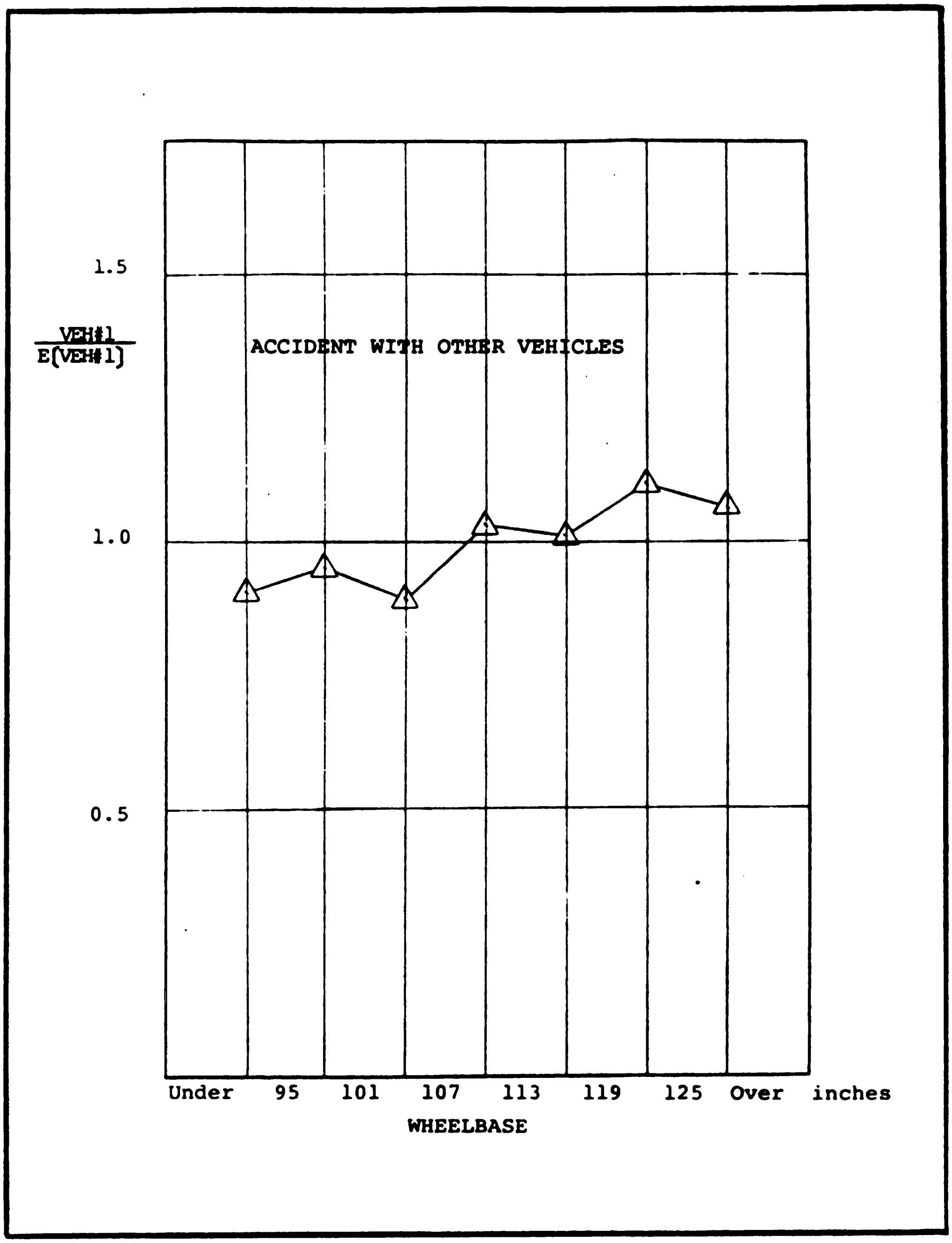

Figure 7.6.14. Other Vehicles

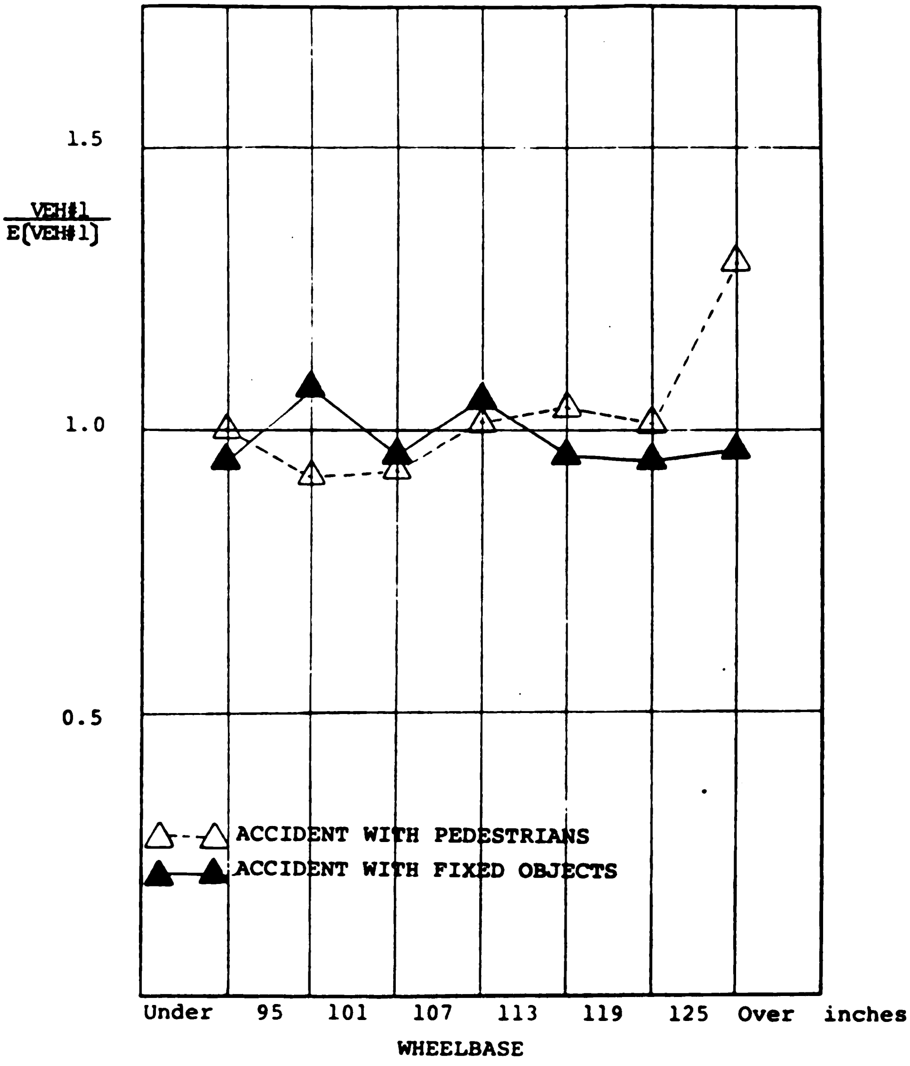

Figure 7.6.15. Pedestrians/Fixed Objects

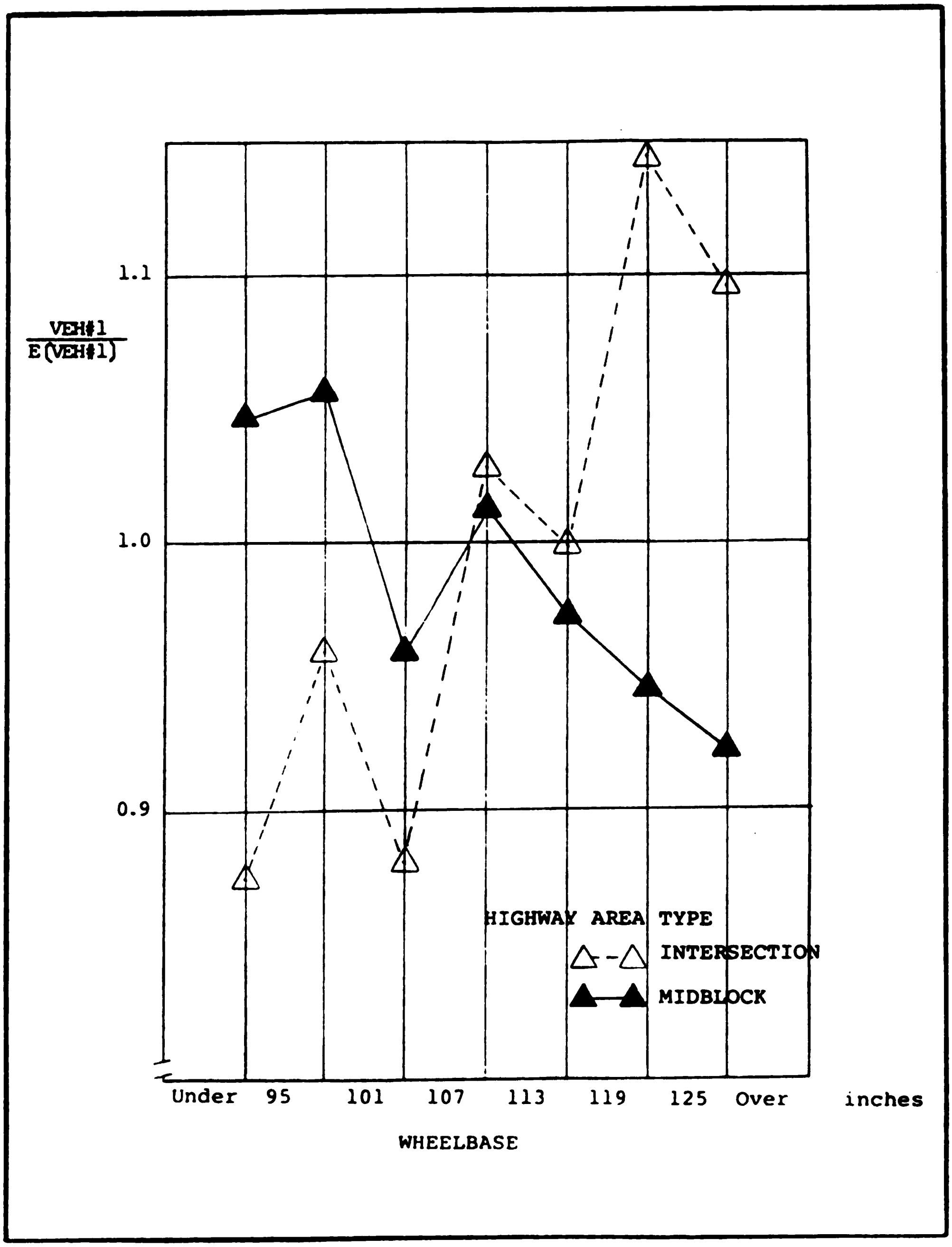

Figure 7.6.16. Area Type

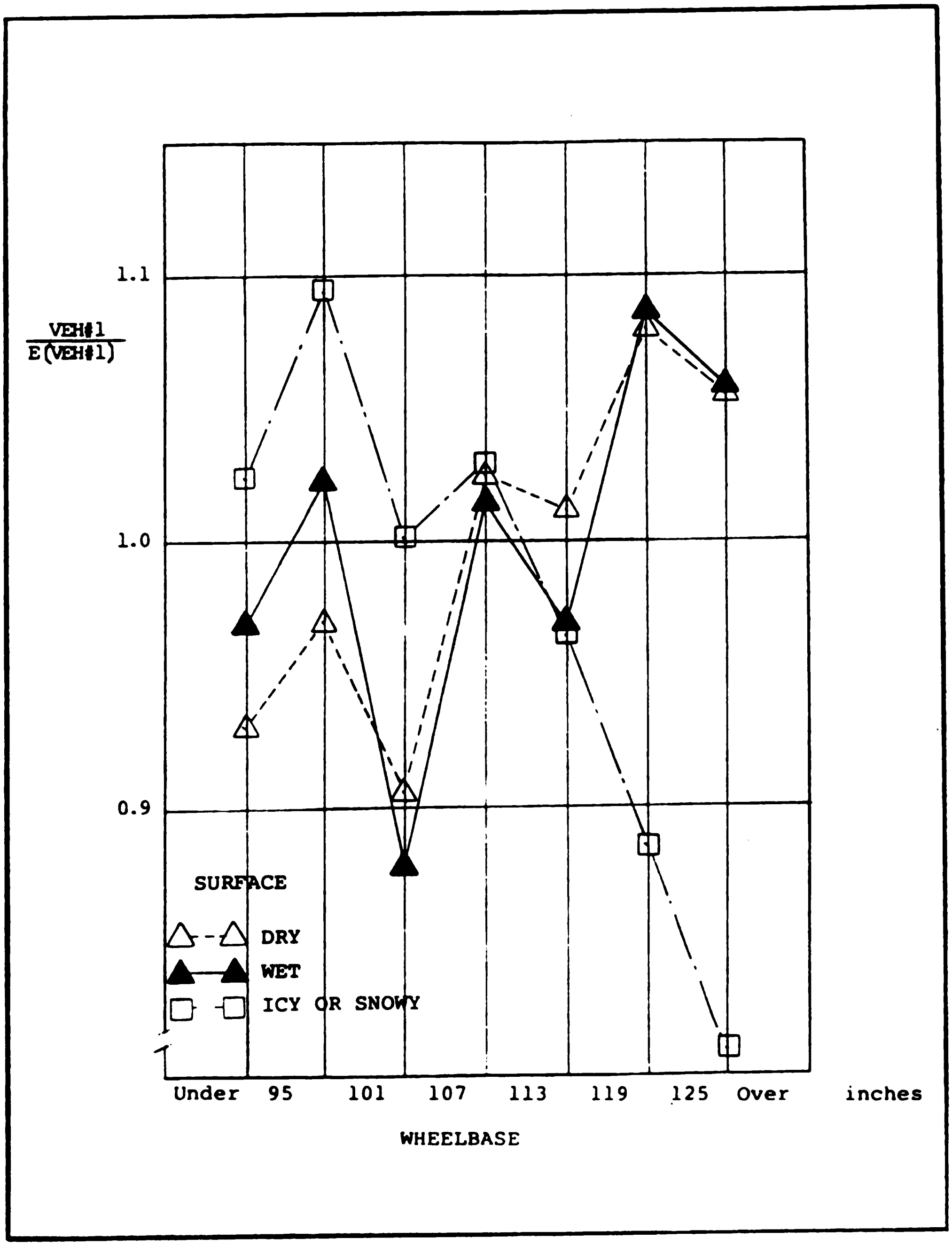

Figure 7.6.17. Surface Type

Table 7.6.1. Best Fitting Curves for Results by Wheelbase Categories

Conditions	Equations	R^2
Inj. VEH #1	$Y = X/(-170 + 2.62\ X)$	.868
Serious Inj. VEH #1	$Y = -1.03 + 2.19\ /X$	.852
Inj. VEH #2	$Y = 1/(-282 + .0119\ X)$	.955
Serious Inj. VEH #2	$Y = -1.86 + 310\ /X$	.969
Single Vehicle	$Y = X/(-70.4 + 1.66\ X)$	.855
Overturned	$Y = 837\ \exp(-.0637\ X)$	.968
Parked Vehicles	$Y = 1/(3.91 - .0261\ X)$	.866
Pedestrians	$Y = 1/(2.21 - .0111\ X)$	.551

where Y = Ratio of the actual to the expected number of accidents

X = Wheelbase

R^2 = Coefficient of determination

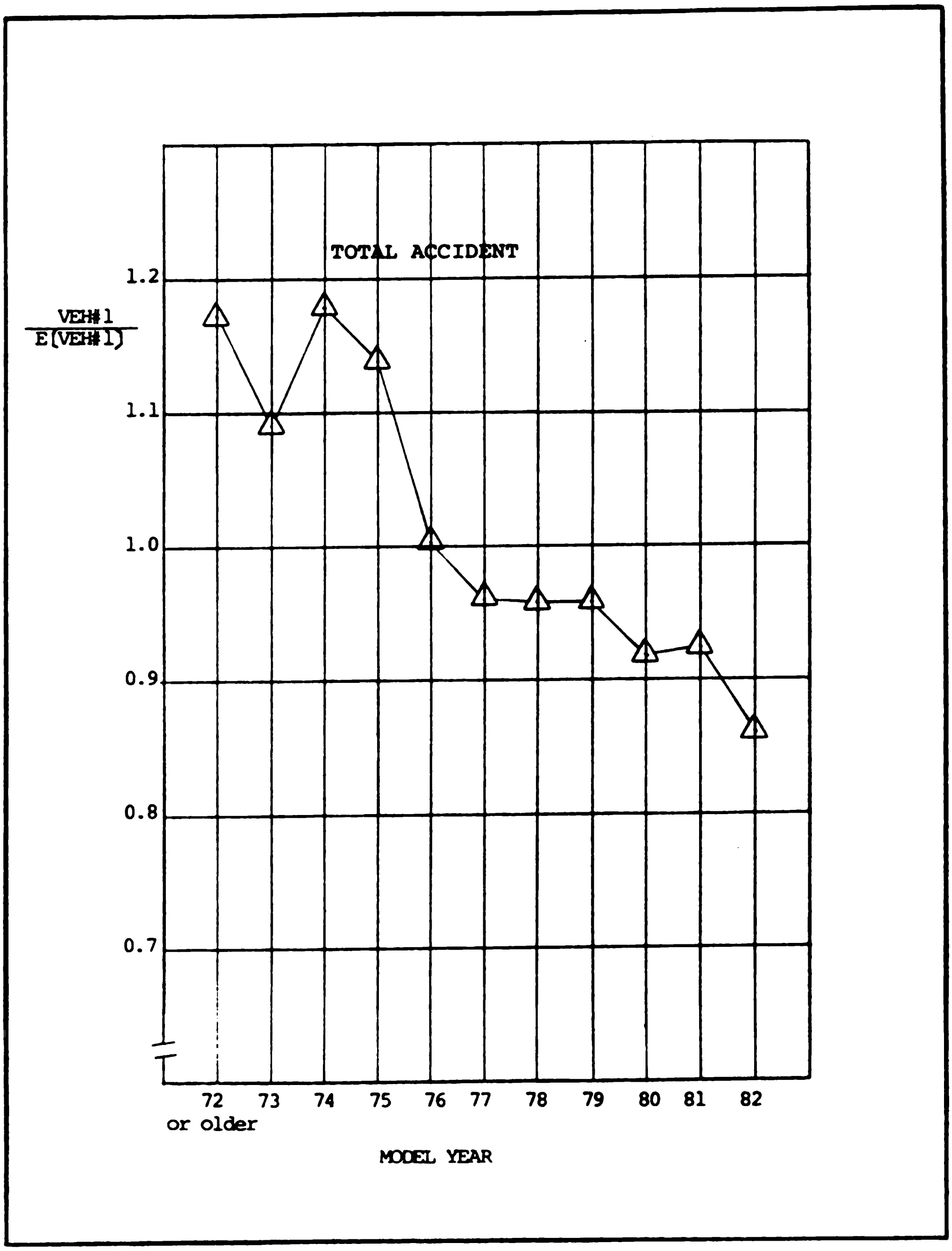

Figure 7.6.18. Total Accidents

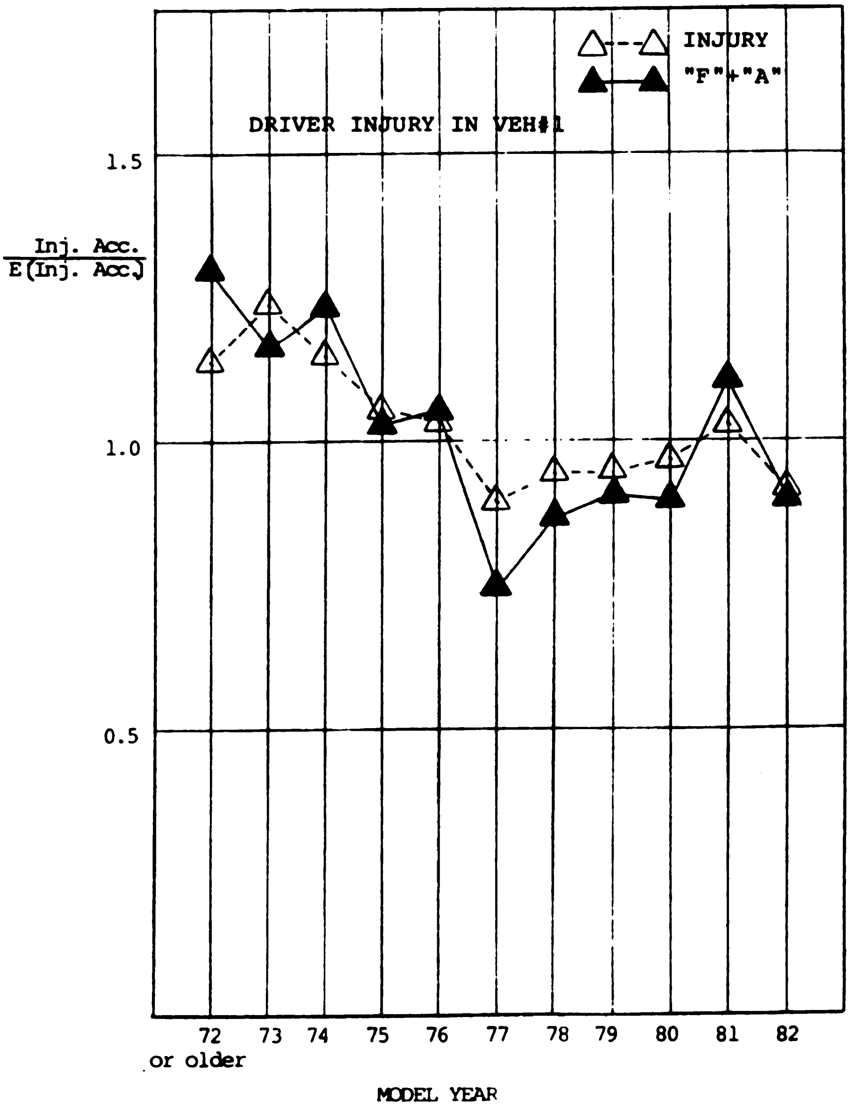

Figure 7.6.19. Driver Injury VEH #1

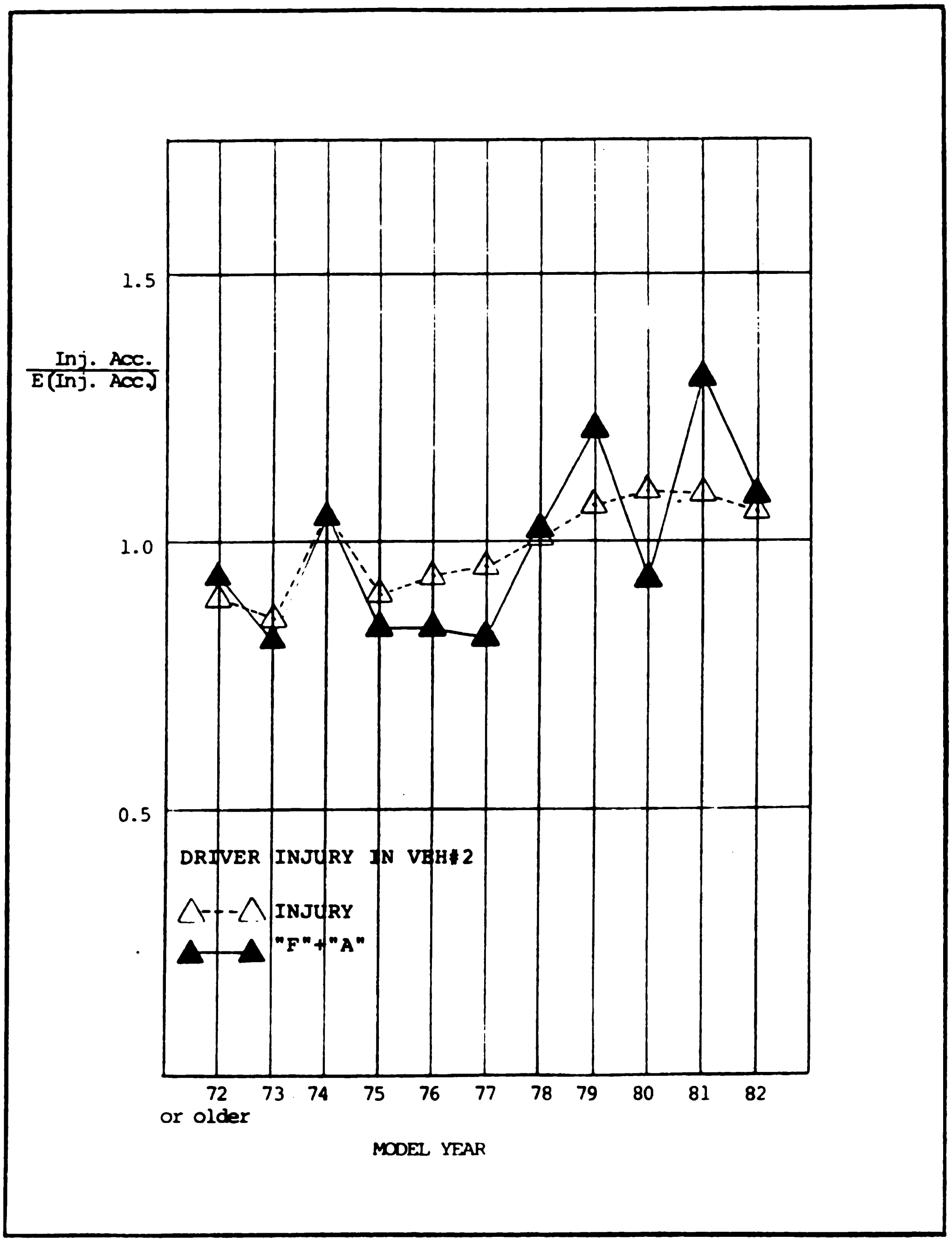

Figure 7.6.20. Driver Injury VEH #2

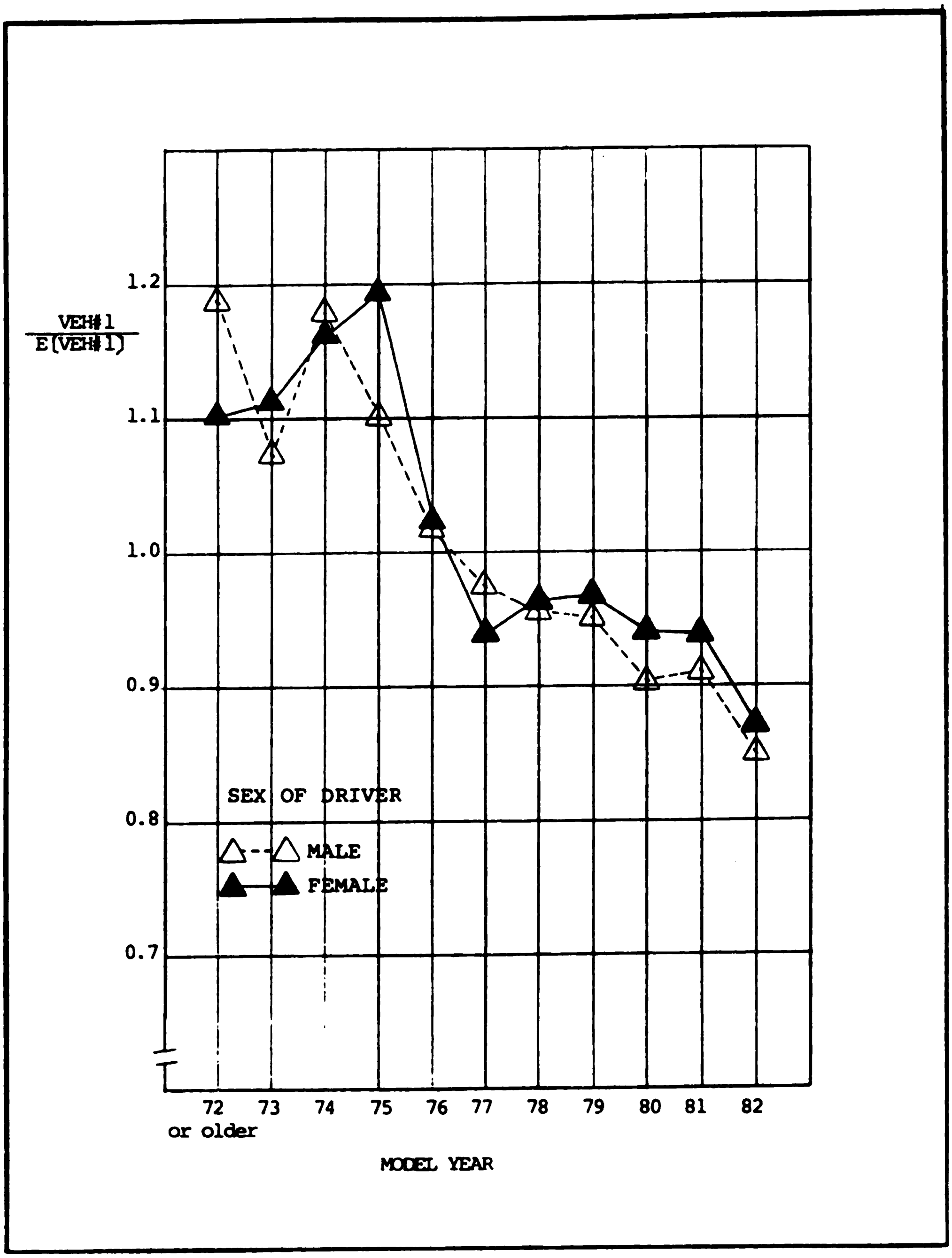

Figure 7.6.21. Sex of Driver

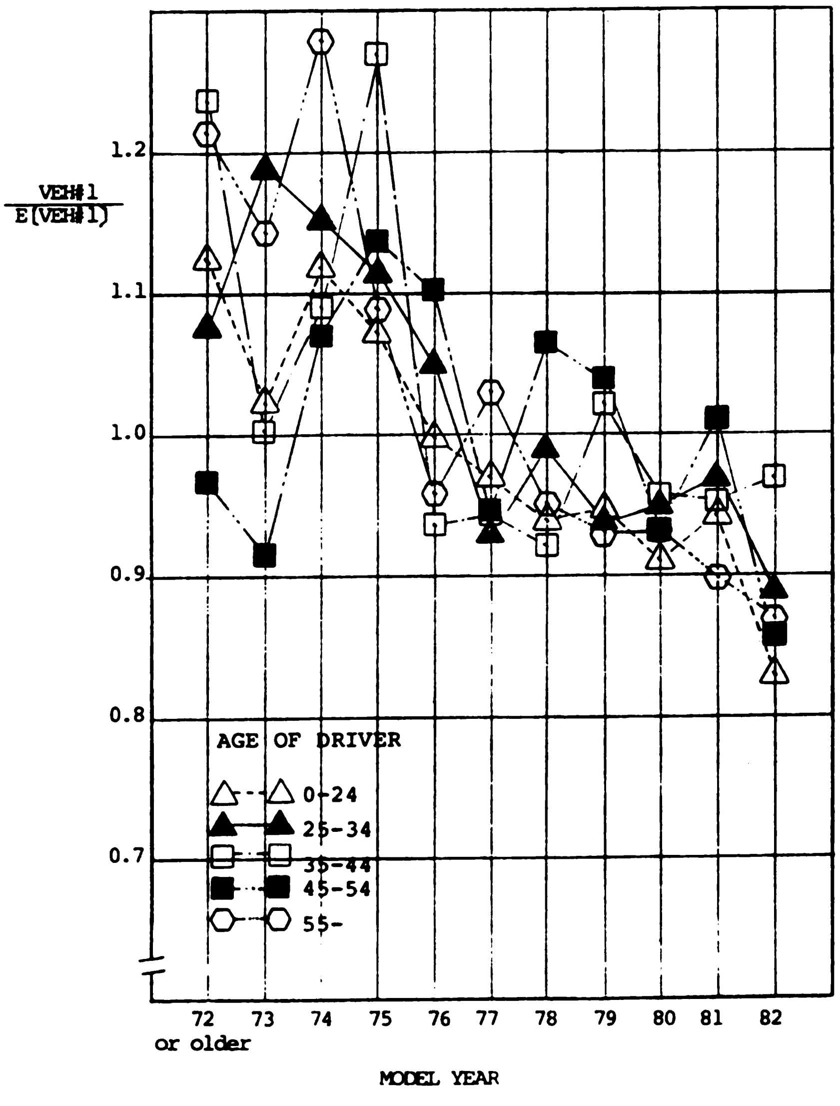

Figure 7.6.22. Age of Driver

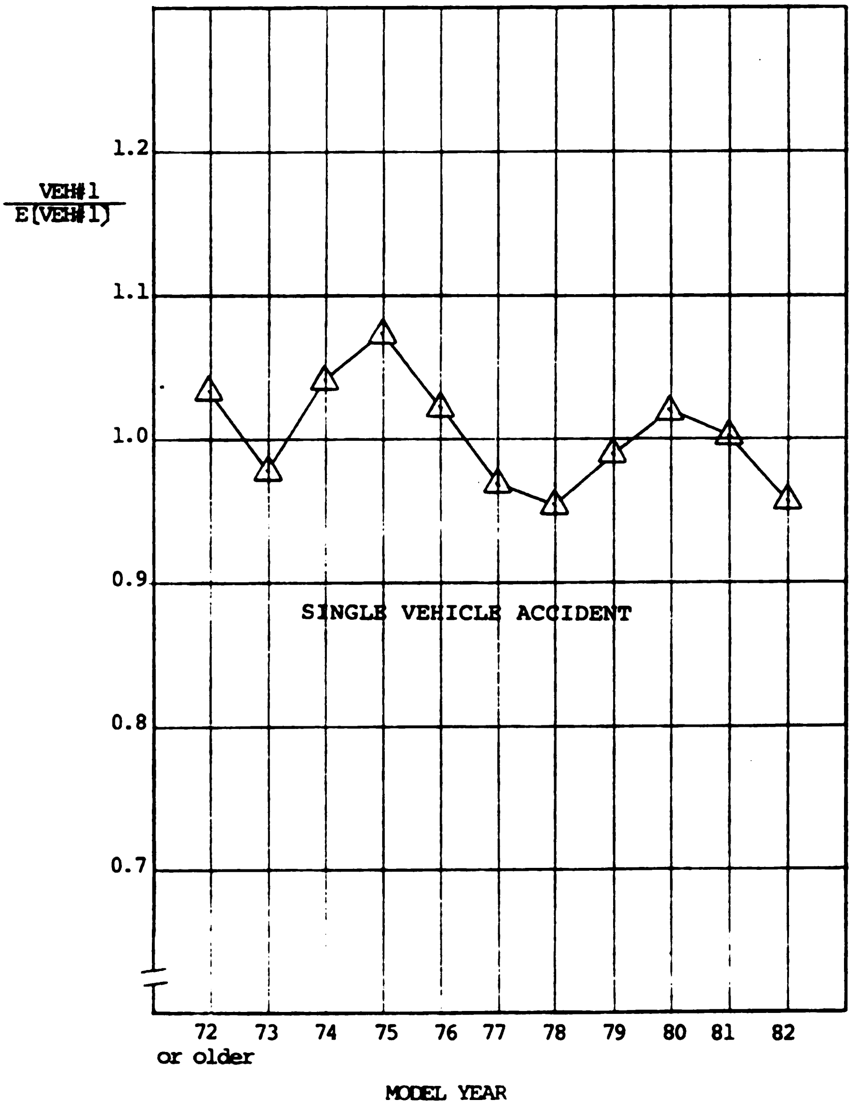

Figure 7.6.23. Single Vehicle

automobiles are found to have a high A/E ratio in conditions of driver injury, single vehicle accident, and overturned vehicle accidents. It was also shown that there is a clear tendency that newer model-year automobiles are smaller than earlier model-years. Therefore, the results obtained by using model-year categories cannot be explained only by model-year itself. Two effects are involved in the results, and they tend to offset the effects of each other in most rural conditions, and they tend to compound the effects in urban conditions.

Examples of where the two factors may offset each other would include single vehicle accidents, overturned vehicle accidents, accidents at midblocks, and accidents on icy or snowy surface conditions (Figures 7.6.24 through 7.6.28). In addition to the size difference, newer automobiles usually have new tires, and thus might be able to maneuver better on icy or snowy surface conditions, even though small automobiles are found to be more hazardous during these conditions.

An example of the compounding effect can be seen in results of accidents at intersections. One factor which explains the overrepresentation of large automobiles is the fact that the accidents involving earlier model-year automobiles are more related to drinking drivers or drivers using drugs than accidents involving newer model-year automobiles. Figure 7.6.29 shows the percentage of drivers involved in accidents as VEH #1 who were drinking or using drugs.

The results obtained above are statistically

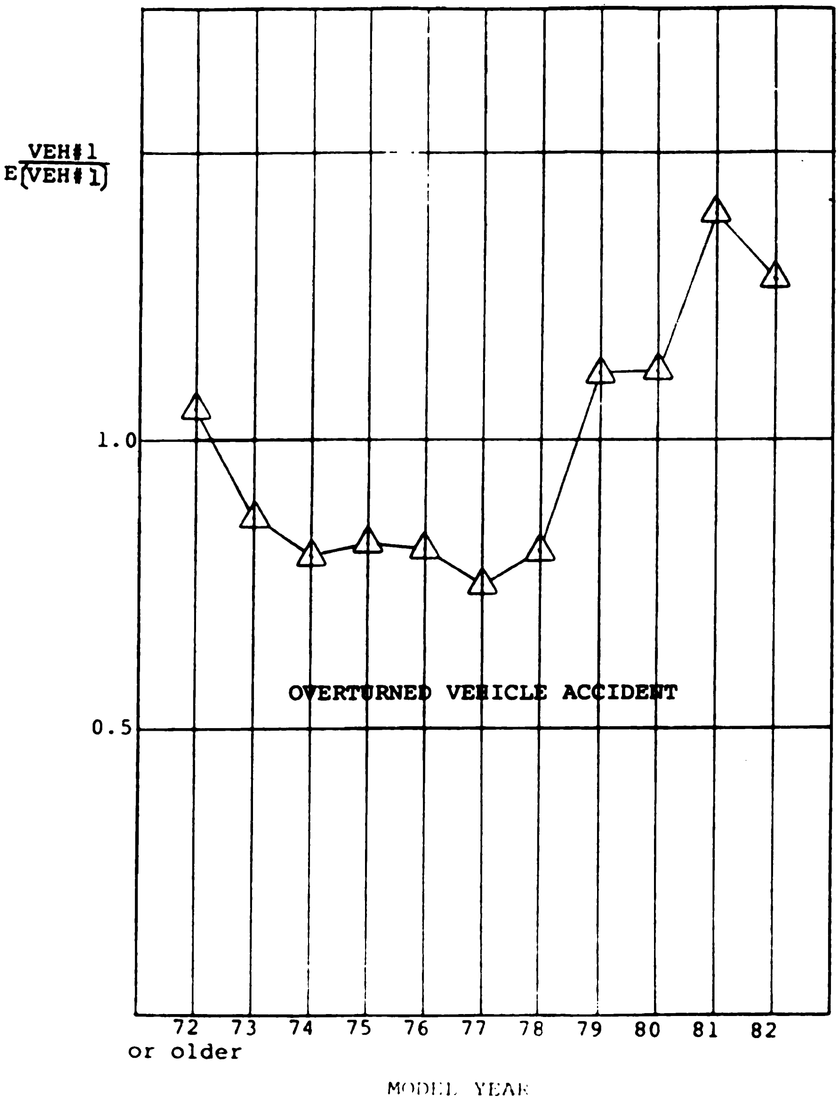

Figure 7.6.24. Overturned Vehicle

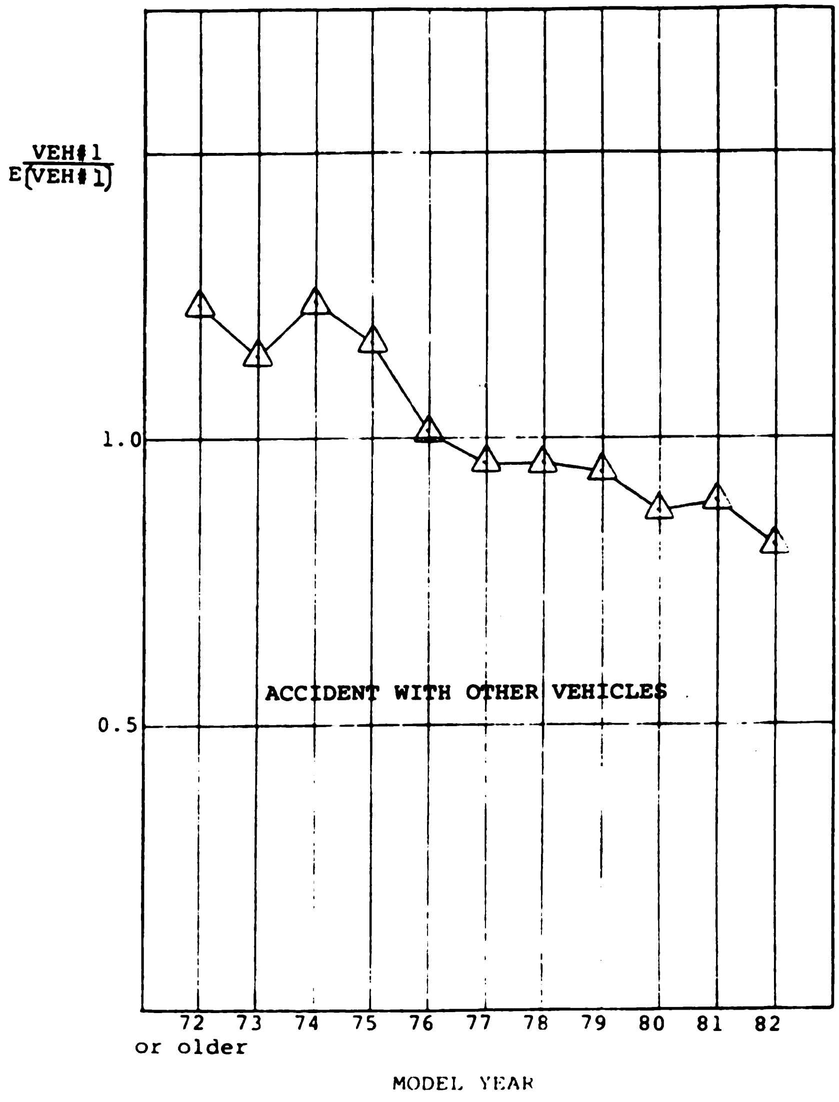

Figure 7.6.25. Other Vehicles

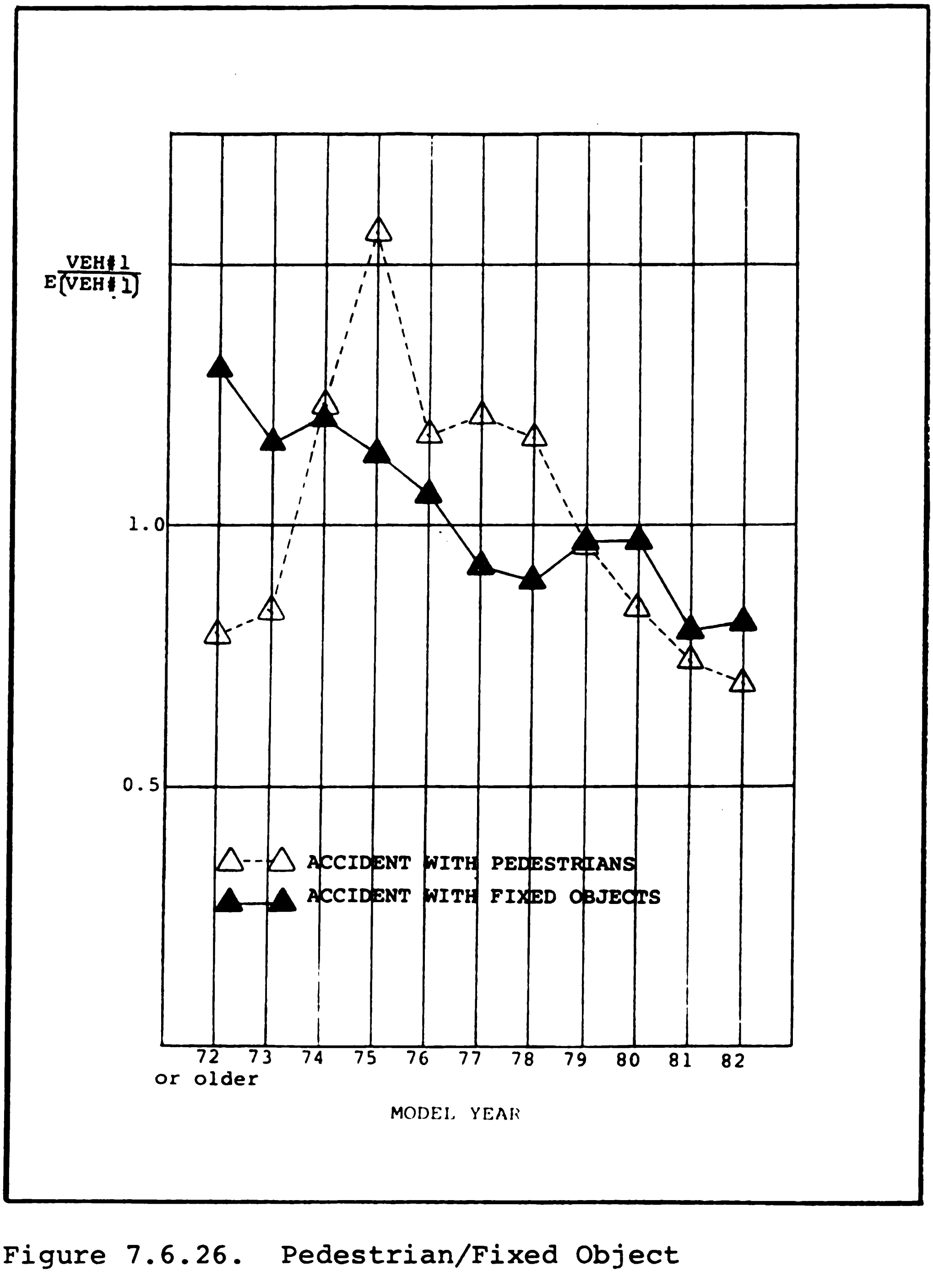

Figure 7.6.26. Pedestrian/Fixed Object

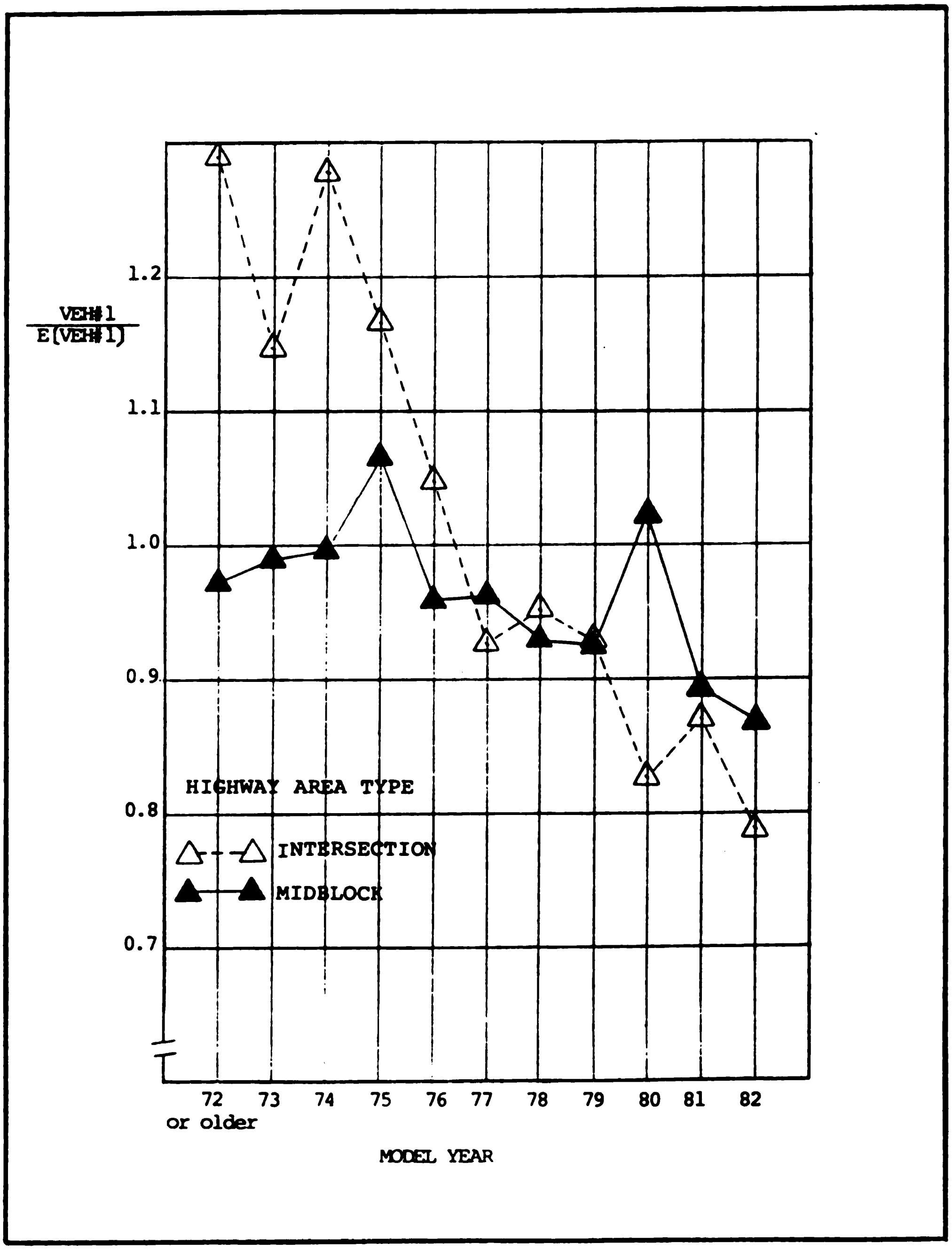

Figure 7.6.27. Area Type

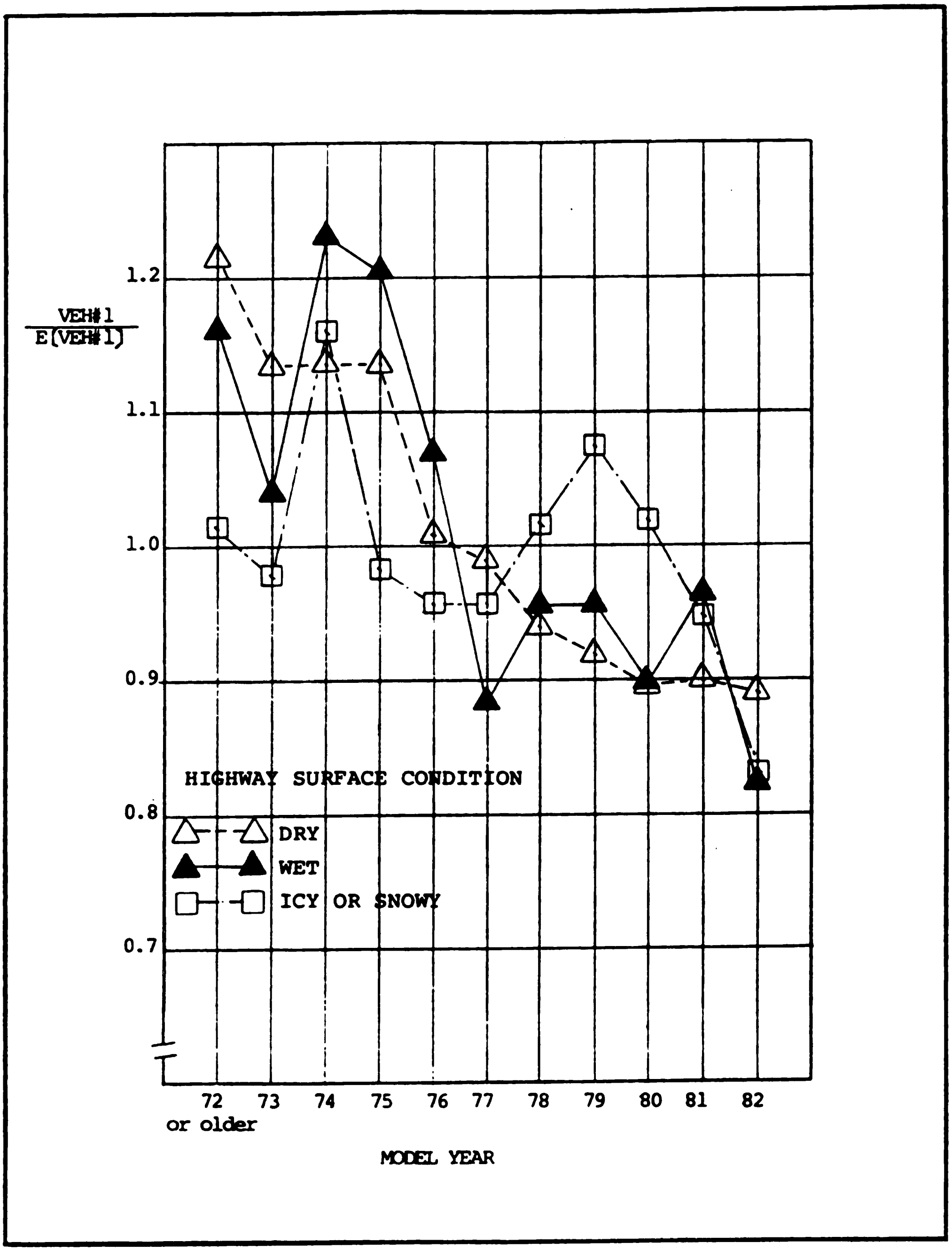

Figure 7.6.28. Surface Condition

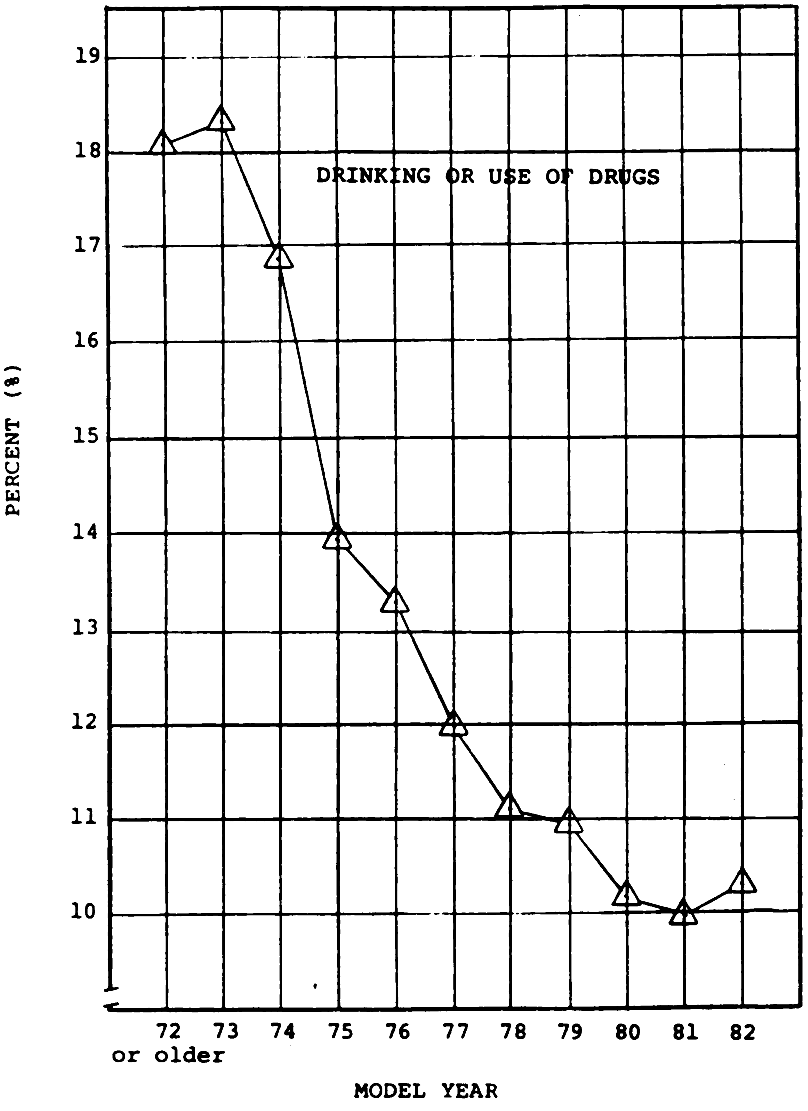

Figure 7.6.29. Drinking/Drugs

significant except for the results of single vehicle accidents.

8.0 CONCLUSIONS

There is consistent evidence that small automobiles have a unique risk of accident involvement. Small automobiles were found to be involved in more accidents than would be expected for their exposure in each of the following cases:

- single vehicle accidents
- overturned vehicle accidents
- on icy or snowy highway surface
- at midblocks
- in rural areas

On the other hand, large automobiles were found to be over represented in the following conditions:

- accidents with other vehicles
- at intersections
- in urban areas

In addition to these general findings, results for geometric features were obtained by examining the accident data for rural and urban areas separately.

The results show remarkable consistency. In rural areas, small automobiles were found to have a high A/E ratio in the following geometric features:

- midblocks
- 2 lane-2 way highways
- no passing zones

In urban areas, large automobiles exhibited a high A/E ratio at intersections.

Drivers of small automobiles were found to have a greater risk of being injured for the same exposure. Drivers of small automobiles are exposed to the risk of being injured regardless of whether they are in VEH #1 (identified as being responsible for the accident) or in VEH #2 (the second automobile). Drivers of automobiles weighing less than 2,000 lbs. have a 72 percent higher risk of being injured in VEH #1, and have a 56 percent higher risk of being injured in VEH #2 than the drivers of automobiles weighing 4,500 lbs. or more for the same exposure.

The curb weight, wheelbase, and model-year were all found to be important measures of accidents. The curb weight and wheelbase categories show similar results, but the curb weight categories provide more consistent results than do the wheelbase categories. It was found that newer model-year automobiles have lower A/E ratios than earlier model-years.

The new exposure approach used in the present study is found to be a useful tool for quantification of exposure. The validation of two assumptions made for the new exposure approach are consistently supported by the data. The results obtained in the study show remarkable consistency and suggest validation of the assumptions.

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